1939

The radio amateur's handbook

THE STANDARD MANUAL OF AMATEUR RADIO COMMUNICATION

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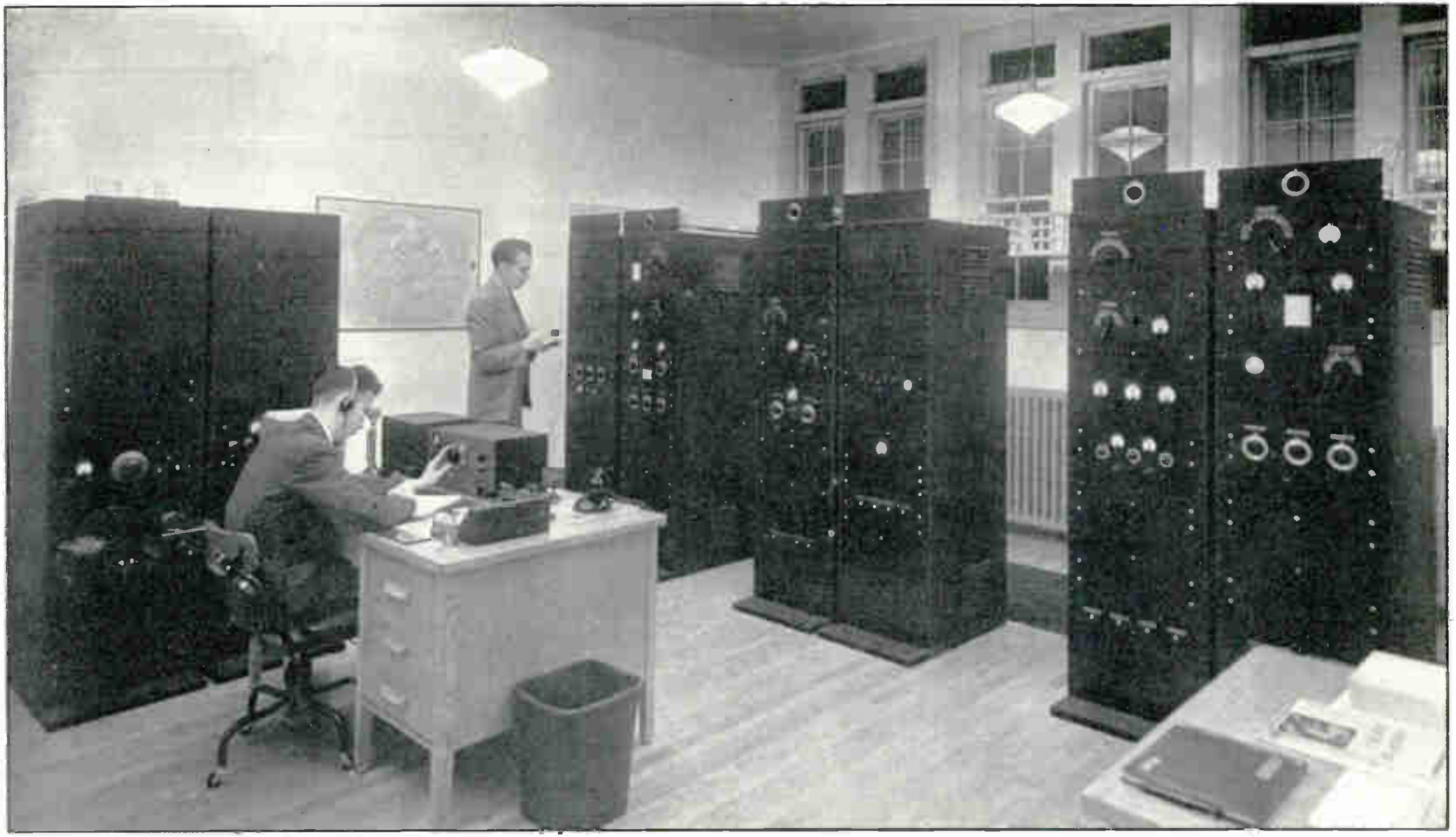
PUBLISHED BY THE AMERICAN RADIO RELAY LEAGUE

THE RADIO AMATEUR'S HANDBOOK

World Radio History



THE OPERATING ROOM AT THE MAXIM MEMORIAL STATION, W1AW, A.R.R.L. HEADQUARTERS

Separate 1-kw. transmitters are installed for each band. Voice transmissions on 1808, 3950, and 14,240 kc. follow simultaneous telegraph messages to all amateurs sent on 1800.5, 3800, 7150 and 14,254 kc. at 7.30 and 11 p.m. CST. Operators "Hal" Bubb (seated) and "Geo" Hart (standing) are always ready for a call from any amateur. See page 423 for further details of W1AW.

World Radio History

SIXTEENTH EDITION

THE RADIO AMATEUR'S HANDBOOK

BY THE HEADQUARTERS STAFF
OF THE
AMERICAN RADIO RELAY LEAGUE

PUBLISHED BY THE AMERICAN RADIO RELAY LEAGUE, INC.
WEST HARTFORD, CONNECTICUT

World Radio History

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World Radio History

THE RADIO AMATEUR'S HANDBOOK

FOREWORD

Over half a million copies of *The Radio Amateur's Handbook* have been distributed to members of the amateur fraternity since the first presentation of the book in 1926. Being devoted to as fast-moving and progressive a science as high-frequency communication, it is only natural that throughout its eminently successful life the *Handbook* should have been treated to sweeping and virtually continuous modification. Since the beginning, a strenuous attempt has been made to keep the book as up-to-date, accurate and reliable as is humanly possible. Every effort has been made to restrict the material to the treatment of modern, sound and well-tried practice. Having always had somewhat the character of an annual review of time-tried and proven methods in apparatus construction and operation, the *Handbook* has never provided a place for freaky circuits or methods. As any practicing amateur is well aware, there is an almost infinite number of different ways of accomplishing a given result in his station — some good, some poor and many indifferent. Because of this, the editorial work has been basically that of selection. It has been necessary to eliminate from the enormous wealth of ideas on technique, methods and procedure, all those which have not proved themselves by successful application in practice.

The history of the *Handbook* has been one of continuous growth. It had its modest beginning in 1925 when Mr. F. E. Handy, the League communications manager, began work on a manual of amateur operating procedure in which it was considered desirable to include a certain amount of technical information. It was published in 1926 and enjoyed immediate success. Mr. Handy revised several successive additions but the rapid progress of the art soon demanded an order of revision which could more correctly be described as rewriting. With the fourth edition in 1928, Mr. Handy was joined in this duty by Mr. Ross A. Hull, the late editor of *QST*, who was directing the technical development program which the A.R.R.L. was then conducting for the special purpose of designing new apparatus and new methods which would meet the difficulties imposed upon amateur radio by the provisions of the new international radio treaty to take effect in 1929. Three editions came under this joint authorship. By that time, extremely rapid technical progress was upon us and it became apparent that the *Handbook*, to serve its purpose, demanded a frequent and comprehensive rewriting of its entire technical material. It was therefore but natural that, with the preparation of the seventh edition in 1930, the technical chapters should be given into the hands of the many technically-skilled specialists comprising the headquarters staff of the League. Since that time the publication has been an annual family affair, the joint product of the headquarters staff, prepared under the editorship of Mr. Hull.

In September of 1938, in the midst of the preparation of this edition, Mr. Hull met accidental death when he came in contact with the high-tension terminals of a plate power supply in his experimental laboratory. Thereby amateur radio lost one of its most brilliant experimenters. His associates have carried the work of revising this edition to completion under the administrative editorship of the undersigned, the League's secretary. To the memory of Ross A. Hull, distinguished amateur, we dedicate this edition.

With a total of nearly thirty printings, the fame of the *Handbook* has echoed around the world; its success has really been inspiring. Quantity orders have come from many a foreign land; schools and technical classes have adopted it as a text; but most important of all it has become the right-hand guide of practical amateurs in every country of the globe. This success derives, in considerable measure, from the splendid coöperation which we have always received from practicing amateurs everywhere. Since the beginning there has been a continuous inflow of suggestions and contributions of ideas and material which have been invaluable in the development of the *Handbook* as an authentic treatise on the technique of to-day.

In this 1939 edition, almost every chapter

World Radio History

has seen comprehensive rewriting. Well over two hundred new illustrations have been provided. Several scores of new pieces of apparatus were especially designed and constructed — and tested! — for this edition. As usual, the work has been divided amongst the staff members. Mr. Byron Goodman has contributed a new chapter on elementary radio principles, while we have retained the more advanced treatment of definitions, values and simple computations prepared by Mr. James J. Lamb, the technical editor of *QST*. Mr. George Grammer, *QST*'s acting technical editor, is responsible for the revision of the chapter on receivers and for the rewriting of the material on antennas. Messrs. Donald H. Mix and Thomas M. Ferrill, Jr., of *QST*'s technical department, are respectively responsible for the difficult chapters on transmitters and on radio telephony, whilst Mr. Mix has also revised the chapter on workshop practice and Mr. Ferrill that on power supplies. Mr. Mix has also rewritten the chapter on assembling a station. The material on vacuum tubes has been modernized by Mr. Clinton B. DeSoto, who also contributes the chapter on instruments and who has brought up-to-date the first two chapters of the book, originally from the pen of Mr. A. L. Budlong. Mr. Goodman has also revised the chapters on keying and on the important topic of emergency equipment, whilst Mr. Handy, our communications manager, has revised those dealing with the A.R.R.L. Communications Department, on operating a station and on message handling. The two chapters on ultra-high frequency working were originally intended to be prepared by Mr. Hull, this being a field in which he was especially interested and qualified. A considerable quantity of the new u.h.f. apparatus in these chapters had been built or outlined by him before his death. The present revision of these chapters is by Mr. Vernon Chambers, Mr. Hull's laboratory assistant and associate in this work. The actual editorial production of this book has been in the competent hands of Mr. Clark C. Rodimon, *QST*'s managing editor.

A feature of the *Handbook* which has been growing steadily in importance is the quite extensive catalog advertising. It is, perhaps, unconventional to make any editorial reference to the very existence of advertising, but this case we believe to be different. To be truly comprehensive as a handbook — to fill all the functions one visualizes with the word "handbook" — this book must bring the reader data and specifications on the manufactured products which are the raw material of amateur radio. Our advertisers have collaborated with us in this purpose by presenting here not mere advertising but catalog technical data. The amateur constructor and experimenter should find it convenient to possess in such juxtaposition both the constructional guidance he seeks and the needed data on available equipment. Both are necessary ingredients of the complete standard manual of amateur high-frequency communication.

It is natural that we shall all feel very happy if the present edition brings as much assistance and inspiration to the amateurs and would-be amateurs as have its predecessors.

Kenneth B. Warner
Managing Secretary, A.R.R.L.

West Hartford
October, 1938

World Radio History

THE RADIO AMATEUR'S HANDBOOK

CONTENTS

PUBLISHED BY THE AMERICAN RADIO RELAY LEAGUE, INC.
WEST HARTFORD, CONNECTICUT

World Radio History

THE RADIO AMATEUR'S HANDBOOK

THE AMATEUR'S CODE

1. *The Amateur is Gentlemanly.* He never knowingly uses the air for his own amusement in such a way as to lessen the pleasure of others. He abides by the pledges given by the A.R.R.L. in his behalf to the public and the Government.

2. *The Amateur is Loyal.* He owes his amateur radio to the American Radio Relay League, and he offers it his unswerving loyalty.

3. *The Amateur is Progressive.* He keeps his station abreast of science. It is built well and efficiently. His operating practice is clean and regular.

4. *The Amateur is Friendly.* Slow and patient sending when requested, friendly advice and counsel to the beginner, kindly assistance and coöperation for the broadcast listener; these are marks of the amateur spirit.

5. *The Amateur is Balanced.* Radio is his hobby. He never allows it to interfere with any of the duties he owes to his home, his job, his school, or his community.

6. *The Amateur is Patriotic.* His knowledge and his station are always ready for the service of his country and his community.

SIXTEENTH EDITION

World Radio History

CHAPTER ONE

THE STORY OF AMATEUR RADIO

How It Started — The Part Played by The A.R.R.L.

Amateur radio represents, to some seventy thousand people, the most satisfying, most exciting of all hobbies. Over 50,000 of these enthusiasts are located in the United States and Canada, for it is this continent which gave birth to the movement and which, since the beginning, has represented its stronghold.

When radio broadcasting was first introduced to the public some years ago it instantly caught the fancy of millions of people all over the world. Why? Because it fired their imagination — because it thrilled them to tune in on a program direct from some distant point, to hear speech and music that was at that moment being transmitted from a city hundreds and even thousands of miles away. To be sure there was also a certain amount of entertainment value, and it is true that as the years have passed this phase has become paramount in the minds of most listeners; yet the thrill of "DX" is still a major factor in the minds of hundreds of thousands of people, as witness the present popularity of international short wave reception of foreign programs.

That keen satisfaction of hearing a distant station is basic with the radio amateur but it has long since been superseded by an even greater lure, and that is the thrill of *talking* with these distant points! On one side of your radio amateur's table is his short-wave receiver; on the other side is his private (and usually homemade) short-wave transmitter, ready at the throw of a switch to be used in calling and "working" other amateurs in the United States, in Canada, Europe, Australia, every corner of the globe! Even a low-power transmitter using nothing more ambitious than one or two receiving-type tubes makes it possible to develop friendships in every State in the Union, in dozens of countries abroad. Of course, it is not to be expected that the first contacts will necessarily be with foreign amateurs. Experience in adjusting the simple transmitter, in using the right frequency band at the right time of day when foreign stations are on the air, and practice in operating are necessary before communication will be enjoyed with amateurs of other nationalities. But patience and experience are the sole prerequisites; neither high power nor expensive equipment is required.

Nor does the personal enjoyment that comes from amateur radio constitute its only benefit. There is the enduring satisfaction that comes from doing things with the apparatus put together by one's own skill. The process of designing and constructing radio equipment develops real engineering ability. Operating an amateur station with even the simplest equipment likewise develops operating proficiency and skill. Many an engineer, operator and executive in the commercial radio field got his practical background and much of his training from his amateur work. So, in addition to the advantages of amateur radio as a hobby, the value of systematic amateur work to a student of almost every branch of radio cannot well be overlooked. An increasing number of radio services, each expanding in itself, require additional personnel — technicians, operators, inspectors, engineers and executives — and in every field a background of amateur experience is regarded as valuable.

How did amateur radio start? What developments have brought it to its present status of a highly-organized and widespread movement?

Amateur radio started shortly after the late Guglielmo Marconi had astounded the world with his first experiments proving that telegraph messages actually could be sent between distant points without wires. Marconi was probably the first amateur — indeed, the distinguished inventor so liked to style himself. But amateur radio as we think of it was born when private citizens first saw in the new marvel a means for personal communication with others and set about learning enough of the new art to build a homemade station. Object: the fun and enjoyment of "wireless" communication with a few friends. Urge: the thrill of DX (one to five miles — maybe!). That was thirty-odd years ago.

Amateur radio's subsequent development may be divided into two periods, the first be-

World Radio History

fore and the second after the World War.

Pre-war amateur radio bore little resemblance to the art as we know it to-day, except in principle. The equipment, both transmitting and receiving, was of a type now long obsolete. The range of even the highest-powered transmitters, under the most favorable conditions, would be scoffed at by the rankest beginner today. No United States amateur had ever heard the signals of a foreign amateur, nor had any foreigner ever reported hearing an American. The oceans were a wall of silence, impenetrable, isolating us from every signal abroad. Even transcontinental DX had to be accomplished in relays. "Short waves" meant 200 meters; the entire wavelength spectrum below 200 meters was a vast silence — no signal ever disturbed it. Years were to pass before its phenomenal possibilities were to be suspected.

Yet the period was notable for a number of accomplishments. It saw the number of amateurs in the United States increase to approximately 4,000 by 1917. It witnessed the first appearance of radio laws, licensing, wavelength specifications for the various services. ("Amateurs? — oh, yes — well, stick 'em on 200 meters: it's no good for anything; they'll never get out of their own back yards with it.") It saw an increase in the range of amateur stations to such unheard-of distances as 500 and, in come cases, even 1,000 miles, with U. S. amateurs beginning to wonder, just before the war, if there were amateurs in other countries across the seas and if — daring thought! — it might some day be possible to span the Atlantic with 200-meter equipment. Because all long-distance messages had to be relayed, it saw relaying developed to a fine art — and what a priceless accomplishment that ability turned out to be later when our government suddenly needed dozens and hundreds of skilled operators for war service! Most important of all, the pre-war period witnessed the birth of the American Radio Relay League, the amateur organization whose fame was to travel to all parts of the world and whose name was to be virtually synonymous with subsequent amateur progress and shortwave development. Conceived and formed by the famous inventor and amateur, the late Hiram Percy Maxim, it was formally launched in early 1914 and was just beginning to exert its full force in amateur activities when this country declared war on Germany and by that act sounded the knell for amateur radio for the next two and one-half years. By presidential direction every amateur station was dismantled. Within a few months three-fourths of the amateurs of the country were serving with the armed forces of the United States as operators and instructors.

Few amateurs to-day realize that the war not only marked the close of the first phase of amateur development but came very near marking its end for all time. The fate of amateur radio was in the balance in the days immediately following declaration of the Armistice, in 1918. The government, having had a taste of supreme authority over all communications in wartime, was more than half inclined to keep it; indeed, the war had not been ended a month before Congress was considering legislation that would have made it impossible for the amateur radio of old ever to be resumed. President Maxim rushed to Washington, pleaded, argued; the bill was defeated. But there was still no amateur radio; the war ban continued in effect. Repeated representations to Washington met only with silence; it was to be nearly a year before licenses were again to be issued.

In the meantime, however, there was much to be done. Three-fourths of the former amateurs had gone to France; many of them would never come back. What of those who had returned? Would they be interested, now, in such things as amateur radio; could they be brought back to help rebuild the League? Mr. Maxim determined to find out and called a meeting of such members of the Board of Directors as he could locate. Eleven men, several still in uniform, met in New York and took stock of the situation. It wasn't very encouraging: amateur radio still banned by law, former members of the League scattered no one

IN THE A.R.R.L. HEADQUARTERS LOBBY
The cabinets house the A.R.R.L. Museum of Amateur Radio.

IN THE *QST* WORKSHOP

knew where, no League, no membership, no funds. But those eleven men financed the publication of a notice to all the former amateurs that could be located, hired Kenneth B. Warner as the League's first paid secretary, floated a bond issue among old League members to obtain money for immediate running expenses, bought the magazine *QST* to be the League's official organ and dunned officialdom until the wartime ban was lifted and amateur radio resumed again. Even before the ban was lifted in October, 1919, old-timers all over the country were flocking back to the League, renewing friendships, planning for the future. When licensing was resumed there was a headlong rush to get back on the air. No doubt about it now — interest in amateur radio was as great as ever!

From the start, however, it took on new aspects. The pressure of war had stimulated technical development in radio; there were new types of equipment, principally the vacuum tube, which was being used for both receivers and transmitters. Amateurs immediately adapted the new apparatus to 200-meter work. Ranges promptly increased; soon it was possible to bridge the continent with but one intermediate relay. Shortly thereafter stations on one coast were hearing those on the other direct!

These developments had an inevitable result. Watching DX come to represent 1,000 miles, then 1,500 and then 2,000, amateurs wondered about that ole debbil ocean. Could we get across? We knew now that there were amateurs abroad. We knew, too, that their listening for our signals was still fruitless, but there was a justifiable suspicion that their unfamiliarity with 200-meter equipment had something to do with it. So in December, 1921, the A.R.R.L. sent abroad one of our most prominent amateurs, Paul Godley, with the best amateur receiving equipment available. Tests were run, and thirty American amateur stations were heard in Europe! The news electrified the amateur world. In 1922 another transatlantic test was carried out; this time 315 American calls were logged by European amateurs, and what was more, one French and two British stations were heard on this side.

Everything now was centered on one objective: two-way communication across the Atlantic by amateur radio! It *must* be possible — but somehow we couldn't quite make it. Further increases in power were out of the question; many amateurs already were using the legal maximum of one kilowatt. Better receivers? We already had the superheterodyne; it didn't seem possible to make any very great advance in that direction.

Well, how about trying another wavelength, then? We couldn't go up,but we could go down. What about those wavelengths below 200 meters? The engineering world said they were worthless — but then, they'd said that about 200 meters, too. There have been many wrong guesses in history. So in 1922 the technical editor of *QST* carried on some tests between Hartford and Boston on 130 meters. The results were encouraging. Early in 1923 the A.R.R.L. sponsored a series of organized tests on wavelengths down to 90 meters and it was noted that as the wavelength dropped the reported results were better. A growing excitement began to filter into the amateur ranks. It began to look as though we'd stumbled on something!

And indeed we had. For in November, 1923, after some months of careful preparation, two-way amateur communication across the Atlantic finally became an actuality when Schnell, 1MO, (now W9UZ) and Reinartz, 1XAM, (now W1QP) worked for several hours with 8AB, Deloy, in France, all three stations using a wavelength of about 110 meters!

There was the possibility, of course, that it was a "freak" performance, but any suspicions in that direction were quickly dispelled when additional stations dropped down to 100 meters and found that they, too, could easily work two-way across the Atlantic. The exodus from the 200-meter region started.

By 1924 the entire radio world was agog and dozens of commercial companies were rushing stations into the 100-meter region. Chaos threatened until the first of a series of radio conferences partitioned off various bands of frequencies for all the different services clamoring for assignments. Although thought was still centered in 100 meters, League officials at the first of these conferences, in 1924, came to the conclusion that the surface had probably only been scratched, and wisely obtained amateur bands not only at 80 meters, but

World Radio History

at 40 and 20 and 10 and even 5 meters.

Many amateurs promptly jumped down to the 40-meter band. A pretty low wavelength, to be sure, but you never could tell about these short waves. Forty was given a whirl and responded by enabling two-way communication with Australia, New Zealand and South Africa.

How about 20? It was given a try-out and immediately showed entirely unexpected possibilities by enabling an east-coast amateur to communicate with another on the west coast, direct, at high noon. The dream of amateur radio — daylight DX! — had come true.

From that time to the present represents a period of unparalleled accomplishment. The short waves proved a veritable gold mine. Country after country came on the air, until the confusion became so great that it was necessary to devise a system of international intermediates in order to distinguish the nationality of calls. The League began issuing what are known as WAC certificates to those stations proving that they had worked all the continents. Over five thousand such certificates have been issued. Representatives of the A.R.R.L. went to Paris and deliberated with the amateur representatives of twenty-two other nations. On April 17, 1925, this conference formed the International Amateur Radio Union — a federation of national amateur societies. We have discovered that the amateur as a type is the same the world over.

Nor has experimental development been lost sight of in the enthusiasm incident to international amateur communication. The experimentally-minded amateur is constantly at work conducting tests in new frequency bands, devising improved apparatus for amateur receiving and transmitting, learning how to operate two and three and even four stations where previously there was room enough for only one.

In particular, the amateur experimenter presses on to the development of the higher frequencies represented by the wavelengths below 20 meters, territory only a short time ago regarded by even most amateurs as comparatively unprofitable operating ground. On ten meters, experiments sponsored by the A.R.R.L. in directive transmission resulted in signals from a Cape Cod station being logged for days on end in New Zealand and reported in England, Canada and many parts of the United States; a large number of amateurs now devote a considerable portion of their operating time to "ten" during certain periods of the year when conditions are particularly favorable for this frequency.

The amateur's experience with five meters is especially representative of his initiative and resourcefulness, and his ability to make the most of what is at hand. In 1924 first amateur experiments in the vicinity of 56 Mc. indicated the band to be practically worthless for distance work; signals at such frequencies appeared capable of being heard only to "horizon range." But the amateur turns even such apparent disadvantages to use. If not suitable for long-distance work, at least it was ideal for "short-haul" communication. Beginning in 1931, then, there took place a tremendous amount of activity in 56-Mc. work by hundreds of amateurs all over the country and a complete new line of transmitters and receivers was developed to meet the special conditions incident to communicating at these ultra-high frequencies. In 1934 additional impetus was given to this band when experiments by the A.R.R.L. with directive antennas resulted in remarkably consistent two-way communication over distances of more than 100 miles, without the aid of "hilltop" locations. While atmospheric conditions appear to have a great deal to do with 5-meter DX, many thousands of amateurs are now spending much of their time in the 56-Mc. region, some having worked as many as four or five hundred different stations on that band at distances up to several hundred miles. Recently the radio world has been astounded by conditions whereby transcontinental contacts have been made on five meters, with hundreds of contacts over a thousand miles or so. To-day's concept of u.h.f. propagation was developed almost entirely through amateur research.

Most of the technical developments in amateur radio have come from the amateur ranks. Many of these developments represent valuable contributions to the art, and the articles about them are as widely read in professional circles as by amateurs. At a time when only a few broadcast engineers in the country knew what was meant by "100% modulation" the technical staff of the A.R.R.L. was publishing articles in *QST* urging amateur 'phones to embrace it and showing them how to do it. When interest quickened in five-meter work, and experiments showed that the ordinary regenerative receiver was practically worthless for such wavelengths, it was the A.R.R.L. that developed practical super-regenerative receivers as the solution to the receiver problem. From the League's laboratory, too, came in 1932, the single-signal superheterodyne — the world's most advanced high-frequency radiotelegraph receiver. In 1934 the commercial production of r.f. power pentodes came as a result of the A.R.R.L. Hq. technical staff's urging and demonstration of their advantages. In 1936 came the "noise-silencer" attachment for superheterodynes, permitting for the first time satisfactory high-frequency reception through the more common forms of man-made electrical interference. During 1938 the use of transmit-

World Radio History

ters whose frequency could be changed by a continuous panel control became common, along with improved directive antenna systems.

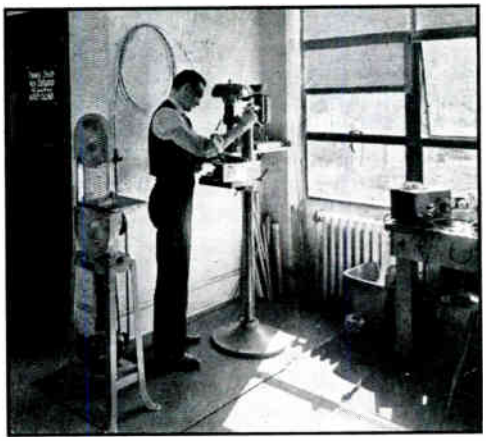
Amateur radio is one of the finest of hobbies, but this fact alone would hardly merit such whole-hearted support as was given it by the United States government at recent international conferences. There must be other reasons to justify such backing. There are. One of them is a thorough appreciation by the Army and Navy of the value of the amateur as a source of skilled radio personnel in time of war. The other is best described by the words "public service."

We have already seen 3,500 amateurs contributing their skill and ability to the American cause in the Great War. After the war it was only natural that cordial relations should prevail between the Army and Navy and the amateur. Several things occurred in the next few years to strengthen these relations. In 1924, when the U. S. dirigible *Shenandoah* made a tour of the country, amateurs provided continuous contact between the big ship and the ground. In 1925 when the United States battle fleet made a cruise to Australia and the Navy wished to test out short-wave apparatus for future communication purposes, it was the League's Traffic Manager who was in complete charge of an experimental high-frequency set on the U.S.S. *Seattle.*

Definite friendly relations between the amateur and the armed forces of the Government were cemented in 1925. In this year both the Army and the Navy came to the League with proposals for amateur coöperation. The radio Naval Reserve and the Army-Amateur Net are the outgrowth of these proposals.

The public service record of the amateur is a brilliant one. These services can be roughly divided into two classes: emergencies and expeditions. It is regrettable that space limitations preclude detailed mention of amateur work in both these classes, for the stories constitute some of the high-lights of amateur accomplishment. As it is, only a general outline can be given.

Since 1913, amateur radio has been the principal, and in many cases the only, means of outside communication in more than one hundred storm, flood and earthquake emergencies in this country. Among the most noteworthy were the Florida hurricanes of 1926, 1928 and 1935, the Mississippi and New England floods of 1927 and the California dam break of 1928. During 1931 there were the New Zealand and Nicaraguan earthquakes, and in 1932 floods in California and Texas; outstanding in 1933 was the earthquake in southern California. In 1934 further floods in California and Oklahoma resulted in notable amateur coöperation. The 1936 eastern states flood, the 1937 Ohio River Valley flood and the 1938 eastern states flood-hurricane disaster saw the greatest emergency effort ever performed by amateurs. In all these and many others, amateur radio played a major rôle in the rescue work and amateurs earned world-wide commendation for their



ANOTHER SECTION OF THE WORKSHOP

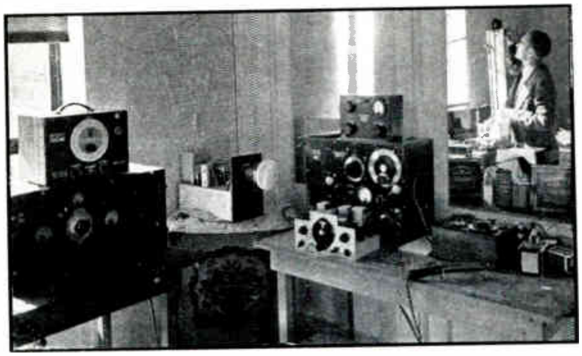
resourcefulness in effecting communication where all other means failed.

It is interesting to note that one of the principal functions of the Army-Amateur network is to furnish organized and coördinated amateur assistance in the event of storm and other emergencies in this country. In addition, Red Cross centers in various parts of the United States are now furnished with lists of amateur stations in the vicinity as a regular part of their emergency measures program.

Amateur coöperation with expeditions started in 1923, when a League member, Don Mix, of Bristol, Conn., accompanied MacMillan to the Arctic on the schooner *Bowdoin* in charge of an amateur set. Amateurs in Canada and the United States provided the home contact. The success of this venture was such that MacMillan has never since made a trip without carrying short-wave equipment and an amateur to operate it.

Other explorers noted this success and made inquiries to the League regarding similar arrangements for their journeys. In 1924 another expedition secured amateur coöperation; in 1925 three benefited by amateur assistance, and by 1928 the figure had risen to nine for that year alone. Each year since then has seen League headquarters in receipt of more and more requests for such service, until now a total of perhaps two hundred voyages and expeditions have been thus assisted. To-day practically no exploring trip starts from this country to remote parts of the world without

World Radio History



THE TEST SECTION IN THE RECEIVING LAB

Part of the transmitting lab is visible through the glass partition.

making arrangements to keep in contact through the medium of amateur radio.

Emergency relief, expeditionary contact, and countless instances of other forms of public service, rendered as they always have been and always will be, without hope or expectation of material reward, have made amateur radio an integral part of our national life.

THE AMERICAN RADIO RELAY LEAGUE

THE American Radio Relay League is today not only the spokesman for amateur radio in this country but is the largest amateur organization in the world. It is strictly of, by and for amateurs, is non-commercial and has no stockholders. The members of the League are the owners of the A.R.R.L. and *QST*.

The League is organized to represent the amateur in legislative matters. It is pledged to promote interest in two-way amateur communication and experimentation. It is interested in the relaying of messages by amateur radio. It is concerned with the advancement of the radio art. It stands for the maintenance of fraternalism and a high standard of conduct. One of its principal purposes is to keep amateur activities so well conducted that the amateur will continue to justify his existence. As an example of this might be cited the action of the League in sponsoring the establishment of a system of Standard Frequency Stations throughout the United States; installations equipped with the most modern available type of precision measuring equipment, and transmitting "marker" signals on year-round schedules to enable amateurs everywhere to accurately calibrate their apparatus.

The operating territory of the League is divided into fourteen United States and six Canadian divisions. You can find out what division you are in by consulting *QST* or the *Handbook*. The affairs of the League are managed by a Board of Directors. One director is elected every two years by the membership of each United States division, and a Canadian General Manager is elected every two years by the Canadian membership. These directors then choose the president and vice-president, who are also directors, of course. No one commercially engaged in selling or manufacturing radio apparatus or literature can be a member of the Board or an officer of the League.

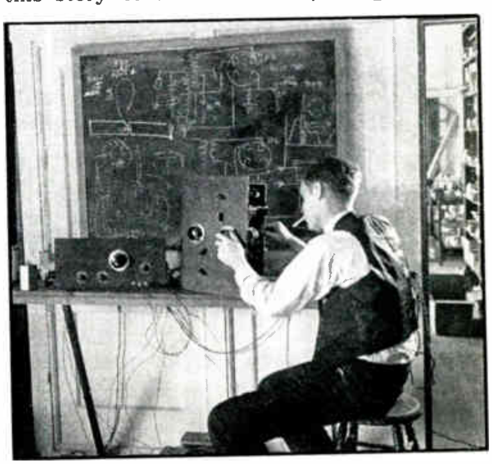
The president, vice-president, secretary, treasurer and communications manager of the League are elected or appointed by the Board of Directors. These officers constitute an Executive Committee which, under certain restrictions, decides how to apply Board policies to matters arising between Board meetings.

The League owns and publishes the magazine *QST*. *QST* goes to all members of the League each month. It acts as a monthly bulletin of the League's organized activities. It serves as a medium for the exchange of ideas. It fosters amateur spirit. Its technical articles are renowned. *QST* has grown to be the "amateur's bible" as well as one of the foremost radio magazines in the world. The profits *QST* makes are used in supporting League activities. Membership dues to the League include a subscription to *QST* for the same period.

The extensive field organization of the Communications Department coördinates practical station-operation throughout North America.

HEADQUARTERS

FROM the humble beginnings recounted in this story of amateur radio, League head-



AT WORK IN THE TRANSMITTING LAB

World Radio History

quarters has grown until now it occupies an entire office building and employs more than three dozen people.

Members of the League are entitled to write to Headquarters for information of any kind, whether it concerns membership, legislation, or general questions on the construction or operation of amateur apparatus. If you don't find the information you want in *QST* or the *Handbook*, write to A.R.R.L. Headquarters, West Hartford, Connecticut, telling us your problem. All replies are made directly by letter; no charge is made for the service.

If you come to Hartford, drop out to Headquarters at West Hartford. Visitors are always welcome.

HEADQUARTERS STATION

From 1927 to 1936 the League operated its headquarters station, W1MK, at Brainerd Field, Hartford's municipal airport on the Connecticut River. During the disastrous flood of 1936 this station was devastated. From the spring of 1936 until early summer of 1938 a temporary station was operated at the headquarters offices, at first under the old auxiliary call W1INF and later as W1AW. The call W1AW, held until his death by Hiram Percy Maxim, was issued to the League by a special order of the Federal Communications Commission for the official headquarters station call.

Beginning September, 1938, the Hiram Percy Maxim Memorial Station at Newington, Conn., has been in operation as the headquarters station. Operating on all amateur bands with separate transmitters rated at the maximum legal input of one kilowatt and a system of elaborate antenna relays, this station is heard with good strength in every part of the country. The building in which it is housed was designed by order of the League's Board of Directors as a permanent memorial to the founder-president, Hiram Percy Maxim.

INTERNATIONAL AMATEUR RADIO UNION

The I.A.R.U. is a federation of thirty-three national amateur radio societies in the principal nations of the world. Its purposes are the promotion and coördination of two-way communication between the amateurs of the various countries, the effecting of coöperative agreements between the various national societies on matters of common welfare, the advancement of the radio art, the encouragement of international fraternalism, and the promotion of allied activities. Perhaps its greatest service lies in representing the amateurs of the world at international telecommunications conferences and technical consulting committee (C.C.I.R.) meetings.

The headquarters society of the Union is the American Radio Relay League. All correspondence should be addressed to 38 LaSalle Road, West Hartford, Conn., U. S. A.

The I.A.R.U. issues WAC (Worked-All-Continents) certificates to amateurs who qualify for this award. The regulations, in brief, stipulate that the applicant must have worked other amateurs in each of the six recognized continental areas of the world, supplying QSL cards or other indisputable proof of two-way contact in connection with his application; and that he must be a member of the member-society of the Union for the country in which he resides. In countries where no member-society exists the certificate may be secured upon payment of a fee of 50¢ to cover mailing costs. Two kinds of certificates are issued, one for radiotelegraph work and one for radiotelephone. There is a special endorsement for 28-Mc. operation.

JOINING THE LEAGUE

The best way to get started in the amateur game is to join the League and start reading *QST*. Inquiries regarding membership should be addressed to the Secretary, or you can use the convenient application blank in the rear of this book. An interest in amateur radio is the only qualification necessary in becoming a member of the A.R.R.L. Ownership of a station and knowledge of the code are *not* prerequisites. They can come later. According to a constitutional requirement, however, only those members who possess an amateur station or operator license are entitled to vote in director elections.

Learn to let the League help you. It is organized solely for that purpose, and its entire headquarter's personnel is trained to render the best assistance it can to you in solving your amateur problems. If, as a beginner, you should find it difficult to understand some of the matter contained in succeeding chapters of this book, do not hesitate to write the Information Service stating your trouble. Perhaps, in such a case, it would be profitable for you to send for a copy of a booklet published by the League especially for the beginner and entitled "How to Become a Radio Amateur." This is written in simple, straightforward language, and describes from start to finish the building of a simple but effective amateur installation. The price is 25 cents, postpaid.

Every amateur should read the League's magazine *QST* each month. It is filled with the latest amateur apparatus developments, "dope" on current expeditions which use short-wave radio for contact with this country, and the latest "ham" news from your particular section of the country. A sample copy will be sent you for 25 cents if you are unable to obtain one at your local newsstand.

World Radio History

CHAPTER TWO

GETTING STARTED

The Amateur Bands — Learning the Code — Obtaining Licenses

This chapter deals with the two major problems of every beginning amateur — learning the code and getting the necessary federal licenses.

Our Amateur Bands

Many people, because they have never heard anything else, seem to think that "radio" means "broadcasting." To such people a few nights listening in on the high frequencies (wavelengths below the broadcast band) will be a revelation. A horde of signals from dozens of different types of services tell their story to whoever will listen. Some stations send slowly and leisurely. Even the beginner can read them. Others race along furiously so that whole sentences become meaningless buzzes. There are both telegraph and telephone signals. Press messages, weather reports, high frequency international broadcasting of voice and music, transmissions from government and experimental stations including picture transmission and television, airplane dispatching, police broadcasts, and signals from private yachts and expeditions exploring the remote parts of the earth jam the short wave spectrum from one end to the other.

Sandwiched in among all these services are the amateurs, thousands of whose signals may be heard every night in the various bands set apart by International Treaty for amateur operation.

Many factors have to be considered in picking a certain frequency band for a certain job, especially the distance and the time of day when communication is desired. In addition to daily changes, there are seasonal changes, and in addition a long-time change in atmospheric conditions which seems to coincide with the 11-year cycle of sun-spot or solar activity. The reliability of communication on a given frequency at a given time of day, the suitability of a given band for traffic or DX, the desires of the individual amateur in choosing his circle of friends with whom he expects to make contact on schedule, the amount of interference to be expected at certain hours, and the time of day available for operating — all influence the choice of an operating frequency.

The 1715-kc. band,* which carried all amateur activity before experimenters opened the way to each of the higher frequency bands in turn, always served amateurs well for general contact between points all over the country. There was a short period, during the height of development of the higher frequencies, when activity in this band dwindled, but it is again on the increase.

The band is popular especially for radiotelephone work. Code practice transmissions are made in this band for beginning amateurs and many beginners may be heard in this region making their first two-way contact with each other. The band is one of our "widest" from the standpoint of the number of stations that may be comfortably accommodated. The band is open to amateur facsimile and picture transmission.

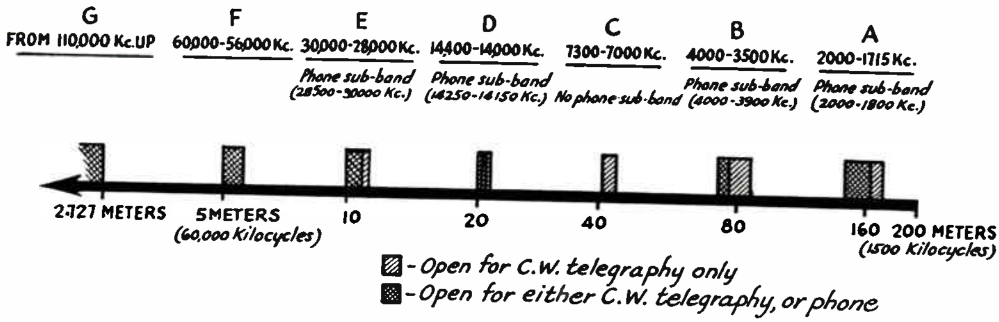
The 3500-kc. band has, in recent years, been regarded as best for all consistent domestic communication. It is good for coast-to-coast work at night all the year except for a few summer months. It has been recommended for all amateur message-handling over medium distances (1,000 miles for example). Much of the friendly human contact between amateurs takes place in the 3500-kc. band. As the winter evening advances, the well-known "skip effect" (explained in detail in Chapter Four) of the higher frequencies has made itself known, the increased range of the "sky wave" brings in signals from the other coast and the increased range also brings in *more* stations, so that the band appears busier.

The 7000-kc. band has been the most popular band for general amateur work for years. It is useful mainly at night for contacts with the opposite coast, or with foreign countries. Power output does not limit the range of a station to the same extent as when working on the lower frequency bands discussed above. However, the band is more handicapped by congestion in the early evenings and more

* Likely to be changed in 1939 to read 1750–2050 kc., with 'phone permitted 1800–2050 kc.

World Radio History

subject to the vagaries of skip-effect and uncertain transmission conditions than are the lower frequency bands, but not to the same extent as the 14-Mc. band. The 7000-kc. band is satisfactory for working distances of several hundred miles in daylight. It is generally considered the most desirable night band for general DX work in spite of difficulties due to interference.



The 14,000-kc. or 14-Mc. band is the best frequency to use to cover great distances in daylight. In fact it is the *only* band generally useful for daylight DX contacts (QSO's) over coast-to-coast and greater distances. Communication over long distances will usually remain good during the early evenings and surprising results can be obtained then, too. Using these higher frequencies there is often difficulty in talking with stations within three or four hundred miles, while greater distances than this (and very short distances within ten or twenty miles of a station) can be covered with ease. The reason that 14-Mc. signals are less useful for general amateur DX late evenings is because the "skip" increases during darkness until the "sky wave" covers greater than earthly distances. The band, while one of the very best for the amateur interested in working foreign stations without much difficulty from domestic interference, is sometimes subject to sudden fluctuations in transmitting conditions.

The 28,000-kc. (28-Mc.) band is principally an experimental amateur band at the present time. It combines both the long-distance characteristics of the 14-Mc. band and some of the local advantages of the 56-Mc. band, but its remarkable long-distance characteristics have been the cause of its tremendous growth in popularity. The band is by no means as reliable as those of lower frequency but the performance to be had on it has been becoming progressively better during the last few years. A well-defined seasonal effect produces much better conditions during the fall and spring than at other times of the year. Though the band was a barren waste a few years ago it is now, particularly during fall and spring, full of splendid activity. It is the place where one can get by far the most miles per watt.

The 56,000-kc. or 56-Mc. band, made available for amateur experimentation at the request of the League, has for many years been regarded as strictly a local and short-distance band for distances of ten to thirty miles. Because of the cheapness, compactness and ease of construction of the necessary apparatus it has proved ideal for this purpose and many hundreds of stations have operated "locally" there. During the latter part of 1934, however, experiments with directive antennas by the technical staff of the A.R.R.L. indicated the possibility of surprisingly consistent two-way work over distances of a hundred miles or more, with the result that tremendous impetus was given to experimentation at these frequencies and is expected to continue even stronger in future. Recent "sky-wave" DX work over several thousand miles on this band and the prospect that much more is to come make the band the prize one for the experimenter.

Above 110,000 kc. but little progress has as yet been made. These frequencies have in the past been generally considered useless for communication over any appreciable distance, just as were the frequencies around 56 Mc. But the developments in that region have resulted in creating considerable interest in the still higher frequencies, and during 1939 it is expected that many experimenters will endeavor to exploit them to their utmost for communication purposes. The 112-Mc. band, in particular, will probably take over much of the purely local activity hitherto occupying the 56-Mc. band.

Memorizing the Code

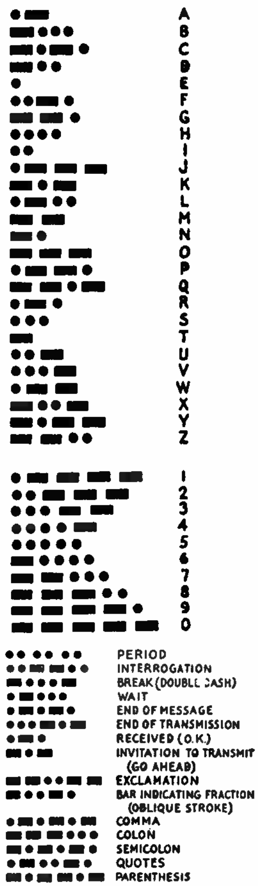
There is nothing particularly difficult incident to taking your place in the ranks of licensed amateurs.

The first job you should tackle is the business of *memorizing* the code. This can be done while you are building your receiver. Thus, by the time the receiver is finished, you will know the characters for the alphabet and will be ready to practice receiving in

World Radio History

order to acquire speed. Speed practice, either by means of a buzzer, or by listening in on your receiver, can be indulged in in odd moments while the transmitter, in turn, is being constructed. The net result of such an organized program should be that by the time the transmitter is finished you will be able to receive the thirteen words a minute required by the government for your amateur operator license, and can immediately proceed to study for the "theoretical" part of your license examination without loss of time.

Memorizing the code is no task at all if you simply make up your mind to apply yourself to the job and get it over with as quickly as possible. The complete Continental alphabet, punctuation marks and numerals are shown in the table given here. The alphabet and all the numerals should be learned, but only the first eight of the punctuation marks shown need be memorized by the beginner. Start by memorizing the alphabet, forgetting the numerals and punctuation marks for the present. Various good systems for learning the code have been devised. They are of undoubted value but the job is a very simple one and usually can be accomplished easily by taking the first five letters, memorizing them, then the next five, and so on. As you progress you should review all the letters learned up to that time, of course. When you have memorized the alphabet you can go to the numerals, which will come very quickly since you can see that they follow a definite system. The punctuation marks wind up the schedule — and be sure to learn at least the first eight — the more commonly-used ones.



THE CONTINENTAL CODE

One suggestion: Learn to think of the letters in terms of *sound* rather than their appearance as they are printed. Don't think of *A* as "dot-dash" but think of it as the sound "dit-dah." *B*, of course, is "dah-dit-dit-dit," *C*, "dah-dit-dah-dit" and so on.

Even better will be listening to the characters as they are sent on a buzzer or code practice oscillator, if someone can be found to send to you. Learning the code is like learning a new language, and the sooner you learn to understand the language without mental "translation" the easier it will be for you.

Don't think about speed yet. Your first job is simply to memorize all the characters and make sure you know them without hesitation. Good practice can be obtained, while building the receiver, if you try to spell out in code the names of the various parts you are working on at the time.

Acquiring Speed by Buzzer Practice

When the code is thoroughly memorized, you can start to develop speed in receiving code transmission. Perhaps the best way to do this is to have two people learn the code together and send to each other by means of a buzzer-and-key outfit. An advantage of this system is that it develops sending ability, too, for the person doing the receiving will be quick to criticize uneven or indistinct sending. If possible, it is a good idea to get the aid of an experienced operator for the first few sessions, so that you will know what well-sent characters sound like.

The diagram shows the connections for a buzzer-practice set. When buying the key it is a good idea to get one that will be suitable for use in the transmitter later; this will save you money.

Another good practice set for two people learning the code together is that using a tube oscillator, as illustrated.

The tube is a 12A7, which combines in one envelope a half-wave rectifier and a pentode.

The 12.6 volts for the heater is obtained from the 115-volt source by means of a resistor line cord, a special cord containing a resistor in addition to the usual two wires from the plug. The resistor is connected to one of the plug blades, and the opposite end is terminated at the oscillator. Hence, there are three leads emerging from the cord. The resistor wire is distinguished by white covering. It is important that the proper-resistance cord be obtained.

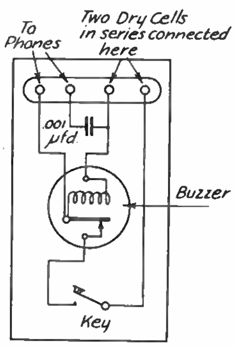
The filter condenser, C_2 and C_3, is a two-section midget electrolytic condenser having a common negative lead and separate positive leads. The common negative lead is connected in the oscillator to the cathode of the pentode section of the 12A7, and to the C connection of the transformer secondary. One of the positive leads of the condenser is connected to the resistor terminal of the line cord and to the resistor R_2. The other positive lead connects to the opposite end of the resistor, and through key and headphones to the B terminal of the transformer. The opposite end of the transformer primary winding, P, is connected to the plate of the pentode section of the 12A7. The grid resistor and grid condenser, R_1 and C_1, are connected between the grid terminal of the tube (the top cap) and one of the secondary terminals marked G. If the oscillator is completed according to the wiring diagram, and all connections have been carefully checked, failure of the set to oscillate when the key is closed will indicate that the incorrect G terminal of the transformer was chosen, in which case it will merely be disconnected and the other G lead will be substituted. This applies on d.c. if closing the key causes a distinct click in the headphones after the tube has warmed for a minute. If a d.c. source is used with the oscillator, the polarity of the plug must be correctly fixed by plugging it in so that the click of the 'phones may be produced by keying the oscillator.

If the pitch produced by the oscillator is found to be too low or too high, it may be varied over a wide range by varying the resistance value of the grid resistor, R_1.

In the operation of this code-practice oscillator, care must be taken that neither the wiring of the oscillator, nor the key nor 'phones be allowed to come in contact with ground. Also, the operator must use caution to refrain from being connected between the oscillator or key and a ground connection.

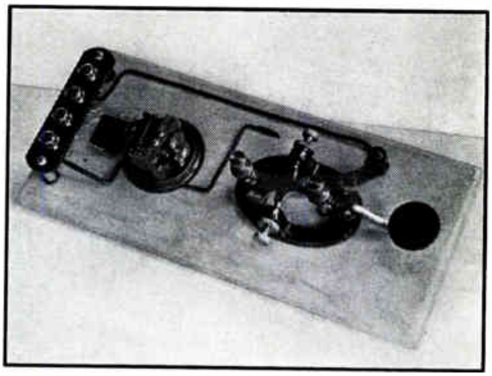
Either the buzzer set or this audio oscillator will give good results. The advantage of the audio oscillator over the buzzer set is that it gives a good signal in the 'phones without making any noise in the room.

After the practice set has been built, and



THE CIRCUIT OF THE CODE PRACTICE SET ILLUSTRATED ABOVE

The phones are connected across the coils of the buzzer with a condenser in series. The size of this condenser determines the strength of the signal in the phones. Should the value given on the diagram provide an excessively loud signal it may be reduced to, perhaps, .00025 µfd.



A BUZZER CODE PRACTICE SET ARRANGED AND WIRED IN ACCORDANCE WITH THE CIRCUIT GIVEN BELOW

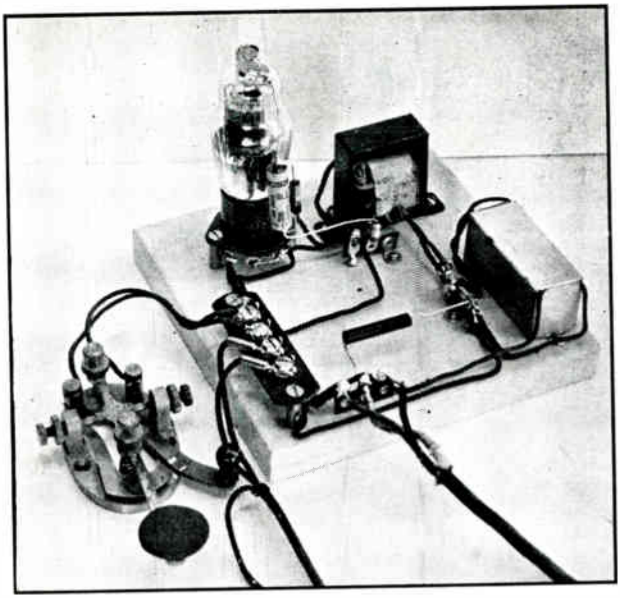
another operator's help secured, practice sending turn and turn about to each other. Send single letters at first, the listener learning to recognize each character quickly, without hesitation. Following this, start slow sending of complete words and sentences, always trying to have the material sent at just a little faster rate than you can copy easily; this speeds up your mind. Write down each letter you recognize. Do *not* try to write down the dots and dashes; write down the letters. Don't stop to compare the sounds of different letters, or think too long about a letter or word that has been missed. Go right on to the next one or each "miss" will cause you to lose several characters you might otherwise have gotten. If you exercise a little patience you will soon be getting every character, and in a surprisingly short time will be receiving at a good rate of speed. When you think you can receive 13 words a minute (65 letters a minute) have the sender transmit code groups rather than straight English text. This will prevent you from recognizing a word "on the way" and filling it in before you've really listened to the letters themselves.

After you have acquired a reasonable degree of proficiency concentrate on the less common characters, as well as the numerals and punctuation marks. It is these that prove the downfall of many applicants taking the code examination under the handicap of nervous stress and excitement.

Learning by Listening

While it is very nice to be able to get the help of another person in sending to you while you are acquiring code-speed, it is not always possible to be so fortunate, and some other method of acquiring speed must be resorted to. Under such circumstances, the time-honored system is to "learn by listening" on your short-wave receiver. With even the simplest short-

World Radio History



THE CODE-PRACTICE OSCILLATOR

The grid-leak and grid condenser, R_1 and C_1, may be seen in front of the tube. The transformer is beside the tube, with the filter condenser in the right foreground. The connection of the line cord resistor is shown in the foreground, while the four screw terminals include two for a key and two for headphones.

wave receivers a number of high-power stations can be heard in every part of the world. It is usually possible to pick a station going at about the desired speed for code practice. Listen to see if you cannot recognize some individual letters. Use paper and pencil and write down the letters as you hear them. Try to copy as many letters as you can.

Whenever you hear a letter that you know, write it down. Keep everlastingly at it. *Twenty minutes or half an hour is long enough for one session.* This practice may be repeated several times a day. Don't become discouraged. Soon you will copy without missing so many letters. Then you will begin to get calls, which are repeated several times, and whole words like "and" and "the." After words will come sentences. You now know the code and your speed will improve slowly with practice.

In "learning by listening" try to pick stations sending slightly faster than your limit. In writing, try to make the separation between words definite. Try to "read" the whole of short words before starting to write them down. Do the writing while listening to the first part of the next word. Practice and patience will soon make it easy to listen and write at the same time. Good operators usually copy several words "behind" the incoming signals.

A word of caution: the U. S. radio communication laws prescribe heavy penalties for divulging the contents of any radiogram to other than the addressee. You may copy anything you hear for practice but you must preserve its secrecy.

Code Practice Helps

There are several code-training courses and mechanical devices on the market designed to assist in building code speed. One such course is based on a special training routine; others are built around automatic sending equipment (either tape or phonograph recordings) which send perfectly-formed code without the help of another person. We heartily suggest that the beginner should examine advertisements for such courses and equipment, especially where difficulty is experienced with more common methods.

Volunteer Code Practice Stations

Each fall and winter season the A.R.R.L. solicits volunteers, amateurs using code only, or often a combination of voice and code transmission, who will send transmissions especially calculated to assist beginners. These transmissions go on the air at specified hours on certain days of the week and may be picked up within a radius of several hundred miles under favorable conditions. Words and sentences are sent at different speeds and repeated by voice, or checked by mail for correctness if you write the stations making the transmissions and enclose a stamped addressed envelope for reply.

The schedules of the score or more volunteer code-practice stations are listed regularly in *QST* during the fall and winter. Information at other times may be secured by writing League headquarters. Some of the stations have been highly successful in reaching both coasts with code-practice transmissions from the central part of the country.

Interpreting What You Hear

As soon as you finish your receiver and hook it up you will begin to pick up different high-frequency stations, some of them perhaps in the bands of frequency assigned to amateurs, others perhaps commercial stations belonging to different services. The loudest signals will not necessarily be those from near-by stations. Depending on transmitting conditions which vary with the frequency, the distance and the

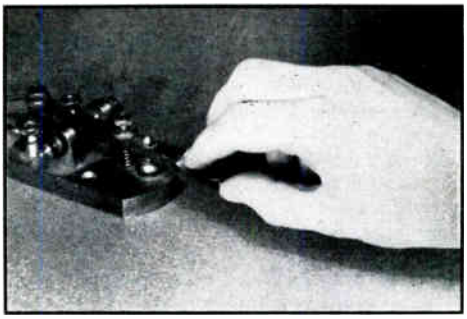
World Radio History

time of day, remote stations may or may not be louder than relatively near-by stations.

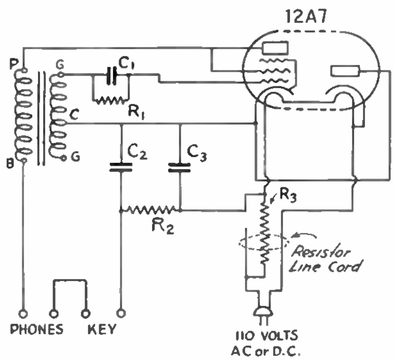
The first letters you identify probably will be the call signals identifying the stations called and the calling stations, if the stations are in the amateur bands. Station calls are assigned by the government, prefixed by a letter (W in the United States, VE in Canada, G in England, etc.) indicating the country. In this country amateur calls will be made up of such combinations as W8CMP, W1KH, W1AW, etc., the number indicating the amateur call area and giving a general idea of the part of the country in which the station heard is located. The reader is referred to the chapter on "Operating a Station" for complete information on the procedure amateurs use in calling, handling messages, and the like. Many abbreviations are used which will be made clear by reference to the tables of Q Code, miscellaneous abbreviations, and "ham" abbreviations included in the Appendix. The table of international prefixes, also in the back of the book, will help to identify the country where amateur and commercial stations are located.

Using a Key

The correct way to grasp the key is important. The knob of the key should be about eighteen inches from the edge of the operating table and about on a line with the operator's right shoulder, allowing room for the elbow to rest on the table. A table about thirty inches in height is best. The spring tension of the key varies with different operators. A fairly heavy spring at the start is desirable. The back adjustment of the key should be changed until there is a vertical movement of about one-sixteenth inch at the knob. After an operator has mastered the use of the hand key the tension should be changed and can be reduced to the minimum spring tension that will cause the key to open immediately when the pressure is released. More spring tension than necessary causes the expenditure of unnecessary energy. The contacts should be spaced by the rear screw on the key only and not by allowing play in the side screws, which are provided merely for aligning the contact points. These side screws should be screwed up to a setting which prevents appreciable side play but not adjusted so tightly that binding is caused. The gap between the contacts should always be at least a thirty-second of an inch, since a too-finely spaced contact will cultivate a nervous style of sending which is highly undesirable. On the other hand too-wide spacing (much over one-sixteenth inch) may result in unduly heavy or "muddy" sending.



ILLUSTRATING THE CORRECT POSITION OF THE HAND AND FINGERS FOR THE OPERATION OF A TELEGRAPH KEY



CIRCUIT DIAGRAM OF THE CODE-PRACTICE OSCILLATOR

C_1 — 0.01-μfd., 600-volt tubular condenser (Sprague).
C_2, C_3 — 2-section midget electrolytic condenser, 10 μfd. each section 25 volts working (Sprague).
R_1 — 3-megohm, M-watt resistor (IRC).
R_2 — 5000-ohm, 1-watt (IRC).
R_3 — Line cord resistor, 360 ohms.
T — Transformer 3:1 midget push-pull input transformer (Thordarson L-6907).

Do not hold the key tightly. Let the hand rest lightly on the key. The thumb should be against the left side of the key. The first and second fingers should be bent a little. They should hold the middle and right sides of the knob, respectively. The fingers are partly on top and partly over the side of the knob. The other two fingers should be free of the key. The photograph shows the correct way to hold a key.

A wrist motion should be used in sending. The whole arm should not be used. One should not send "nervously" but with a steady flexing of the wrist. The grasp on the key should be firm, not tight, or jerky sending will result. None of the muscles should be tense but they should all be under control. The arm should rest lightly on the operating table with the wrist held above the table. An up-and-down motion without any sideways action is best. The fingers should never leave the key knob.

Sending

Good sending *seems* easier than receiving, but don't be deceived. A beginner should not send fast. Keep your transmitting speed down to the receiving speed, and bend your efforts to sending *well*.

When sending do not try to speed things up too soon. A slow, even rate of sending is the mark of a good operator. Speed will come with time alone. Leave special types of keys alone until you have mastered the knack of properly handling the standard-type telegraph key. Because radio transmissions are seldom free from interference a "heavier" style of sending is best to develop for radio work. A rugged key of heavy construction will help in this.

Obtaining Government Licenses

When you are able to copy 13 words per minute, have studied basic transmitter theory and familiarized yourself with the radio law and amateur regulations, you are ready to give serious thought to securing the government combination amateur operator-station license which is issued you, after examination, through the Federal Communications Commission, at Washington, D. C.

Because a discussion of license application procedure, license renewal and modification, exemptions, and detailed information on the nature and scope of the license examination involve more detailed treatment than it is possible to give within the limitations of this chapter, it has been made the subject of a special booklet published by the League, and at this point the beginning amateur should possess himself of a copy and settle down to a study of its pages in order to familiarize himself with the intricacies of the law and prepare himself for his test. The booklet, "*The Radio Amateur's License Manual*," may be obtained from A.R.R.L. headquarters for 25¢ postpaid. From the beginner's standpoint one of the most valuable features of this book is its list of nearly 200 representative examination questions with their correct answers.

A few general remarks:

While no government licenses are necessary to operate receivers in the United States, you positively must have the required amateur licenses before doing sending of any kind with a transmitter. This license requirement applies for any kind of transmitter on any wavelength. Attempts to engage in transmitting operation of any kind, without holding licenses, will inevitably lead to arrest, and fine or imprisonment.

Amateur licenses are free, but are issued only to citizens of the United States; this applies both to the station authorization and the operator's personal license, with the further provision in the station license that it will not be issued where the apparatus is to be located on premises controlled by an alien. But the requirement of citizenship is the only limitation, and amateur licenses are issued without regard to age or physical condition to anyone who successfully completes the required examination. There are licensed amateurs as young as twelve and as old as eighty. Many permanently bedridden persons find their amateur radio a priceless boon and have successfully qualified for their "tickets"; even blindness is no bar — several stations heard regularly on the air are operated by people so afflicted.

Persons who would like to operate at amateur stations, but do not have their own station as yet, may obtain an amateur operator license without being obliged to take out a station license. But no one may take out the station license alone; all those wishing station licenses must also take out operator licenses.

Extracts from the basic Communications Act and the complete text of the amateur regulations current at the time this *Handbook* went to press will be found in the Appendix. Because the regulations are subject to occasional changes or additions, however, it is recommended that your study of them be from the *License Manual* already mentioned, since this latter publication is always revised, or a "change sheet" incorporated with it, whenever such alterations in our regulations take place.

Canadian Regulations

Canadian amateurs wishing operators' licenses must pass an examination before a radio inspector in transmission and reception at a speed of ten words per minute or more. They must also pass a verbal examination in the operation of amateur apparatus of usual types, must have a working knowledge of procedure, and must have a little operating ability prior to taking the examination. Nothing is likely to be asked which is not covered in this *Handbook* or the *License Manual*. The fee for examination as operator is 50 cents and is payable to the Radio Inspector who examines the candidate.

The form for application for station license may be obtained either from a local Radio Inspector's office or direct from the Radio Division, Department of Transport, Ottawa. The applicant must also sign a declaration of secrecy which, as a matter of fact, is executed at the time of obtaining the operator's license. The annual fee for station licenses for amateur work in Canada is $2.50.

World Radio History

CHAPTER THREE

ELEMENTARY RADIO PRINCIPLES

Current Flow — Conductors and Insulators — Condensers — Coils — The Tuned Circuit

THERE are as many different types of radio amateurs as there are phases to this fascinating hobby. Some amateurs are perfectly content to pound brass or use a microphone with only the vaguest conception of how and why their equipment works, while others are not satisfied unless they understand what goes on in the transmitter and receiver, and the space between. The inquisitive amateur will find this chapter one intended to acquaint him with the elementary principles of electricity so necessary to a more complete understanding of radio itself.

Understanding electrical and radio principles involves no greater effort than that necessary to form mental images of the processes involved. A little close reading, coupled with some clear thinking will make a fascinating subject out of one that, at first glance, seems quite involved. If you are something of a Steinmetz or an Einstein you can read right through as you would a novel; if you aren't, ponder over paragraphs until you can explain them to someone else without reference to the text.

Elementary principles are the bricks that serve as the foundation for all technical knowledge — with a smooth and solid foundation, the rest is easy.

FACTS ABOUT ELECTRONS

IF YOU remember your high-school chemistry you will recall that all matter — solids, liquids and gases — is made up of fundamental units called *molecules*, the smallest subdivision of matter. These molecules in turn are found to consist of *atoms* of the component elements. Molecules and atoms are infinitesimally small, and can't be seen even with the most powerful microscopes. The thing to remember, however, is simply that all matter is made up of molecules which are in turn combinations of atoms of the component elements.

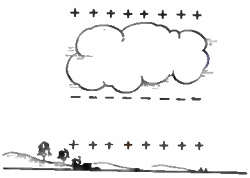


FIG. 301 — LIGHTNING IS caused by the discharge of electricity that builds up on a cloud reaching a potential high enough to break down the air between the cloud and ground or another cloud. The charge is believed to be caused by friction of air masses or dust particles.

Electrons

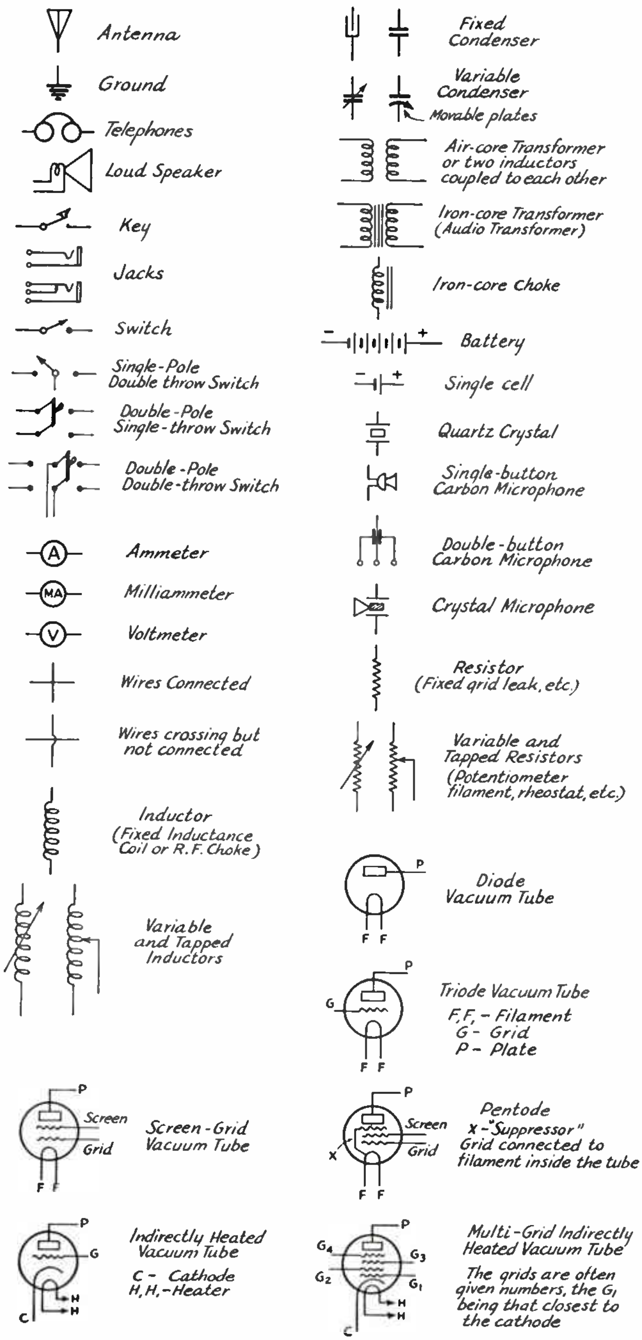
If atoms could be examined through an infinitely powerful microscope or other means of magnifying them, a striking thing would be observed. You would find that *all* atoms are made up of particles, or charges, of electricity — nothing more — and that atoms differ from each other only in the number and arrangement of these charges. These charges are called electrons, and the atom has a nucleus composed of both positive and negative electrons, but with the positive predominating so that the nature of the nucleus is positive. Positive electrons are referred to as *protons* and negative electrons simply as *electrons*. The electrons and protons of the nucleus are intimately and closely bound together. However, exterior to the nucleus are negative electrons that are not so closely bound and, in many instances, they can be made to leave the immediate vicinity of the nucleus without much urging. These electrons whirl around the nucleus like the planets around the sun, and their orbits are not random paths but geometrically-regular ones determined by the charges on the nucleus and the number of electrons. Ordinarily the atom is electrically neutral, the outer negative electrons balancing the positive nucleus, but when something disturbs this balance electrical activity becomes evident, and it is the study of what happens in this unbalanced condition that makes up electrical theory.

ELECTRONS AT REST

IT WAS mentioned above that in some materials it is relatively easy to move the electrons away from the nucleus. There are also many materials in which this is difficult to do. A material in which it is hard to move or displace the electrons by electrical means is said to have a high *resistance*, and further along you will see why this is also an appropriate term from other standpoints.

World Radio History

SCHEMATIC SYMBOLS USED IN CIRCUIT DIAGRAMS



Static Charges

Peculiarly enough, many of the materials that have a high resistance can be made to acquire a charge (surplus or deficiency of electrons) by mechanical means. You have often heard the "electricity" crackling when you ran your hard-rubber comb through your hair on a dry winter day, or have noticed the tiny spark that jumps from your finger tip to a metal object after you have walked across a rug in a dry room. This was caused simply by the friction of the comb passing through your hair and of your shoes passing over the carpet. The spark, in either case, was caused by the attempt of the charge that had built up, to equalize itself. In other words, when you ran the comb through your hair, there was a surplus of electrons left on the comb, forming a charge, and the next time you brought the comb near your hair the charge was in such a hurry to equalize itself that it jumped a short distance through the air. The higher the charge, the greater the distance it can jump. Lightning is nothing more than the same thing on a gigantic scale; clouds pick up a tremendous charge (meteorologists don't agree as to *why*, but friction of air masses or dust particles is believed to be a contributing factor) and when the charge becomes great enough it breaks over in a blinding flash to ground or to another cloud with the *opposite* charge. Yes, objects can have either a surplus or a deficiency of electrons — it is called a *negative* charge if there is a surplus of electrons; a *positive* charge if there is a lack of them. As with all things in nature, there must always be a balance, and for every negative charge there will be found a similar positive charge, since each electron that leaves an atom to form a negative charge leaves the rest of the atom with a positive charge.

You will have the essence if you remember that these charges or potentials are nothing more than a lack or surplus of electrons.

If two objects are oppositely charged, a *potential* difference is said to exist between them, and this difference is measured by an

World Radio History

electrical unit called the *volt*. The greater the potential difference, the higher (numerically) the voltage. The difference in electrons between the two objects which causes this potential difference or voltage exerts an electrical pressure or *force* which is trying to equalize and thus nullify the charges, and for this reason it is often called *electromotive force* or, simply, *e.m.f.* But when you become more familiar with it you'll think of it as voltage, remembering that voltage represents the electrical potential difference set up by a surplus or lack of electrons.

Condensers

Right now is a good time to become acquainted with an electrical device you're going to run across quite often in your electrical and radio work, the *condenser*. So far, only simple static charges on combs and clouds have been mentioned. However, if something that has a very high resistance, like glass, mica, oil, or even air, is made into a thin sheet and a metal plate is placed on either side of the sheet, it will be found that the two plates can be given a charge by connecting them to a source of potential difference such as a battery or other power supply, and the potential difference, or voltage, will be equal to that of the source. The *quantity* of the charge will depend upon the voltage of the charging source and the capacity of the condenser. The value of capacity of a condenser is a constant depending upon the physical dimensions, increasing with the area of the plates and the thinness and *dielectric constant* of the insulating material in between.

Capacity is measured in *farads*, a unit much too large for practical purposes, and in radio work the terms *microfarad* (abbreviated *µfd.*) and *micro-microfarad* (*µµfd.*) are used. The microfarad is one-millionth of a farad, and the micro-microfarad is one-millionth of that.

You can easily demonstrate to yourself the difference in the quantity-holding ability of condensers by taking two of different capacity out of your junk box, touching them one at a time across a 45-volt B battery to charge them, and then discharging them with a screw-driver across the terminals. The one with the larger capacity will give a fatter spark when it is discharged. Since they were both charged to exactly the same potential — the voltage of the battery — the difference in the discharges was due to the difference in the amount of stored charge.

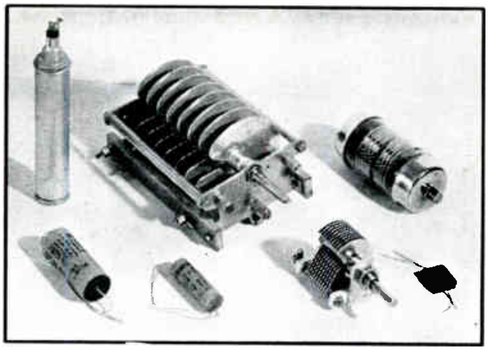


FIG. 302 — VARIOUS FORMS OF CONDENSERS

The *electrolytic* condenser at the left front is a low-voltage one used as an audio by-pass across cathode resistors. The long, cylindrical can directly in back houses a higher-voltage electrolytic condenser used in receiver and low-voltage transmitter power-supply filters. The small paper (front row, second from left) and the small mica (front row, extreme right) fixed condensers are used in receiver and low-voltage transmitter applications. The small *variable* condenser in the front row is used in receivers and low-voltage transmitters; the variable condenser with the heavy plates and greater spacing is used in high-power transmitters. The small, compact vacuum condenser is a new type of fixed condenser for transmitting having an even greater voltage rating than the large variable condenser and losses low enough so that it may be used in a transmitter tank circuit.

ELECTRONS IN MOTION

It was mentioned above that a material in which it is difficult to move the electrons is said to have high resistance. Conversely, a material in which it is easy to move the electrons is said to have low resistance or, more simply, it is called a good *conductor*. Most of the metals fall into this class, with silver and copper being among the best, followed by aluminum, brass, zinc, platinum and iron, in the order named. Conductors will, of course, conduct electricity regardless of their shape, but in most electrical work the most efficient form of conductor is a round wire, and henceforth when the word "conductor" is used, it should be visualized as a wire.

Current Flow

If a difference of potential exists across the ends of a conductor (by connecting the wire to a battery or generator or other source of voltage) there will be a continuous drift of electrons passing from atom to atom, and an electrical *current* is said to be flowing. The electrons do not streak from one end of the conductor to the other — their actual movement is quite minute — but it is more like a "bucket brigade" where, instead of firemen handing buckets down the line, atoms pass a potential difference down the line of the conductor until it is neutralized. The current itself is traveling quite fast, close to the speed of light, but the actual electrons themselves move only a short distance.

The current is measured in *amperes*, and if you wish to visualize that in terms of electrons, try to remember that a current of one ampere

World Radio History

represents nearly 10^{19} (ten million, million, million) electrons flowing past a point in one second; or that a micro-ampere (millionth of an ampere) is nearly 10 million electrons per micro-second (millionth of a second).

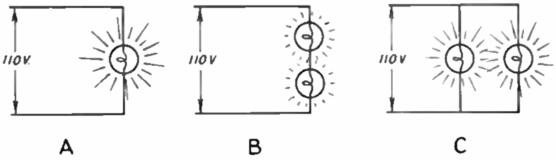


FIG. 303 — A SIMPLE EXAMPLE OF OHM'S LAW

At A, a single lamp across the 110-volt line burns with normal brilliancy, indicating normal current through the lamp.

At B, the two lamps in *series* give an effective resistance of twice that of a single lamp, and the current through them is therefore only half normal current. This is indicated by half brilliancy of the lamps.

At C, the lamps are connected in *parallel*, and since the lamps have 110 volts across them they burn with normal brilliancy. But twice as much light is given off, so the system must be drawing twice as much current and the effect of the two lamps in parallel is to place a load across the line of half the resistance of one lamp.

The current in a conductor is determined by two things, the voltage across the conductor and the resistance of the conductor. The unit of resistance is the *ohm,* and, by definition, an e.m.f. of one volt will cause a current of one ampere to flow through a resistance of one ohm. Since the three quantities are interdependent, if we know the values of any two we can easily determine the third by the simple relation known as Ohm's Law (described more

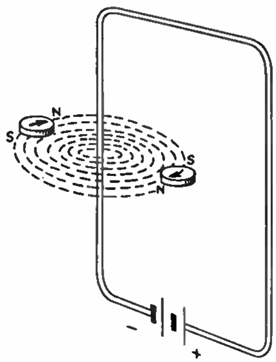


FIG. 304 — WHENever current passes through a wire, a magnetic field exists around the wire. Its direction can be traced by means of a small compass.

in detail in the following chapter). All you need visualize now is the pressure or e.m.f. (volts) forcing a current (amperes) through the resistance (ohms) of the conductor.

Insulators

Materials with a high resistance, like hard rubber, steatite, bakelite, isolantite, mycalex, mica, quartz, sulphur and vacuum are called *insulators.* If an insulator is used to separate the plates of a condenser, it is called a *dielectric.* Poor conductors are good insulators, and *vice versa.* Insulators are used where it is desired to avoid current flow through a physical connection.

Heating Effect

When current passes through a conductor, there is some amount of molecular friction, and this friction generates heat. This heat is dependent only upon the current in the wire and the resistance of the wire. It also is described more in detail in the following chapter. One need only know now that this heat is used in many useful ways, as can be seen by a quick glance around a house or factory equipped with electric heating devices. It also means that electricity cannot be conducted without some loss due to

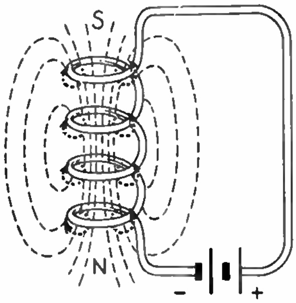


FIG. 305 — WHEN THE CONDUCTING WIRE IS COILED, THE INDIVIDUAL MAGNETIC FIELDS OF EACH TURN ARE IN SUCH A DIRECTION AS TO PRODUCE A FIELD SIMILAR TO THAT OF A BAR MAGNET

heating effects, which often must be taken into consideration.

Magnetic Effects

Any physicist will tell you that *moving electrons generate a magnetic field.* This magnetic field is exactly the same as the strange force that exists in the vicinity of any magnet and is capable of attracting other magnetic materials. Since a current in a wire is electrons in motion, it is not strange that a magnetic field is found in the vicinity of a conductor with current flowing through it. If the wire is wound in circles to form a coil, the magnetic effect becomes cumulative, and the effect can be increased still further by placing an iron core within the coil.

There is a converse to this. When a conductor is moved through a magnetic field (or the field is moved past the conductor) electrons in the conductor are forced to move, producing a current. This is something to remember: *An electric current generates a magnetic field about*

World Radio History

it and, conversely, an electric current is generated by a magnetic field moving (or changing) past the conductor.

Electric Circuits

You will often see mention of an electric "circuit." It is sufficient to remember that this is simply a complete path along which electrons can transmit their charge. More completely, there will normally be a source of energy — a battery, generator, or magnetic means for inducing current flow — and a *load* or portion of the circuit where the current is made to do useful work. There must be an unbroken path through which the electrons can transmit their charges, with the source of energy acting as an electron pump and sending them around the circuit. The circuit is said to be *open* when no charges can move, due to a break in the path. It is *closed* when no break exists — when switches are closed and all connections are properly made.

Ionization in Gases

All conduction does not necessarily take place in solid conductors. If a glass tube is fitted with metal plates at each end, and filled with a gas or even ordinary air (a mixture of gases) at reduced pressure, an electric current may be passed *through the gas* if a high-enough voltage is applied across the metal terminals. The commonly-used neon advertising signs utilize this principle, since the current flow also generates light, the color depending upon the gas being used. When the voltage is applied across the tube, the positively charged plate attracts a few electrons, which are given considerable velocity due to the acceleration of the electric charge and the fact that the reduced pressure in the tube (less gas) permits the electrons to travel farther before colliding with a gas atom. When they do collide with the atoms, they knock off outer electrons of the gas atom and these electrons also join the procession towards the positive plate, and of course knock off more electrons from other atoms. The atoms that have had an electron or two knocked off are no longer true atoms but *ions*, and since they have a positive charge (due to the electron deficiency) they are called "positive ions." These positive ions, being heavier than the electrons, travel more slowly towards the negative plate, where they acquire electrons and become neutral atoms again. The net result is a flow of electrons, and hence of current, from negative plate to positive plate. The light given off, it may be mentioned, is considered incidental to the recombination of ions and free electrons at the negative plate. This kind of conduction, made possible by ionization by collision, is utilized in the operation of certain types of gaseous rectifiers, and in combination with another principle in mercury-vapor rectifiers.

Ionization in Liquids

A very large number of chemical compounds have the peculiar characteristic that when they are put into solution the component parts become ionized. For example, common table salt or sodium chloride, each molecule of which is made up of one atom of sodium and one of chlorine, will, when put into water, break down into a sodium ion (positive, with one electron deficient) and a chlorine ion (negative, with one excess electron). This can only occur as long as the salt is in solution — take away the water and the ions are recombined into the neutral sodium chloride. This spontaneous *disassociation* in solution is of course another form of ionization, and if two wires with a difference of potential across them are placed in the solution, the negative wire will attract the positive sodium ions and the positive wire will attract the negative chlorine ions, and a current will flow through the solution. When the ions reach the wires the electron surplus or deficiency will be remedied, and a neutral atom will be formed. The energy supplied by the source of potential difference is used to move the ions through the liquid and to supply or remove electrons. This type of current flow is due to *electrolytic conduction*, and the principle was utilized in the now almost-obsolete "electrolytic rectifier." It also forms a basis for the construction of the "electrolytic condenser."

Batteries

All batteries depend upon chemical action for the generation of a potential difference across their terminals. The common *dry cell* (which won't work *completely* dry) depends upon zinc ions (the metal case of a dry cell is the zinc plate) with a positive charge going into solution and leaving the zinc plate strongly negative. The electrical energy is derived from the chemical energy, and in time the zinc will be used up or worn away. However, in lead *storage batteries*, such as are used in automobiles for starting, the electrical energy is stored by chemical means and entails no destruction of the battery materials. The water that must be replaced from time to time is lost by evaporation.

It might be pointed out here that the term "battery" is used correctly only when speaking of more than one cell — a single cell is not a battery, but two or more connected together become a battery.

Thermionic Electron Emission

There is still another method of electric current conduction, one of the most important

World Radio History

in radio because it is the foundation for the whole wonderful family of *vacuum tubes* used in both reception and transmission. If a suitable metallic conductor, such as tungsten or oxide-coated or thoriated tungsten, is heated to a high temperature in a vacuum (by passing current through it until it heats to the proper temperature) electrons will be emitted from the surface. The reason that the electrons are freed from this *filament* or *cathode* is that it has been heated to a temperature that activates them sufficiently to allow them to break away from the surface. The process is called *thermionic electron emission*, or simply *emission*. Once free, these electrons will form a cloud of negative electrons immediately surrounding the cathode which will repel further electrons that try to break through this *space charge*. A few will be given sufficient velocity to travel some distance from the cathode, but the majority will stay in the vicinity of the cathode. However, if a plate is placed in the vacuum tube, and given a positive charge by connecting a battery between plate and cathode, this plate or *anode* will attract a number of the electrons that surround the cathode. The passage of these electrons from cathode to anode constitutes an electric current. Some of the electrons that reach the anode may have sufficient velocity to dislodge an electron or two from the plate, and these electrons can be attracted to other positively-charged plates in the vicinity. If there are no other positive plates nearby, the electrons are attracted back to the plate from which they came. The process of dislodging electrons by other fast-moving electrons is called *secondary emission*. The important thing to remember is that all thermionic vacuum tubes depend for their operation on the emission of electrons from a hot cathode, and that the current flowing through a vacuum tube is simply the flow of these electrons being attracted to a positively-charged plate or anode.

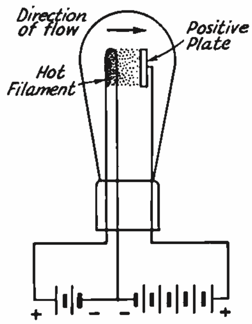


FIG. 306 — ILLUSTRATING CONDUCTION BY THERMIONIC EMISSION OF ELECTRONS IN A VACUUM TUBE

One battery is used *only* to heat the filament to a temperature where it will emit electrons. The other battery places a positive potential on the plate, with respect to the filament, and the electrons are attracted to the plate. The flow of electrons completes the electrical path, and current flows in the plate circuit.

ELECTRONS IN MOTION — ALTERNATING CURRENT

Thus far only direct current, i.e., current traveling in one direction, has been discussed. This was done to acquaint you with the picture of current flow. However, most electrical and radio work utilizes *alternating current*, or current that alternates its direction in periodic fashion.

It was suggested that you remember that an electric current can be generated by a magnetic field moving or changing past a conductor. If the magnetic field moves in one direction, the electric current will flow in one direction; if the magnetic field moves in the opposite direction (decreasing is the same thing, in effect) the current will move in the opposite direction. Mechanical methods are used to generate alternating current by this principle, using rotating machinery, and the machines are called *alternating-current generators* or *alternators*. Their design is such that the current in the wire (or voltage across the terminals) will go from zero to a peak value and back to zero, and up to a peak value *in the opposite direction* and back to zero, in what is called a *sine wave* (see Chapter IV). The length of time that it takes to go through this cycle is called the *period;* the number of times it goes through this cycle, per second, is called the *frequency*.

It may be a little difficult at first to visualize how the *values* of alternating currents and voltages can be obtained, since they vary from one direction to the other, and the average value would be zero in spite of any peak value they might have. Actually, however, it is simplified by defining a current of one ampere as that amount of alternating current which will produce the same amount of heat through a resistance as one ampere of direct current. From this, one volt of alternating current

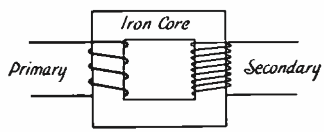


FIG. 307 — SCHEMATIC REPRESENTATION OF A TRANSFORMER

Alternating current flowing in the primary winding induces a current in the secondary winding. The ratio of the primary voltage to secondary voltage is very nearly equal to the ratio of primary turns to secondary turns.

World Radio History

would force one ampere through a resistance of one ohm. The subject is treated more fully in Chapter IV.

Transformers

If two coils of wire are wound on a laminated iron core, and one of the coils is connected to a source of alternating current (abbreviated *a.c.*), it will be found that there is an alternating voltage across the terminals of the other coil of wire, and an alternating current will flow through a conductor connecting the two terminals. The explanation is simple: The alternating current in the first coil, or *primary*, causes a changing magnetic field in the iron core, and this changing magnetic field causes or induces an alternating current in the second coil, or *secondary*. The proportion of primary voltage to secondary voltage is very nearly the same as the ratio of primary turns; i.e., twice as many secondary turns as primary turns will give twice as much secondary voltage, etc. The current proportion goes the other way — it is inversely proportional to the turns ratio.

Inductance

When a source of alternating voltage is connected across a coil the coil will not pass as much current as when an equal direct-current voltage is placed across the coil. The reason for this is that when the alternating current is passed through the coil, the magnetic field around the coil will increase and decrease in accordance with the reversals of the alternating current. The varying field, however, will induce a varying voltage back in the coil and the current induced by this varying voltage will always be in the opposite direction to that of the current originally passed through the wire. The result, therefore, is that, because of this property of *self-induction*, the coil tends constantly to oppose any change in the current flowing through it and hence to limit the amount of alternating current flowing. The effect can be visualized as electrical inertia. In the case of the direct current passing through the coil, the self-inductance only tries to prevent the current flow as it is building up; after the current has come to a steady value the self-inductance has no effect and the current is limited only by the resistance of the wire in the coil.

The *inductance* of a coil is measured in *henrys* or, when smaller units are more convenient, the millihenry (one-thousandth of a henry) or microhenry (one-millionth of a henry).

It should be remembered that the higher the frequency of the current the more the inductance will try to prevent its flow. The rate at which the magnetic field cuts the coil affects

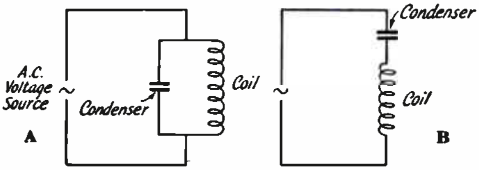


FIG. 308 — TWO TYPES OF COIL-CONDENSER CIRCUITS

The connection at the left is called a "parallel" tuned circuit, that at the right a "series" circuit. The parallel circuit has its maximum *impedance* at the resonant frequency and hence limits the current flow at that frequency. The series circuit works just oppositely: the minimum impedance and hence the maximum current occurs at the resonant frequency of the circuit.

the self-induced "back voltage" so that it is easy to understand why the retarding force becomes greater as the magnetic field changes more rapidly. The combined effect of frequency and inductance in coils is called *reactance* or *inductive reactance.*

Resonance

Consider a coil and condenser connected as in Fig. 308-A, with a source of alternating voltage connected across the circuit. If the frequency of the alternating voltage is low, practically all of the current will pass through the coil, since its reactance is low and the condenser reactance is high at low frequencies. When the voltage-source frequency is high, practically all of the current will flow through the condenser, since its reactance is low and the coil's is high. However, at some point between these two frequency limits there will be a frequency where the coil reactance is equal to the condenser reactance, and it is at this point that the minimum amount of current will flow through the circuit. This is called the "*resonance frequency*" of the circuit, and follows a simple relation given in Chapter IV.

Exactly the opposite effect takes place with the "series" circuit of Fig. 308-B. Here, when the frequency is low the condenser limits the current flow and when the frequency is high the coil limits it, since the current must pass through both to complete the circuit. However, when the reactances are equal, the maximum amount of current will flow. This frequency is also called the "resonance frequency" and, if the coil and condenser were the same in this series circuit as in the above-described "parallel circuit," the resonance frequencies in the two cases would be the same. However, in the parallel circuit the current would be a minimum and in the other a maximum, at resonance.

If a source of current is connected to a circuit containing inductance and capacity, the condenser will become charged and will dis-

World Radio History

charge through the coil. The rate of flow of current will be retarded by the inductive reactance of the coil and the discharge of the condenser will not be instantaneous. As the current continues to flow from the condenser into the coil, the energy initially stored in the condenser will become stored in the magnetic field about the coil. When substantially all the energy in the circuit is stored in this field, the field will start to collapse, causing a continued flow of current through the circuit and charging the condenser, but *in the opposite direction.* Then, when all the energy again is

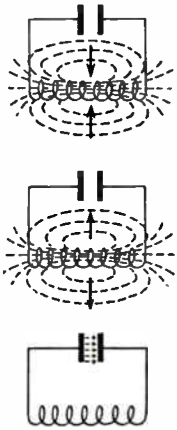


FIG. 309 — THE SEQUENCE OF A HALF-CYCLE OSCILLATION IN A RESONANT CIRCUIT

The condenser discharging through the coil sets up a magnetic field around the coil. When the condenser is fully discharged, the magnetic field starts to collapse, cutting the coil in the opposite direction. This causes current to flow in the opposite direction and the condenser is charged again, but with the opposite polarity.

stored in the condenser, the sequence is repeated in the opposite direction. This process is called *oscillation* and will occur at the resonant frequency of the coil and condenser combination. The process would continue indefinitely if it were possible to make coils and condensers without resistance, but it isn't, and so the energy is dissipated rapidly in the form of heat caused by the current flowing through the resistance of the coil. The process of the oscillation dying out because of resistance losses is called *damping,* and is overcome in practical circuits by continuously supplying energy to replace that which is dissipated. It must, of course, be supplied at the correct frequency, else it would buck the oscillations and prevent their building up. The fact that the coil and condenser combination will respond best to only one frequency is often utilized in radio work since, if either the inductance or capacity is made variable, any resonance frequency can be selected, over the range of variation. "Tuning" a receiver or transmitter generally only means adjusting the circuits to resonance and hence, best response for the desired frequency.

You can demonstrate resonance to yourself by fastening a rubber band to a fountain pen or other suitable weight. Hold the other end of the rubber band, with the weight dangling, and move your hand up and down slowly over a distance of an inch or two. The weight will move up and down with your hand, the rubber band stretching but little. Now move your hand up and down quite rapidly; the weight will stand still and the band will take all the motion. Experiment with different speeds, or frequencies, and you will find a point where both weight and band will move the most, and you will also observe that you need only supply a small amount of energy to keep the system oscillating. The weight represents inductance (inertia), the rubber band acts like the condenser, and the motion of your hand is the applied voltage or current.

ELECTRONS IN MOTION—RADIO FREQUENCY

You are now familiar with oscillating circuits where the energy is stored in the magnetic field of the coil and the electrostatic field of the condenser, and always returned to the circuit. This is true where the frequency is relatively low, but as the frequency is increased to above 20,000 cycles per second or so, it will be found that all of the energy does not return but escapes in the form of *electromagnetic radiation.* In other words, the energy is radiated into space. Not much escapes from the conventional tuned circuit described above, but if this tuned circuit is replaced by its electrical equivalent in the form of a long wire (see Chapter IV) practically all of the energy will be sent out into space. This radiation of energy through space is the basis of all radio communication, since intelligence can be transmitted if the radiated energy is varied in accordance with telegraph characters or speech syllables, and picked up at the receiver and reconverted into sound.

You now have the complete picture of the family of moving electrons, or electricity. Electrons at rest in the form of static (meaning *still*) charges; electrons moving in one direction forming direct-current flow; electrons moving back and forth at regular periods to form alternating current, and, when the frequency becomes great enough, radiating their energy out into space. One thing is important: The radio-frequency currents in the antenna set up *fields of energy* which travel through space — the electrons themselves are not hurtled through the air. Radio waves travel through space with the speed of light, roughly about 186,000 miles per second, or seven times around the world in one second. Normally traveling in straight lines from the radiating point, radio waves can be bent or refracted in the upper atmosphere and thus transmitted to a point on the opposite side of the earth.

World Radio History

CHAPTER FOUR

RADIO CIRCUIT EQUATIONS, TERMS AND DEFINITIONS

Now that we have some conception of what an electric current really is and of the different forms in which electricity is to be found, we may proceed to examine its effects in the apparatus which is to be used in radio work.

We have already mentioned that any substance in which an electric current can flow is a conductor and we have also pointed out that some substances conduct more readily than others — they have less resistance. Most of the conductors in radio apparatus — such as wiring, coils, etc. — are required to have the greatest conductivity or the least resistance possible. They are of metal, usually copper. But many of the conductors are actually placed in the circuit to offer some definite amount of resistance. They are known under the general term of *resistors* and the amount of resistance they (or any conductor) offer is measured in *ohms*.

OHM'S LAW

When a current flows in any electric circuit, the magnitude of the current is determined by the electromotive force in the circuit and the resistance of the circuit, the resistance being dependent on the material, cross-section and length of the conductor. The relations which determine just what current flows are known as *Ohm's Law*. It is an utterly simple law but one of such great value that it should be studied with particular care. With its formula, carrying terms for current, electromotive force and resistance, we are able to find the actual conditions in many circuits, provided two of the three quantities are known. When I is the current in amperes, E is the electromotive force in volts and R is the circuit resistance in ohms, the formulas of Ohm's Law are:

$$R = \frac{E}{I} \qquad I = \frac{E}{R} \qquad E = IR$$

The *resistance* of the circuit can therefore be found *by dividing the voltage by the current:* the *current* can be found *by dividing the voltage by the resistance:* the *electromotive force or e.m.f.* is equal to the *product of the resistance and the current.*

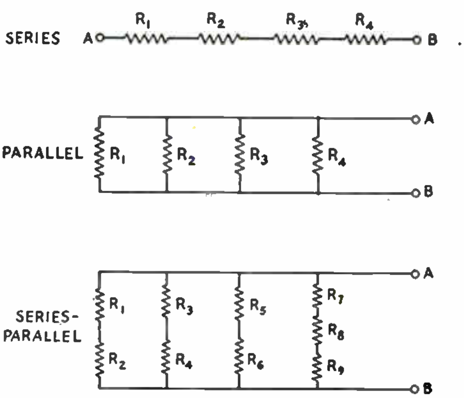


FIG. 401 — DIAGRAMS OF SERIES, PARALLEL AND SERIES-PARALLEL RESISTANCE CONNECTIONS

RESISTANCES IN SERIES AND PARALLEL

Resistors, like battery cells, may be connected in series, in parallel or in series-parallel. When two or more resistors are connected in series, the total resistance of the group is higher than that of any of the units. Should two or more resistors be connected in parallel, the total resistance is decreased. Fig. 401 and the following formulas show how the value of a bank of resistors in series, parallel or series-parallel may be computed, the total being between A and B in each case.

Resistances in series:

$$\textit{Total resistance in ohms} = R_1 + R_2 + R_3 + R_4$$

Resistances in parallel:

$$\textit{Total resistance in ohms} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}}$$

Or, in the case of only 2 resistances in parallel,

$$\textit{Total resistance in ohms} = \frac{R_1 R_2}{R_1 + R_2}$$

Resistances in series-parallel:

$$\textit{Total resistance in ohms} = \frac{1}{\frac{1}{R_1 + R_2} + \frac{1}{R_3 + R_4} + \frac{1}{R_5 + R_6} + \frac{1}{R_7 + R_8 + R_9}}$$

World Radio History

ALTERNATING CURRENT VALUES

In Fig. 402 a curve describing the voltage developed by an alternating-current generator during one complete cycle is shown. This curve is actually a graph of the instantaneous values of the voltage amplitude, plotted against time, assuming a theoretically perfect generator. It

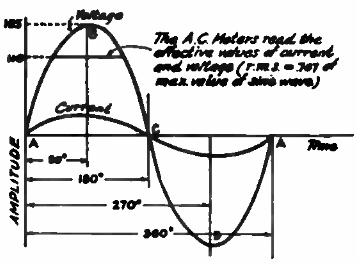


FIG. 402 — REPRESENTING SINE-WAVE ALTERNATING VOLTAGE AND CURRENT

is known as a *sine* curve, since it represents the equation

$$e = E_{max} \sin \omega t$$

where e is the instantaneous voltage, E_{max} is the maximum voltage and t is the time from the beginning of the cycle. The term ω, or $2\pi f$, represents the *angular velocity*, there being 2π *radians* in each complete cycle and f cycles per second. All the formulas given for alternating current circuits have been derived with the assumption that any alternating voltage under consideration would follow such a curve.

It is evident that both the voltage and current are swinging continuously between their positive maximum and negative maximum values, and it might be wondered how one can speak of so many amperes of alternating current when the value is changing continuously. The problem is simplified in practical work by considering that *an alternating current has an effective value of one ampere when it produces heat at the same average rate as one ampere of continuous direct current flowing through a given resistor.* This effective value is the square root of the mean value of the instantaneous current squared. For the sine-wave form,

$$E_{eff} = \sqrt{\tfrac{1}{2}E_{max}^2}$$

For this reason, the effective value of an alternating current, or voltage, is also known as the *root-mean-square* or *r.m.s.* value. Hence, the effective value is the square root of ½ or 0.707 of the maximum value — practically considered 70% of the maximum value.

Another important value, involved where alternating current is rectified to direct current, is the *average*. This is equal to 0.636 of the maximum (or peak) value of either current or voltage. The three terms *maximum* (or *peak*), *effective* (or *r.m.s.*) and *average* are so important and are encountered so frequently in radio work that they should be fixed firmly in mind right at the start.

They are related to each other as follows:

$$E_{max} = E_{eff} \times 1.414 = E_{ave} \times 1.57$$
$$E_{eff} = E_{max} \times .707 = E_{ave} \times 1.11$$
$$E_{ave} = E_{max} \times .636 = E_{eff} \times .9$$

The relationships for current are the same as those given above for voltage. The usual alternating current ammeter or voltmeter gives a direct reading of the effective or r.m.s. (root mean square) value of current or voltage. A direct current ammeter in the plate circuit of

ABBREVIATIONS FOR ELECTRICAL AND RADIO TERMS

Alternating current	a.c.	Megohm	MΩ
Ampere (amperes)	a.	Meter	m.
Antenna	ant.	Microfarad	μfd.
Audio frequency	a.f.	Microhenry	μh.
Centimeter	cm.	Micromicrofarad	μμfd.
Continuous waves	c.w.	Microvolt	μv.
Cycles per second	c.p.s.	Microvolt per meter	μv/m.
Decibel	db	Microwatt	μw.
Direct current	d.c.	Milliampere	ma.
Electromotive force	e.m.f.	Millivolt	mv.
Frequency	f.	Milliwatt	mw.
Ground	gnd.	Modulated continuous waves	m.c.w.
Henry	h.	Ohm	Ω
High frequency	h.f.	Power	P.
Intermediate frequency	i.f.	Power factor	p.f.
Interrupted continuous waves	i.c.w.	Radio frequency	r.f.
Kilocycles (per second)	kc.	Ultra-high frequency	u.h.f.
Kilowatt	kw.	Volt (volts)	v.
Megacycle (per second)	Mc.	Watt (watts)	w.

World Radio History

a vacuum tube approximates the average value of rectified plate current. Maximum values can be measured by a peak vacuum-tube voltmeter. Instruments for making such measurements are treated in Chapter Sixteen.

COMPLEX WAVES

ALTERNATING currents having the ideal sine-wave form just described are practically never found in actual radio circuits, although waves closely approximating the perfectly sinusoidal can be generated with laboratory-type equipment. Even the current in power mains is somewhat non-sinusoidal, although it can be considered sinusoidal for most practical purposes. In the usual case, such a current actually has components of two or more frequencies integrally related, as shown in Fig. 403. The

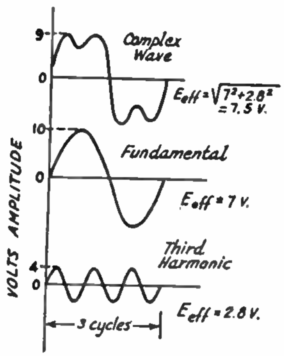


FIG. 403 — A COMPLEX WAVE AND ITS SINE-WAVE COMPONENTS

lowest and principal frequency is the *fundamental*. The additional frequencies are whole-number multiples of the fundamental frequency (twice, three times, etc.), and are called *harmonics*. One of double frequency is the second harmonic, one of triple frequency the third harmonic, etc. Although the wave resulting from the combination is non-sinusoidal the wave-form of each component taken separately has the sine-wave form.

The effective value of the current or voltage for such a complex wave will not be the same as for a pure sine wave of the same maximum value. Instead, *the effective value for the complex wave will be equal to the square root of the sum of the squares of the effective values of the individual frequency components*. That is,

$$E = \sqrt{E_1^2 + E_2^2 + E_3^2}$$

where E is the effective value for the complex wave, and E_1, E_2, etc., are the effective values of the fundamental and harmonics. The same relation also applies where currents of different frequencies not harmonically related flow in the same circuit.

COMBINED A.C. AND D.C.

THERE are many practical instances of simultaneous flow of alternating and direct current in a circuit. When this occurs there is a *pulsating* current and it is said that an alternating

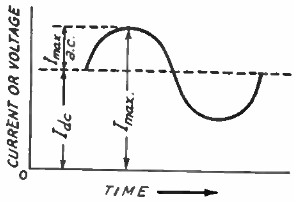


FIG. 404 — PULSATING CURRENT COMPOSED OF ALTERNATING CURRENT SUPERIMPOSED ON DIRECT CURRENT

current is *superimposed* on a direct current. As shown in Fig. 404, the maximum value is equal to the d.c. value plus the a.c. maximum, while the minimum value (on the negative a.c. cycle) is the difference between the d.c. and the maximum a.c. values. If a d.c. ammeter is used to measure the current, only the average or direct-current component will be indicated. An a.c. meter, however, will show the effective value of the combination. But this effective value is *not* the simple arithmetical sum of the effective value of the a.c. and the d.c., *but is equal to the square root of the sum of the effective a.c. squared and the d.c. squared.*

$$I = \sqrt{I_{ac}^2 + I_{dc}^2}$$

where I_{ac} is the effective value of the a.c. component, I is the effective value of the combination and I_{dc} is the average (d.c.) value of the combination. If the a.c. component is of sine-wave form, its maximum value will be its effective value, as determined above, multiplied by 1.414. If the a.c. component is not sinusoidal the maximum value will have a different ratio to the effective value, of course, depending on its wave form, as discussed in the preceding section.

QUANTITY, ENERGY AND POWER UNITS

IN ADDITION to the volt (unit of pressure), ampere (unit of flow) and ohm (unit of resistance), there are three other electrical units which are to be distinguished. These are the *coulomb*, the unit of quantity (Q); the *joule*, the unit of work or energy (W); and the *watt*, the unit of power or rate of work (P).

One coulomb is the quantity of electricity represented by a current flow of 1 ampere for 1 second. In other words, I coulomb equals I ampere-second.

One joule represents the work done in moving 1 coulomb against an electrical pressure of 1 volt.

World Radio History

In other words, it is a current flow of 1 ampere for 1 second between two points having a potential difference of 1 volt.

Power is the *rate* at which work is done. Hence, *one watt is equal to 1 joule per second.* In other words, it is the rate of work done when 1 ampere flows between two points having a potential difference of 1 volt. Therefore, *power in watts equals volts multiplied by amperes.*

Heating Effect and Power (P)

The heating effect of the electric current is due to molecular friction in the wire caused by the flow of electricity through it. This effect depends on the resistance of the wire; for a given time (seconds) and current (amperes) the heat generated will be proportional to the resistance through which the current flows. The power used in heating or the heat dissipated in the circuit (which may be considered sometimes as an undesired power loss) can be determined by substitution in the following equations:

Since $P = EI$

and $E = IR$

Therefore, $P = IR \times I = I^2R$

Also, since $I = \dfrac{E}{R}$

$$P = \frac{E^2}{R^2} \times R = \frac{E^2}{R}$$

P being the power in watts, E the e.m.f. in volts, and I the current in amperes.

It will be noted that if the current in a resistor and the resistance value are known, we can readily find the power. Or if the voltage across a resistance and the current through it are known or measured by a suitable voltmeter and ammeter, the product of volts and amperes will give the power. Knowing the approximate value of a resistor (ohms) and the applied voltage across it, the power dissipated is given by the last formula.

Likewise, when the power and resistance in a circuit are known, the voltage and current can be calculated by the following equations derived from the power formulas given above:

$$E = \sqrt{PR}$$

$$I = \sqrt{\frac{P}{R}}$$

Just as we can measure power dissipation in a resistance, we can determine the plate power input to a vacuum-tube transmitter, oscillator or amplifier, by the product of the measured plate voltage and plate current. Since the plate current is usually measured in *milliamperes* (thousandths of amperes), it is necessary to divide the product of plate volts and milliamperes by 1000 to give the result directly in watts.

Power With Pulsating Current

In a resistance circuit, the power developed by a pulsating current such as that illustrated in Fig. 404 will be I_2R watts, I being the effective or r.m.s. value of the current and R the resistance of the circuit in ohms. In the special case of sine-wave a.c. having *maximum* value equal to the d.c., which represents 100% modulation of the d.c. by the a.c., the effective value of the a.c. component is 0.707 (70%) of its maximum a.c. value and likewise of the d.c. value. If the two maximum values are each 1 ampere,

$$\begin{aligned} I &= \sqrt{1^2 + .707^2} \\ &= \sqrt{1.5} \\ &= 1.226 \\ P &= I^2\,R \\ &= 1.5\,R \end{aligned}$$

Hence, when sine-wave alternating current is superimposed on direct current in a resistance circuit *the average power is increased 50% if the maximum value of the a.c. component is equal to the d.c. component.* If the a.c. is not sinusoidal, the power increase will be greater or less, depending on the alternating-current wave form. This point is discussed further in connection with speech modulation in Chapter Ten.

ELECTROMAGNETISM

WHEN any electric current is passed through a conductor, magnetic effects are produced. *Moving electrons produce magnetic fields.* They are in the form of lines surrounding the wire; they are termed *lines of magnetic force.* These lines of force, in the form of concentric circles around the conductor, lie in planes at right angles to the axis of the conductor.

The magnetic field constituted by these lines of force exists only when current is flowing through the wire. When the current is started through the wire, we may visualize magnetic field as coming into being and sweeping outward from the axis of the wire. And on the cessation of the current flow, the field collapses toward the wire again and disappears. *Thus energy is alternately stored in the field and returned to the wire.* When a conductor is wound into the form of a coil of many turns, the magnetic field becomes stronger because there are more lines of force. The force is expressed in terms of *magneto-motive force* (*m.m.f.*) which depends on the number of turns of wire, the size of the coil and the amount of current flowing through it. The same magnetizing effect can be secured with a great many turns and a weak current or with fewer turns and a greater current. If ten amperes flow in

World Radio History

one turn of wire, the magnetizing effect is 10 *ampere-turns*. Should one ampere flow in ten turns of wire, the magnetizing effect is also 10 ampere-turns.

The length of the magnetic circuit, the material of which it is made and the cross-sectional area, determine what *magnetic flux* (Φ) will be present. And just as the resistance of the wire determines what current will flow in the electric circuit, the *reluctance* (μ) of the magnetic circuit (depending on length, area and material) acts similarly in the magnetic circuit.

$$I = \frac{E}{R} \text{ in the electric circuit; so}$$

$$\Phi = \frac{m.m.f.}{\mu} \text{ in the magnetic circuit.}$$

Permeability is the ratio between the flux density produced in a material by a certain m.m.f. and the flux density that the same m.m.f. will produce in air. Iron and nickel have higher permeability an air. Iron has a permeability some 3000 times that of air, is of low cost, and is therefore very commonly used in magnetic circuits of electrical devices.

Inductance (L)

The unit of self-inductance is the *henry.* A coil has a self-inductance of 1 henry when a rate of current change of 1 ampere per second causes an induced voltage of 1 volt. This basic unit is generally used with iron-core coils (as in power-supply filter circuits), but is too large for convenience in many radio applications. Therefore, smaller units are also used. These are the *millihenry* (*mh*), equal to one-thousandth henry; and *microhenry* (μh), one-millionth henry. The practical formula for computing the inductance of air-core radio coils is:

$$L = \frac{0.2\ A^2N^2}{3A + 9B + 10C}$$

where L is the inductance in microhenrys

A is the mean diameter of the coil in inches

B is the length of winding in inches

C is the radial depth of winding in inches

N is the number of turns.

The quantity C may be neglected if the coil is a single-layer solenoid, as is nearly always the case with coils for high frequencies.

For example, assume a coil having 35 turns of No. 30 d.s.c. wire on a receiving coil form having a diameter of 1.5 inches. Consulting the wire table, we find that 35 turns of No. 30 d.s.c. will occupy a length of one-half inch. Therefore,

$$A = 1.5$$
$$B = .5$$
$$N = 35$$

and

$$L = \frac{0.2 \times (1.5)^2 \times (35)^2}{(3 \times 1.5) + (9 \times .5)}$$

or 61.25 microhenrys.

To calculate the number of turns of a single-layer coil for a required value of inductance:

$$N = \sqrt{\frac{3A + 9B}{0.2A^2} \times L}$$

More rapid and convenient calculations in designing coils can be made with the A.R.R.L. *Lightning Radio Calculator* (Type A). Data for iron-core coils are given in Chapter Fifteen. Stated generally, *the self-inductance of a coil is inversely proportional to the reluctance of its magnetic circuit and is proportional to the square of the number of turns.* If the magnetic circuit is a closed iron core, for instance, the inductance value might be several thousand times what it would be for the same coil without the iron core, the reluctance being that much less than with an air-core. Also, doubling the number of turns would make the inductance 4 times as great.

Inductances in Series and in Parallel

Coils may be connected in series, in parallel, or in series-parallel. If connected in series, the total inductance is increased just as the total resistance is increased with resistances in series, *provided the magnetic flux of either coil does not link with the turns of the other.* With the same restriction, the total inductance of coils connected in parallel is reduced just as the total resistance is reduced with resistors connected in parallel. Correspondingly, coils may be connected in series-parallel combinations. The equations for inductances in series, in parallel and in series-parallel are the same as those given for resistances, with the proper inductance values substituted for resistance values.

Magnetic Energy Storage (W)

The tendency of coils to prevent changes in current flow gives them the ability to store energy. This energy storage is proportional to the inductance of the coil and to the square of the current.

$$\textit{Energy stored in coil} = \frac{LI^2}{2}$$

where the energy is in joules or watt seconds, L is the inductance in henrys, I is the current in amperes.

This property is of particular importance in the filter systems used for transmitter and receiver power supply which are described in a later chapter.

Inductive Reactance (X_L)

As we have learned, a coil tends to limit the amount of current which an alternating voltage

World Radio History

can send through it. A further very important fact is that a given coil with a fixed amount of inductance will retard the flow of a high frequency alternating current much more than a low frequency current. We know, then, that the characteristic of a coil in retarding an alternating current flow depends both on the inductance of the coil and on the frequency of the current. This combined effect of frequency and inductance in coils is termed *reactance*, or *inductive reactance.*

The inductive reactance formula is:

$$X_L = 2\pi fL$$

where: X_L is the inductive reactance in ohms
π is 3.1416
f is the frequency in cycles per second
L is the inductance in henrys

From this it is evident that inductive reactance is directly proportional to frequency and also directly proportional to the value of inductance.

Capacity or Capacitance (C)

The characteristic which permits a condenser to be charged is termed *capacity* or *capacitance.* The capacity of a condenser depends on the number of plates in each element, the area of the plates, the distance by which they are separated by the dielectric and the nature of the dielectric. Glass or mica as the dielectric in a condenser would give a greater capacity than air — other things being equal.

The unity of capacity is the *farad.* A more common term in practical work is the *microfarad* (abbreviated μfd.) while another (used particularly for the small condensers in high-frequency apparatus) is the *micromicrofarad* (abbreviated μμfd.). The μfd. is one millionth of a farad; the μμfd. is one millionth of a microfarad.

The formula for the capacitance of a condenser is

$$C = \frac{kA\ (n-1)}{4\pi d \times 9 \times 10^5}$$

$$= .0088\frac{kA}{d}(n-1)\ 10^{-5}\mu\text{fd.}$$

where A = area of one side of one plate (sq. cm.)
n = total number of plates
d = separation of plates (cm.)
k = specific inductive capacity or dielectric constant of the dielectric.

When A is the area of one side of one plate *in square inches* and d is the separation of the plate *in inches,*

$$C = .02235\frac{kA}{d}(n-1)\ 10^{-5}\mu\text{fd.}$$

The dielectric constant determines the quantity of charge which a given separation and area of plates will accumulate for a given applied voltage. The "inductivity" of the dielectric varies as in the table. "*k*" is the ratio of the capacitance of a condenser with a given dielectric to its capacitance with air dielectric.

Table of Dielectric Constants

Dielectric	"*k*"	*Puncture voltage* *Kilovolts per cm.*	*Puncture voltage* *Kilovolts per inch.*
Air (normal pressure)	1.00	7.8–9.0	19.8–22.8
Flint Glass	6. to 10	900	2280
Mica	4.6 to 8	1500	3810
Paraffin Wax (solid)	2.0 to 2.5	400	1017
Sulphur	3.9 to 4.2	—	—
Castor Oil	4.7	150	381
Porcelain	4.4	—	—
Quartz	4.5	—	—
Resin	2.5	—	—
Olive Oil	3.1	120	305
Gutta Percha	3.3 to 4.9	80–200	203–508
Shellac	3.1	—	—
Common Glass	3.1 to 4.0	300–1500	762–3810
Turpentine	2.23	110–160	280–406
Dry Oak Wood	2.5 to 6.8	—	—
Formica Bakelite, etc.	5 to 6	—	—

A considerable variety of types of condensers is used in radio work. Perhaps the most commonly known type is the variable condenser — a unit comprising two sets of metal plates, one capable of being rotated and the other fixed and with the two groups of plates interleaving. In this case, the dielectric is almost invariably air. Fixed condensers are also widely used. One type consists of two sets of metal foil plates separated by thin sheets of mica, the whole unit being enclosed in molded bakelite. Yet another type — usually of high capacity — consists of two or more long strips of metal foil separated by thin waxed paper, the whole thing being rolled into compact form and enclosed in a metal can. Paper impregnated with oil or Pyranol is used as the dielectric in compact high-voltage units. Units of this type have capacities of from a fraction of a microfarad to four microfarads or more, and voltage ratings ranging from several hundred to several thousand volts.

Electrolytic Condensers

Still another type is the electrolytic condenser, widely used in filters of low-power transmitter plate supplies and in receivers. One plate of these condensers consists of sheets of aluminum or aluminum alloy on which a thin insulating film of aluminum oxide is formed by polarization; that is, by connecting this plate to the positive of a d.c. supply. This electrode is immersed in a liquid electrolyte in a "wet" type condenser, the electrolyte actually serving as the other "plate," to which a conductive connection is made by a second aluminum electrode immersed in the electrolyte. The latter electrode is negative. The electrolyte is usually a solution of borax and

World Radio History

boric acid. The "dry" type electrolytic condenser is similar but has its electrolyte soaked into a strip of gauze separating the filmed and non-filmed electrodes. In both types the thin film is the dielectric which, together with the relatively large plate area achieved by the various methods of construction, gives the electrolytic condenser a very high capacitance in small space. But there is one important difference between electrolytic condensers and the other fixed condensers previously described. *The plate on which the film is formed always must be maintained at a positive potential with respect to the other electrode.* Hence, these condensers can be used only with steady d.c. or pulsating d.c. voltage applied. Unlike other types of fixed condensers, *they cannot be used in circuits carrying only alternating current.* They are ordinarily used in capacitances ranging from 5 to 16 microfarads per unit, although a few types have capacitance of 100 μfd. or more, and have voltage ratings of 25 to 500 volts or higher.

The various types of condensers are usually designated by their dielectric material, or some distinguishing component of the dielectric. Hence, an air-dielectric type is called an "air" condenser, one having paper impregnated with Pyranol is called a "Pyranol" condenser, and so on.

Capacitive Reactance (X_C)

We can readily understand how very different will be the performance of any condenser when direct or alternating voltages are applied to it. The direct voltages will cause a sudden charging current, but that is all. The alternating voltages will result in the condenser becoming charged first in one direction and then the other — this rapidly changing charging current actually being the equivalent of an alternating current through the condenser. Many of the condensers in radio circuits are used just because of this effect. They serve to allow an alternating current to flow through some portion of the circuit but at the same time prevent the flow of any direct current.

Of course, condensers do not permit alternating currents to flow through them with perfect ease. They impede an alternating current just as an inductance does. The term *capacitive reactance* is used to describe this effect in the case of condensers. Condensers have a reactance which is *inversely* proportional to the capacitance and to the frequency of the applied voltage. The formula for capacitive reactance is

$$X_C = \frac{1}{2\pi f C_{fd}}$$

where X_C is the capacitive reactance in ohms
π is 3.1416
f is the frequency in cycles per second
$C_{fd.}$ is the condenser capacitance in *farads.*

Where the capacitance is in microfarads (μfd.), as it is in most practical cases, the formula becomes

$$X_C = \frac{10^6}{2\pi f C_{\mu fd.}}$$

10_6 being 1,000,000.

Condensers in Series and Parallel

Capacitances can be connected in series or in parallel like resistances or inductances, as shown in Fig. 405. However, connecting condensers in parallel makes the total capacitance *greater* while in the case of resistance and inductance, the value is lessened by making a parallel connection.

The equivalent capacity of condensers connected in parallel is the sum of the capacities of the several condensers so connected

$$C = C_1 + C_2 + C_3$$

The equivalent capacity of condensers connected in series is expressed by the following formula:

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

When but two condensers are connected in series, the following expression can be used

$$C = \frac{C_1 C_2}{C_1 + C_2}$$

Where the net capacitance of a series-parallel combination is to be found, the capacitance of the series groups can be worked out separately and then added in parallel combination. As is also true in the case of resistances in parallel, the Series-Parallel type *Lightning Calculator* is a useful aid in making such determinations.

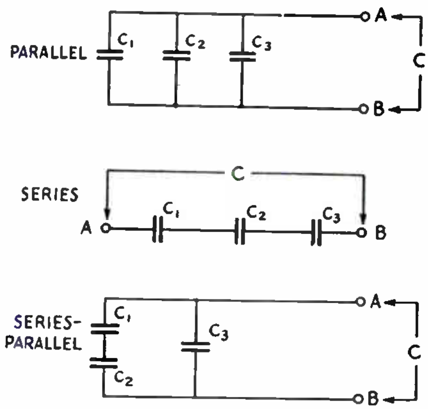


FIG. 405 — DIAGRAMS OF SERIES, PARALLEL AND SERIES-PARALLEL CAPACITANCE CONNECTIONS

World Radio History

Connecting condensers in series increases the breakdown voltage of the combination although, of course, it decreases the capacitance available. Condensers of identical capacitance are most effectively connected in series for this purpose. Voltage tends to divide across series condensers in inverse proportion to the capacitance, so that the smaller of two series condensers will break down first if the condensers are of equal voltage rating. Before selecting filter condensers the operating conditions, voltage peaks and r.m.s. values should be carefully considered. For further information on this matter see Chapter Fourteen.

Energy Stored in Condensers (W)

As has been previously shown, magnetic energy is stored in coils. Likewise, energy is stored in condensers. But where the amount of energy is associated with current value in the case of the coil, it is associated with e.m.f. in the instance of the condenser. Hence, it is termed *electrostatic* energy. The amount of energy stored by a condenser is given by this equation:

$$\text{Energy stored in condenser} = \frac{CE^2}{2}$$

where the energy is in joules (or watt-seconds), C is the capacitance in farads, and E is the e.m.f. in volts. When the capacitance is in microfarads, as is usual in practical cases, the equation is

$$\text{Energy stored} = \frac{C_{\mu fd.}E^2}{2 \times 10^6}$$

10^6 being 1,000,000 and the answer being in joules.

This energy storage relation for condensers, like the energy storage relation for coils, is of importance in power supply filter circuits.

Resistance-Capacitance Time Constant (RC)

If a charged condenser had infinite resistance between its plates, it would hold the charge indefinitely at its initial value. However, since all practical condensers do have more or less definite resistance (through the dielectric and between the connecting terminals), the charge gradually leaks off. Good condensers have a very high "leakage resistance," however, and will hold a charge for days if left undisturbed.

In a circuit containing only capacitance and resistance, the time required for the potential difference between the charged plates of a condenser to fall to a definite percentage of its initial value is determined by the capacitance of the condenser and the value of the resistance. The relation is of practical importance in many circuit applications in amateur transmission and reception, as in time delay with automatic volume control, resistance-capacitance filters, etc. For the voltage to fall to 37% (0.37) of its initial value,

$$t = RC,$$

where t is the time in *microseconds* (millionths of a second), R is the resistance in ohms, and C is the capacitance in microfarads. RC should be divided by 1 million to give the answer in seconds. This is called the *time constant* of the combination. The time required for the voltage to fall to one-tenth (10%) of its initial value can be found by multiplying RC, as given above, by 2.4.

Time constant, t, for 90% fall in voltage $= 2.4\frac{RC}{10^6}$, t being in *seconds*, R in ohms and C in *μfd.*

Impedance (Z)

The combined effect of resistance and reactance is termed *impedance* in the case of both coils and condensers. The symbol for impedance is Z and it is computed from this formula:

$$Z = \sqrt{R^2 + X^2}$$

where R is the resistance and X is the reactance. The terms Z, R and X are all expressed in ohms. Ohm's Law for alternating current circuits then becomes

$$I = \frac{E}{Z} \quad Z = \frac{E}{I} \quad E = IZ$$

When a circuit contains resistance, capacitance and inductance, all three in series, the value of reactance will be the difference between that of the coil and that of the condenser. Since for a given coil and condenser the inductive reactance increases with frequency and capacitive reactance decreases with frequency, X_L is conventionally considered positive and X_C negative.

In finding the current flow through a condenser in an alternating current circuit we can usually assume that $I = \frac{E}{X_C}$ (X_C being the capacitive reactance of the condenser). The use of the term Z (impedance) is, in such cases, made unnecessary because the resistance of the usual good condenser is not high enough to warrant consideration. When there is a resistance in series with the condenser, however, it can be taken into account in exactly the same manner as the resistance of the coil. The impedance of the condenser-resistance combination is then computed and used as the Z term in the Ohm's Law formulas.

Phase

It has been mentioned that in a circuit containing inductance, the rise of current is delayed by the effect of electrical inertia pre-

World Radio History

sented by the inductance. Both increases and decreases of current are similarly delayed. It is also true that a current must flow into a condenser before its elements can be charged and so provide a voltage difference between its terminals. Because of these facts, we say that a current "lags" behind the voltage in a circuit which has a preponderance of inductance and that the current "leads" the voltage in a circuit where capacity predominates. Fig. 406 shows three possible conditions in an alternating current circuit. In the first, when the load is a pure resistance, both voltage and current rise to the maximum values simultaneously. In this case the voltage and current are said to be *in phase*. In the second instance, the existence of inductance in the circuit has caused the current to lag behind the voltage. In the diagram, the current is lagging one quarter cycle behind the voltage. The current is therefore said to be 90 degrees *out of phase* with the voltage (360 degrees being the complete cycle). In the third example, with a capacitive load, the voltage is lagging one quarter cycle behind the current. The *phase difference* is again 90 degrees. These, of course, are theoretical examples in which it is assumed that the inductance and the condenser have no resistance. Actually, the angle of lag or lead depends on the ratio of reactance to resistance in the circuit.

Another kind of phase relationship frequently encountered in radio work is that between two alternating currents of identical frequency flowing simultaneously in the same circuit. Even in a circuit of pure resistance the two currents will augment or nullify each other, depending on whether they are in phase

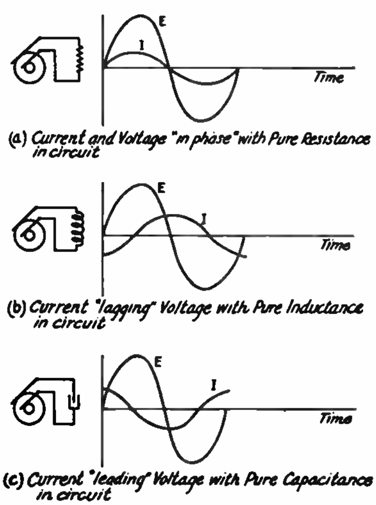


FIG. 406 — VOLTAGE AND CURRENT PHASE RELATIONS WITH RESISTANCE AND REACTANCE CIRCUITS

or out of phase. When two such currents are of the same frequency and in phase they are said to be *synchronized*, the maximum amplitude of the combination then being the arithmetical sum of the two separate amplitudes. The maximum amplitude will be lessened as the phase differs, reducing to zero amplitude with two equal currents when the phase angle becomes 180 degrees. The latter condition is known as *phase opposition.*

Power Factor

In a direct current circuit, or in an alternating current circuit containing only resistance, the power can be computed readily by multiplying the voltage by the current. But it is obviously impossible to compute power in this fashion for an alternating current circuit in which the current may be maximum when the voltage is zero; or for any case in which the voltage and current are not exactly in phase. In computing the power in an a.c. circuit we must take into account any phase difference between current and voltage. This is made possible by the use of a figure representing the *power factor*.

The power factor is equal to the actual power in the circuit (watts) divided by the product of the current and voltage (volt-amperes). In terms of a circuit property, *it is equal to the resistance divided by the impedance in the circuit.* In the case of a circuit containing resistance only, the ratio is 1 and, hence, the power factor is 100% (unity). If there is reactance only in the circuit (zero resistance), then the power factor is zero. In circuits containing both resistance and reactance the power factor lies between these two values. As instances, a good condenser should have nearly zero power factor as should a good choke coil. Resistors for use in a.c. circuits should, on the other hand, have a power factor of 100%.

Oscillation Frequency — Resonance

It has been shown that the inductive reactance of a coil and the capacitive reactance of a condenser are oppositely affected with frequency. Inductive reactance increases with frequency; capacitive reactance decreases as the frequency increases. In any combination of inductance and capacitance, therefore, there is one particular frequency for which the inductive and capacitive reactances are equal and, since these two reactances oppose each other, for which the net reactance becomes zero, leaving only the resistance of the circuit to impede the flow of current. The frequency at which this occurs is known as the *resonant frequency* of the circuit and the circuit is said to be *in resonance* at that frequency or *tuned* to that frequency.

In practical terms, since at resonance the

World Radio History

inductive reactance must equal the capacitive reactance, then

$$X_L = X_C \text{ or } 2\pi f L = \frac{1}{2\pi f C}$$

The resonant frequency is, therefore,

$$f = \frac{1}{2\pi\sqrt{LC}} \times 10^6$$

where

f is the frequency in kilocycles per second
2π is 6.28
L is the inductance in microhenrys (μh.)
C is the capacitance in micro microfarads ($\mu\mu$fd.)

The resonance equation in terms of wavelength is

$$\lambda = 1.885\sqrt{L_{\mu h.} C_{\mu\mu fd.}}$$

where

λ is the wavelength in meters
$L_{\mu h.}$ is the inductance in microhenrys
$C_{\mu\mu fd.}$ is the capacitance in micromicrofarads

LC Constants

From this it is evident that the product of L and C is a constant for a given frequency and that *the frequency of a resonant circuit varies inversely as the square root of the product of the inductance and capacitance.* In other words, doubling both the capacitance and the inductance (giving a product of 4 times) would halve the frequency; or, reducing the capacitance by one-half and the inductance by one-half would double the frequency; while leaving the inductance fixed and reducing the capacitance to one-half would increase the frequency 40%. To double the frequency, it would be necessary to reduce either the capacitance or the inductance to one-fourth (leaving the other fixed).

LC Constants for Amateur and Intermediate Frequencies

Frequency Band	*L* *μh.*	*C* *μμfd.*	*L × C*
1750-kc.	90	90	8100
3500-kc.	45	45	2025
7000-kc.	22.5	22.5	506.25
14-Mc.	11.25	11.25	126.55
28-Mc.	5.63	5.63	31.64
56-Mc	2.82	2.82	7.91
450-kc.	355	355	126,025

The accompanying table gives LC values for reference at amateur-band and superhet intermediate frequencies. This table, in combination with the above general rules, will be of practical use in estimating the constants of tuned circuits for amateur transmitters and receivers. Note that the numerically equal inductance and capacitance values listed are in microhenrys and micromicrofarads, respectively, giving L/C ratios for the three lower frequency amateur bands approximating those usual in receiver tuned circuits. These ratios would be considered relatively "low-C" or "high-L" in transmitter practice (low ratio of capacitance to inductance, or high ratio of inductance to capacitance). Extremely high-C circuits for these bands would have capacitances greater by 10 times or so, and inductances proportionately smaller. Actual circuits for the three higher-frequency bands would necessarily have to have smaller inductance values because the minimum capacitances attainable in circuits would be larger than those indicated. Practical values are given in the later chapters describing apparatus.

SERIES AND PARALLEL RESONANCE

All practical tuned circuits can be treated as either one of two general types. One is the

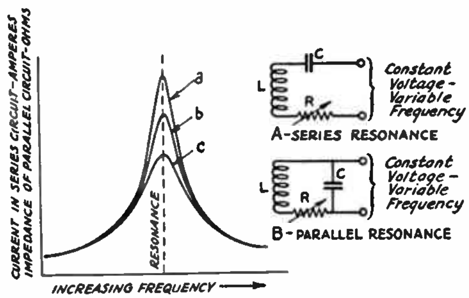


FIG. 407 — CHARACTERISTICS OF SERIES-RESONANT AND PARALLEL-RESONANT CIRCUITS

series resonant circuit in which the inductance, capacitance, resistance and source of voltage are in series with each other. With a constant-voltage alternating current applied as shown in A of Fig. 407 the current flowing through such a circuit will be maximum at resonant frequency. The magnitude of the current will be determined by the resistance in the circuit. The curves of Fig. 407 illustrate this, curve *a* being for minimum resistance and curves *b* and *c* being for greater resistances.

The second general case is the parallel resonant circuit illustrated in B of Fig. 407. This also contains inductance, capacitance and resistance in series, but the voltage is applied in parallel with the combination instead of in series with it as in A. Here we are not primarily interested in the current flowing *through* the circuit but in its characteristics as viewed from its terminals, especially in the *parallel impedance* it offers. The variation of parallel impedance of a parallel resonant circuit with

World Radio History

frequency is illustrated by the same curves of Fig. 407 that show the variation in current with frequency for the series resonant circuit. The parallel impedance is maximum at resonance and increases with decreasing series resistance. Although both series and parallel resonant circuits are generally used in radio work, the parallel resonant circuit is most frequently found, as inspection of the diagrams of the equipment described in subsequent chapters will show.

High parallel impedance is generally desirable in the parallel resonant circuit and low series impedance is to be sought in series resonant circuits. Hence low series resistance is desirable in both cases.

Sharpness of Resonance (Q)

It is to be noted that the curves become "flatter" for frequencies near resonance frequency as the internal series resistance is increased, but are of the same shape for all resistances at frequencies further removed from resonance frequency. The relative sharpness of the resonance curve near resonance frequency is a measure of the *sharpness of tuning or*

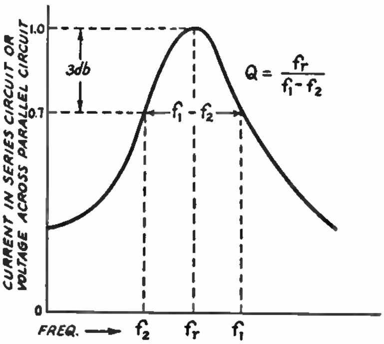


FIG. 408 — HOW THE VALUE OF Q IS DETERMINED FROM THE RESONANCE CURVE OF A SINGLE CIRCUIT

selectivity (ability to discriminate between voltages of different frequencies) in such circuits. This is an important consideration in tuned circuits used for radio work. Since the effective resistance is practically all in the coil, the condenser resistance being negligible, the efficiency of the coil is the important thing determining the "goodness" of a tuned circuit. A useful measure of coil efficiency, and hence of tuned circuit selectivity, is the ratio of the coil's reactance to its effective series resistance. This ratio will be recognized as approximately the reciprocal of the circuit property of power factor previously discussed, and is designated by Q.

$$Q = \frac{2\pi f L}{R}$$

The value of Q is determined directly from the resonance curve of either a series-resonant or parallel-resonant circuit as shown in Fig. 408. It is given by the ratio of the resonance frequency to the difference between the frequencies at which the series current (for the series-resonant circuit) or the parallel voltage (for the parallel-resonant circuit) becomes 70% of the maximum value. A Q of 100 would be considered good for coils used at the lower amateur frequencies, while the Q of coils for the higher frequencies may run to several hundred. It must be remembered, however, that Q represents a ratio, so that the actual frequency width of the resonance curve would be proportionately greater for a high-frequency circuit than for a low-frequency circuit having the same value of Q.

Radio Frequency Resistance — Skin Effect

The effective resistance of conductors and coils at radio frequencies may be many times the "ohmic" resistance of the same conductors as it would be measured for direct current or low-frequency alternating current. This is largely due to the *skin effect*, so called because the high-frequency current tends to concentrate on the outside of the conductor, leaving the inner portion carrying little or no current. It is for this reason that hollow copper tubing is widely used in the coils and connections of high-frequency circuits. However, the current may not be distributed uniformly over the surface. With flat conductors the current tends to concentrate at the edges and with square conductors it tends to concentrate at the corners. In addition to the skin effect, dielectric losses due to insulators and resistance losses in other conductors in the field of the conductor contribute to its effective resistance. *The effective resistance is measured as the power in the circuit divided by the square of the maximum effective radio-frequency current.*

Parallel-Resonant Circuit Impedance (Z)

The parallel-resonant circuit offers pure resistance (its resonant impedance) between

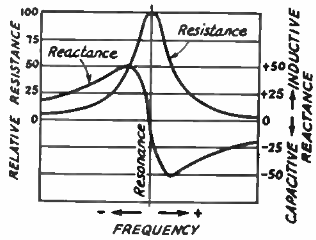


FIG. 409 — THE IMPEDANCE OF A PARALLEL-RESONANT CIRCUIT SEPARATED INTO ITS REACTANCE AND RESISTANCE COMPONENTS

The parallel resistance is equal to the parallel impedance at resonance.

its terminals at resonance frequency, and becomes reactive for frequencies higher and lower. The manner in which this reactance varies with frequency is shown by the indicated curve in Fig. 409. This figure also shows the *parallel resistance* component which combines with the reactance to make up the impedance. The reactive nature of parallel impedance at frequencies off resonance is important in a number of practical applications of parallel-tuned circuits, in both transmitters and receivers, and it will be helpful to keep this picture in mind.

The maximum value of parallel impedance which is obtained at resonance is proportional to the square of the inductance and inversely proportional to the series resistance. (This resistance should not be confused with the resistance component of parallel impedance which has just been mentioned.)

$$\text{Resonant impedance} = \frac{(2\pi f_r L)^2}{R}$$

$$\text{Since } \frac{2\pi f_r L}{R} = Q,$$

$$\text{Resonant impedance} = (2\pi f_r L)Q$$

In other words, the impedance is equal to the inductive reactance of the coil (at resonant frequency) times the Q of the circuit. Hence, the voltage developed across the parallel resonant circuit will be proportional to its Q. For this reason the Q of the circuit is not only a measure of the selectivity, but also of its gain or amplification, since the voltage developed across it is proportional to Z. Likewise, the Q of a circuit is related to the frequency stability of an oscillator in which it is used, the frequency stability being generally better as the circuit Q is higher. This is illustrated in practical applications described in subsequent chapters.

Coupled Circuits

Resonant circuits are not used alone in very many instances but are usually associated with other resonant circuits or are *coupled* to other circuits. It is by such coupling that energy is transferred from one circuit to another. Such coupling may be *direct*, as shown in A, B and C of Fig. 410, utilizing as the mutual coupling element, inductance (A), capacitance (B) or resistance (C). These three types of coupling are known as *direct inductive, direct capacitive*, or *direct resistive*, respectively. Current circulating in one LC branch flows through the common element (C, R or L) and the voltage developed across this element causes current flow in the other CL branch. Other types of coupling are the *indirect capacitive* and *transformer* or *inductive* shown below the others. The coupling most common in high-frequency circuits is of the latter type. In such an arrangement the coupling value may be changed by changing the number of active turns in either coil or by changing the relative position of the coils (distance or angle between them).

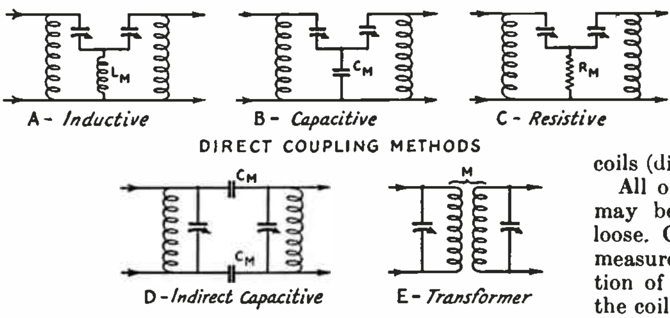


FIG. 410 — BASIC TYPES OF CIRCUIT COUPLING

All of the above coupling schemes may be classified as either tight or loose. Coupling cannot, however, be measured simply in "inches" separation of coils. The separation between the coils (distance and angle between axes) and the inductance in each determine the *coefficient of coupling.*

Coefficient of Coupling (k)

The common property of two coils which gives transformer action is their *mutual inductance* (M). Its value is determined by self-inductance of each of the two coils and their position with respect to each other. In practice, the coupling between two coils is given in terms of their *coefficient of coupling,* designated by k. The coupling is maximum (unity or 100%) when all of the flux produced by one coil links with all of the turns of the other. With air-core coils in radio-frequency circuits the coupling is much "looser" than this, however. It is generally expressed by the following relation:

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

in which k is the coefficient of coupling expressed either as a decimal part of 1, or, when multiplied by 100, as a percentage; M is the mutual inductance; L_1 is the self-inductance of one coil; and L_2 is the self-inductance of the other coil. M, L_1 and L_2 must be in the same units (henrys, millihenrys or microhenrys).

Critical coupling is that which gives the maximum transfer of energy from the primary to the secondary. However, the sharpness of resonance for the combination is considerably lessened under this condition. With coupling

World Radio History

greater than critical, the resonance curve has two "humps" appreciably separated. For good selectivity the coupling is therefore made considerably less than the critical value, even though this reduces the amplification or gain. With the coil combinations used in radio receivers, coupling of the order of $k = 0.05\%$ or less is representative, whereas for critical coupling the coefficient might be 0.5% to 1.0%. The value of the coefficient for critical coupling is also related to the respective *Q's* of the two coils:

$$k_{crit.} = \frac{1}{\sqrt{Q_p Q_s}}$$

where the two Q values are for the primary and secondary, respectively. For instance, if the primary and secondary *Q's* are equal, the value of critical k is the reciprocal of the Q for one coil — 0.01 or 1% where each has a Q of 100. Therefore, for the same values of self-inductance, k becomes smaller as Q becomes higher.

IMPEDANCE MATCHING

It should be kept in mind that, as has been previously mentioned, both single resonant circuits and coupled circuits are used in conjunction with other circuit elements. These other elements introduce resistance into the resonant circuits, and modify the constants that they would have by themselves. In practice it is seldom possible for the amateur to precalculate the effect of such reactions, since the other quantities are usually unknown. In any case, it is usually necessary to arrive at "best conditions" by the practical process of adjustment. However, the foregoing general information is helpful in preliminary design or choice of tuned circuit combinations, and in understanding why certain changes are likely to cause different behavior in circuit performance.

It is a well-known principle in radio circuit design that the maximum gross power of a generator, such as a vacuum tube, will be delivered to its load when the load resistance is equal to the internal resistance of the generator. In other words, maximum power would be taken from the generator when its resistance was exactly *matched* by the load resistance. Although this particular statement is literally true, it might not describe the most desirable condition of loading. For one thing, the efficiency would be only 50%, half the power being consumed in the generator and half in the load. From the principle, however, has grown up a system of more or less standard practice in designing radio circuits which comes under the broad heading of *impedance matching.* The term means, generally, *that the load impedance presented to the source is transformed to suit given requirements.* This is accomplished by transformers and other coupling devices.

Iron-core transformers are widely used for coupling between load and vacuum-tube in audio-frequency amplifiers, for instance. In such cases the value of proper load resistance (load impedance) for maximum undistorted power output will be given for the tube. This *load* resistance, it will be noted, is not the same as the rated *plate* resistance of the tube, which is equivalent to its internal resistance as a generator. A second figure will be given for the actual impedance of the load device to which the tube must supply undistorted power. The matching of this load to the given requirements of the tube is the job of the coupling transformer, the job being to make the actual impedance of the load device appear as the rated load impedance of the tube, so far as the tube is concerned. This requires that the transformer have the proper ratio of secondary to primary turns. *The turn ratio will be equal to the square root of the impedance ratio.*

$$\frac{N_s}{N_p} = \sqrt{\frac{Z_s}{Z_p}}$$

where N_s and N_p are the numbers of secondary and primary turns, Z_s is the impedance of the load device and Z_p is the rated load resistance of the tube. *This will also be the voltage ratio of the transformer.*

Transformers are also used to provide proper impedance matching in radio-frequency circuits, although here the problem is not one of simply choosing a calculated turn ratio. Rather, the right condition is arrived at by adjustment of turns and distance between coils, as shown in the later chapters on transmitters.

Matching by Tapped Circuits

In addition to impedance matching by inductive coupling with tuned circuits, frequent use is made of tapped resonant circuits. Two methods for parallel resonant circuits are illustrated in Fig. 411. In one case (A) the tapping is across part of the coil, while in the other (B) it is across one of two tuning condensers in series. In both cases *the impedance between the tap points will be to the total impedance practically as the square of the reactance*

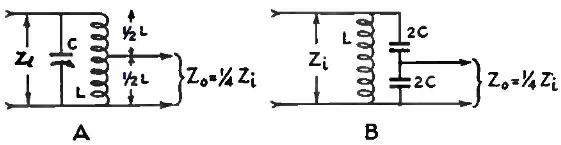


FIG. 411 — METHODS OF TAPPING THE PARALLEL IMPEDANCE OF RESONANT CIRCUITS FOR IMPEDANCE MATCHING

World Radio History

between the tap points is to the total reactance of the branch in which the tapping is done. That is, if the coil is tapped in the center the reactance between the tap points will be one-half the total inductive reactance and the impedance between these points will be $(\frac{1}{2})^2$ or one-fourth the total parallel impedance of the circuit. The same will apply if the tap is made across one of two equal capacitance condensers connected in series. If the condenser across which the tap was made had twice the capacitance of the other, however, the impedance Z_0 would be one-ninth the total, since the reactance between the tap points would then be but a third — capacitive reactance decreasing as the capacitance is increased.

Link Coupling

Another coupling arrangement used for impedance matching radio-frequency circuit is that known as *link coupling.* It is used for transferring energy between two tuned circuits

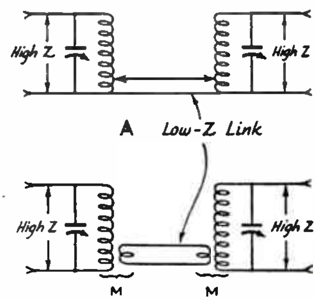


FIG. 412 — METHODS OF USING LINK COUPLING FOR IMPEDANCE MATCHING

which are separated by space so that there is no direct mutual coupling between the two coils. It is especially helpful in minimizing incidental capacitive coupling between the two circuits due to the distributed capacitance of the windings, thereby minimizing the transfer of undesired harmonic components of the desired fundamental. Two typical versions of link coupling are shown in Fig. 412. Both represent an impedance step-down from one tuned circuit to the coupling line, and then an impedance step-up from the line to the other tuned circuit.

The arrangement of Fig. 412-A will be recognized as an adaptation of the impedance-tapping method previously shown in Fig. 411-A. It is sometimes called auto-transformer link coupling, because the link turns are also included in the tuned-circuit turns. The arrangement of 412-B differs only in that the link turns are separate and inductively coupled to the tuned-circuit turns. The latter system is somewhat more flexible in adjustment than the tapping method, since the coupling at either end of the line can be adjusted in small steps by moving the link turns with respect to the tuned-circuit coils. Practical applications of such link coupling in various forms are described in Chapter Eight.

FILTER CIRCUITS

ALTHOUGH any resonant circuit is useful for selecting energy of a desired frequency and rejecting energy of undesired frequencies, certain combinations of circuit elements are better

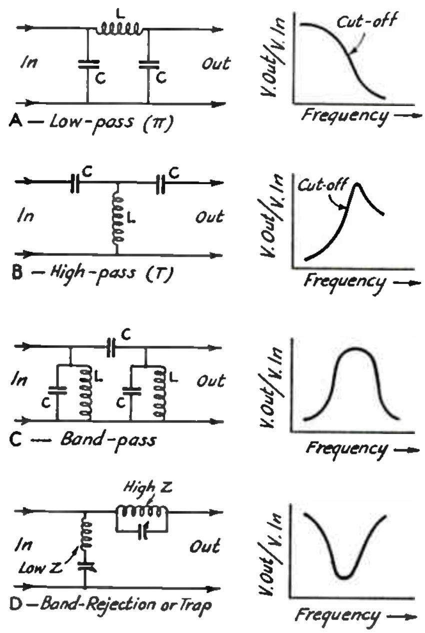


FIG. 413 — TYPES OF FILTERS AND APPROXIMATE CHARACTERISTICS OF EACH

adapted to transmitting more or less uniformly over a *band* of frequencies, or to rejecting over a *band* of frequencies. Such rejecting action is known as *attenuation* and such combinations are called *filters.* Filter combinations are basically of three types, as illustrated in the simple forms of Fig. 413. A *low-pass* filter, as shown in *A*, is used to transmit energy below a given frequency limit and to attentuate energy of higher frequencies. Filters of this type are generally used with iron-core coils or filter chokes in plate power supply systems for transmitters and receivers. A combination of inductance and capacitance elements of the arrangement of *A* is known as a "π" or "*pi*" *section* because its appearance resembles that of the Greek letter. A section of the type illustrated in *B* is of opposite character to that shown in *A*, passing frequencies above a designated cut-off limit and attentuating lower

World Radio History

frequencies and therefore being designated *high-pass*. The one shown is known as a "T" section, because its form resembles that letter.

A type of filter for transmitting over a band of frequencies and attenuating outside this band is shown in *C*. A combination giving this action is termed a *band-pass filter*. The particular section shown will be recognized as having the same form as the indirect-capacitive coupling arrangement of Fig. 410-D. Similar performance is also obtainable with two tuned circuits inductively coupled. Therefore, such tuned transformers with proper coupling are used as band-pass filters, particularly in the intermediate-frequency circuits of superheterodyne receivers.

A particular combination of series-resonant and parallel-resonant circuit intended to attenuate over a narrow band of frequencies and transmit at frequencies outside that band is shown in *D* of Fig. 413. The series-resonant circuit would give a very low shunt path impedance at one particular frequency, while the parallel-resonant circuit in the series path would have high impedance at that frequency. Both would therefore combine to reject or trap out energy over a narrow band of frequencies. Such action is used in wave traps for use with receivers.

A given type of filtering action is increased by using more sections in cascade, or combined effects are obtained by combining different types of filter sections. The subject of filters in all their variations is a highly specialized and complex matter, however, and cannot be covered in further detail here. The interested reader may refer to any standard communication or radio engineering text for further information.

In addition to filters employing only coils and condensers, there are also special types which use piezo-electric crystals (quartz and rochelle salts) as selective elements. These are treated in Chapter Seven.

BRIDGE OR NEUTRALIZING CIRCUITS

Another special type of circuit widely used in transmitters, and to some extent in receivers, is the *bridge circuit*. Employing combinations of inductance and capacitance, it is used especially to neutralize the undesired coupling effect of a capacitance while permitting desired coupling. For instance, bridge combinations are generally used for neutralizing the grid-plate capacitance of triode tubes in transmitter r.f. amplifiers to prevent the feed-back of energy from the plate to the grid circuit. A bridge circuit is also used in the crystal filter of the Single-Signal type superheterodyne to modify the effective shunt capacitance of the crystal. Such bridge circuits are generally of the forms shown in Fig. 414. When the bridge is balanced, there will be no voltage across one pair of terminals when excitation is applied to the other terminals. In most practical cases two arms of the bridge will be capacitances C_1

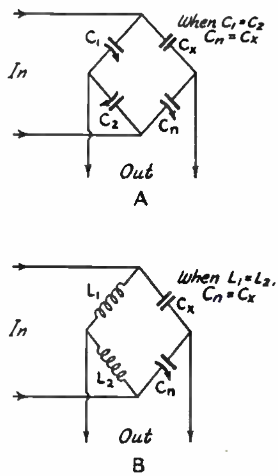


FIG. 414 — CAPACITANCE AND INDUCTANCE-CAPACITANCE BRIDGE CIRCUITS WIDELY USED FOR NEUTRALIZING IN TRANSMITTERS AND RECEIVERS

and C_2 as shown in *A*, or inductances L_1 and L_2 shown in *B*. In both cases C_x is the capacitance to be neutralized, while C_n is the capacitance adjusted to obtain the balance. With the capacitance arms of *A*, balance will be obtained when

$$C_n = \frac{C_2 C_x}{C_1}$$

while with inductance arms of *B*, balance will be obtained when

$$C_n = \frac{L_1 C_x}{L_2}$$

When $L_1 = L_2$ in *A*, or when $C_1 = C_2$ in *B*, then $C_n \times C_x$. This represents a desirable condition in practical neutralizing circuits, because balance will be maintained over a wider frequency range of L_1, L_2 or C_1, C_2 tuning.

Bridge circuits are also generally used in resistance, inductance and capacitance measurement. Such bridges usually have calibrated resistances in two arms, and in calibrated resistance, inductance or capacitance in the "*n*" arm, the unknown being connected in the "*x*" arm. Another field in which bridges find important applications is wire communication. Standard texts describe a number of these interesting applications. Those just explained

World Radio History

are the ones of greatest practical use to amateurs, however.

CIRCUITS WITH DISTRIBUTED CONSTANTS—ANTENNAS AND R.F. CHOKES

In addition to resonant circuits containing lumped capacitance and inductance, there are important tuned circuits which utilize the distributed capacitance and inductance that are inevitable even in a circuit consisting of a single straight conductor. Transmitting and receiving antennas are such circuits and depend on their distributed capacitance and inductance for tuning. A peculiarity of such a circuit is that when it is excited at its resonant frequency the current or voltage, as measured throughout its length, will have different values at different points. For instance, if the wire happens to be one in "free space" with both ends open circuited, when it is excited at its resonant frequency *the current will be maximum at the center and zero at the ends.* On the other hand, *the voltage will be maximum at the ends and zero at the center.* The explanation of this is that the traveling waves on the wire are reflected when they reach an end. Succeeding waves traveling toward the same end of the wire (the *incident* waves) meet the returning waves (*reflected* waves) and the consequence of this meeting is that currents add up at the center and voltages cancel at the center; while voltages add up at the ends and currents cancel at the ends. A continuous succession of such incident and reflected waves therefore gives the effect of a *standing wave* in the circuit.

A similar standing-wave or straight-line resonance effect is experienced even when the conductor is wound in a long spiral, or coil having diameter small in proportion to its length. A single-layer *radio-frequency choke* is such a coil. It offers particularly high impedance between its ends at its resonant frequency and also, as will be presently shown for antennas, at multiples of its fundamental resonant frequency. Either side of these resonance peaks it has fairly high impedance, if it is a good choke, and therefore is useful over a considerable band of frequencies. Practically the same results are obtained with chokes consisting of a number of layer-wound sections, with all the sections connected in series.

Frequency and Wavelength

Although it is possible to describe the constants of such line circuits in terms of inductance and capacitance, or in terms of inductance and capacitance per unit length, it is more convenient to give them simply in terms of fundamental resonant frequency or of length. In the case of a straight-wire circuit, such as an antenna, *length is inversely proportional to lowest resonant frequency.* Since the velocity of the waves in space is 300,000 kilometers (186,000 miles) per second, the *wavelength* of the waves is

$$\lambda = \frac{300,000}{f_{kc.}}$$

where λ is the wavelength in meters and $f_{kc.}$ is the frequency in kilocycles. The *electrical* length of an antenna is specified in terms of the wavelength corresponding to the lowest frequency at which it will be resonant. This is known as its *fundamental* frequency or wavelength. As shown in the chapter on Antennas, the physical length is a few percent less than an actual half-wavelength for an ungrounded (Hertz) antenna and a quarter-wavelength for a grounded (Marconi) antenna. This shortening effect occurs because the velocity of the waves is less in a conductor than in space. It is common to describe antennas as *half-wave, quarter-wave,* etc., for a certain frequency ("half-wave 7000-kc. antenna," for instance).

Wavelength is also used interchangeably with frequency in describing not only antennas but also for tuned circuits, complete transmitters, receivers, etc. Thus the terms "high-frequency receiver" and "short-wave receiver," or "75-meter fundamental antenna" and "4000-kilocycle fundamental antenna" are synonymous.

Harmonic Resonance

Although a coil-condenser combination having lumped constants (capacitance and inductance) resonates at only one frequency, circuits such as antennas containing distributed constants resonate readily at frequencies

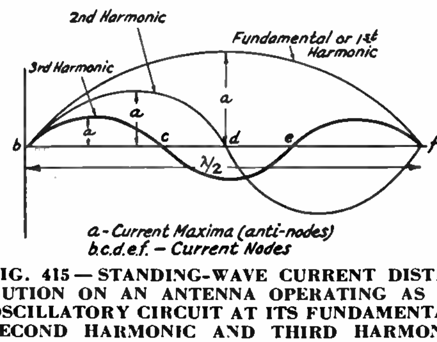


FIG. 415 — STANDING-WAVE CURRENT DISTRIBUTION ON AN ANTENNA OPERATING AS AN OSCILLATORY CIRCUIT AT ITS FUNDAMENTAL, SECOND HARMONIC AND THIRD HARMONIC FREQUENCIES

which are very nearly, although not exactly, integral multiples of the fundamental frequency (or wavelengths that are integral fractions of the fundamental wave length). These frequencies are therefore in *harmonic* relationship to the fundamental frequency

World Radio History

and, hence, are referred to as *harmonics*. In radio practice the fundamental itself is called the *first harmonic*, the frequency twice the fundamental is called the *second harmonic*, and so on.

Fig. 415 illustrates the distribution of the standing waves on a Hertz antenna for fundamental, second and third harmonic excitation. There is one point of maximum current with fundamental operation, there are two when operation is at the second harmonic and three at the third harmonic; the number of current maxima corresponds to the order of the harmonic and the number of standing waves on the wire. As noted in the figure, the points of maximum current are called *anti-nodes* (also known as "loops") and the points of zero current are called *nodes*.

Radiation Resistance and Power

It will be remembered that it was shown that current flow in a conductor was accompanied by a magnetic field about the conductor; and

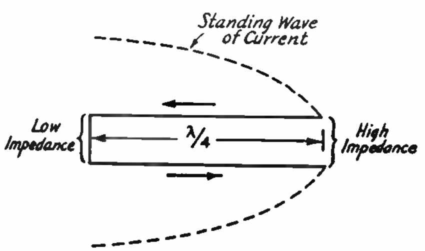


FIG. 416 — STANDING WAVE AND INSTANTANEOUS CURRENT CONDITIONS OF A FOLDED RESONANT-LINE CIRCUIT

that with an alternating current the energy was alternately stored in the field in the form of lines of magnetic force and *returned to the wire*. But when the frequency becomes higher than 15,000 cycles or so (radio frequency) all the energy stored in the field is not returned to the conductor but some escapes in the form of electro-magnetic waves. In other words, energy is radiated. Energy radiated by an antenna is equivalent to energy dissipated in a resistor. The value of this equivalent resistance is known as *radiation resistance*. Radiation resistance values for antennas of different lengths are given in Chapter Thirteen. Since it is impossible to measure radio-frequency power directly with ordinary instruments, the approximate value of the power in an antenna can be computed by multiplying its assumed radiation resistance by the square of the maximum current (the current at the center of a fundamental Hertz antenna).

Antenna power (watts) = Radiation resistance (ohms) × Current Squared (Amperes^2)

Resonant-Line Circuits

The effective resistance of a resonant straight wire — that is, of an antenna — is seen to be considerable. Because of the power radiated, or "coupled" to the surrounding medium, the resonance curve of such a straight-line circuit is quite broad. In other words, its Q is relatively low. However, by folding the line, as suggested by Fig. 416, the fields about the adjacent sections largely cancel each other and very small radiation results. The radiation resistance is greatly reduced and we have a line-type circuit which can be made to have a very sharp resonance curve or high Q.

A circuit of this type will have a standing wave on it, as shown by the dash-line of Fig. 416, with the instantaneous current flow in each wire opposite in direction to the flow in the other, as indicated by the arrows on the diagram. This opposite current flow accounts for the cancellation of radiation. Furthermore, the impedance across the open ends of the line will be very high, thousands of ohms, while the impedance across the line near the closed end will be very low, as low as 25 ohms or so at the lowest. Hence, such lines can be used for impedance matching, as shown for antenna systems in Chapter Thirteen, as well as for stable oscillator circuits in ultra-high frequency transmitters, as shown in Chapter Twelve. Resonant lines having electrical lengths of odd multiples of a quarter-wavelength, or multiples of a half-wavelength, are also widely used by amateurs for coupling between the transmitter and the radiating portion of the antenna system, as is also shown in Chapter Thirteen on antenna systems.

Matched-Impedance Lines

If a two-wire line were made infinitely long there would be no reflection from its far end when radio-frequency energy was supplied to the input end. Hence, there would be no standing waves on the line and it would be, in effect, non-resonant. The input impedance of such a line would have a definite value of impedance determined, practically, by the size of the wires, their spacing and the dielectric between them. This impedance is called the *surge* impedance or *characteristic* impedance. If this line were cut and it was terminated, at a definite distance from the input end, by an impedance equal to the surge impedance of the infinite line, again there would be no reflections from the far end and, consequently, no standing waves. Hence, suiting the surge impedance of the line by the proper terminating load impedance is a practical case of impedance matching. As with the resonant lines mentioned above, matched-impedance lines are also used for coupling amateur transmitters to antenna-

World Radio History

system radiators. The practical design features of these lines are discussed in Chapter Thirteen.

MODULATION AND DETECTION

For practical communication between our stations it is not enough simply to generate radio-frequency power continuously and radiate it from an antenna. Something must be done before the waves are transmitted to make them carry the messages we wish to convey. Application of this intelligence to the transmitted wave is accomplished by a process

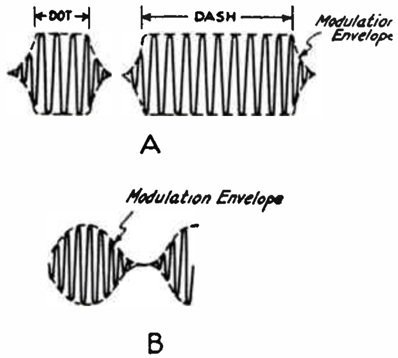


FIG. 417 — REPRESENTING THE MODULATED CURRENT OF A TELEGRAPH WAVE (A) AND SINUSOIDALLY MODULATED SPEECH WAVE (B), AMPLITUDE MODULATION

of *modulation*. Without such modulation the radio wave would carry no more intelligence to the receiver than would a mail letter containing only a blank sheet of paper. A further processing of the wave must occur in the receiver

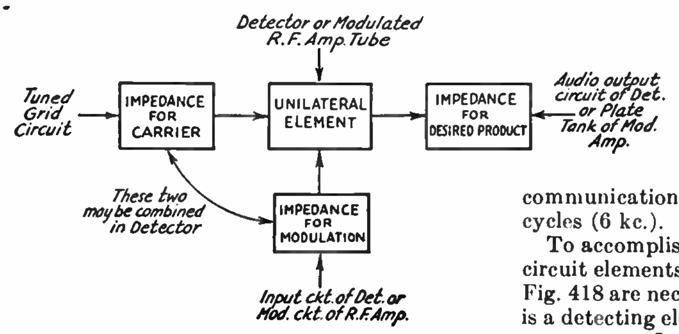


FIG. 418 — GENERALIZED SYSTEM FOR MODULATION OR DETECTION, INDICATING THE ESSENTIAL ELEMENTS

to make the message understandable to our human senses. This is accomplished by a process of *detection* or, as it is sometimes known, *demodulation*. Practical methods of modulation and detection by vacuum-type circuits are described separately in the next and subsequent chapters. Only a generalized explanation which suggests their broad principle and shows their kindred nature will be given here.

Modulation is the process of varying the radio wave to impart to it the signal which we wish to transmit; while detection is the process of extracting from the wave the signal imparted to it in the modulating process. In amateur communication the variation applied is in amplitude; that is we use *amplitude modulation.* The *signal* may be either speech, for telephony, or the dot-and-dash combinations of the telegraph code. Variations in radio-frequency current generally representative of amplitude modulation by these two types of signal are shown in Fig. 417. Telegraph modulation to form the letter "A" is shown in diagram *A*, while modulation by a sinusoidal sound is shown in *B*. It must be emphasized that these pictures, like the one of a complex wave in Fig. 403, do not tell the whole story. They only picture the *synthesis wave* which actually contains components of more than one frequency.

In reality, each modulated wave shown would contain components of at least three radio frequencies. It is a physical fact that any change in amplitude of a wave results in additional components having frequencies equal to the sum and difference of the original frequency and the modulation frequency. These additional frequencies are called *side-band frequencies,* while the original frequency component is called the *carrier.* With hand keying the modulation frequency for telegraphy is relatively low, averaging only a few cycles per second. Hence a telegraph wave in amateur communication requires a relatively narrow *communication band* (50 cycles and less). With speech, however, the essential modulation frequencies range up to approximately 3000 cycles per second and the side-bands extend correspondingly either side of the carrier, so that speech telephony requires a communication band width as great as 6000 cycles (6 kc.).

To accomplish modulation the four essential circuit elements shown in the block diagram of Fig. 418 are necessary. The heart of the system is a detecting element having unilateral or one-way current flow properties. The vacuum tube is such a device, and is universally used for the purpose. A similar combination is required for detection when the modulated wave is received, also shown by Fig. 418. In reception of speech-modulated waves the side-band components intermodulate or *beat* with the carrier to reproduce the original modulating signal (speech) in the output.

CHAPTER FIVE

VACUUM TUBES

Operating Principles — Types of Amplifiers — Rectifiers — Tube Type Data

The simplest type of vacuum tube is that shown in Fig. 501. It has but two elements, cathode and plate, and is therefore called a *diode*. The cathode is heated by the "A" battery and emits electrons which flow to the plate *when the plate is positive with respect to the cathode*. The tube is a conductor in one direction only. If a battery is connected with its negative terminal to cathode and positive to plate (the "B" battery in Fig. 501) this flow of electrons will be continuous. But if a source of alternating voltage is connected between the cathode and plate, then electrons will flow only on the positive half-cycles of alternating voltage; there will be no electron flow during the half cycle when the plate is negative. Thus the tube can be used as a *rectifier*, to change alternating current to pulsating direct current. This alternating current can be anything from the 60-cycle kind to the highest radio frequencies, making it possible to use the diode as a rectifier in power supplies furnishing direct current for our transmitters and receivers or to use it as a rectifier (detector) of radio-frequency current in receivers.

CHARACTERISTIC CURVES

The performance of the tube can be reduced to easily-understood terms by making use of what are known as *tube characteristic curves*. A typical characteristic curve for a diode is shown at the right in Fig. 501. It shows the currents flowing between the various tube elements and cathode (usually only between plate and cathode, since the plate current is of chief interest in determining the output of the tube) with different d.c. voltages applied to the elements. The curve of Fig. 501 shows that, with fixed cathode temperature, the plate current increases as the voltage between cathode and plate is raised. For an actual tube the values of plate current and plate voltage would be plotted along their respective axes.

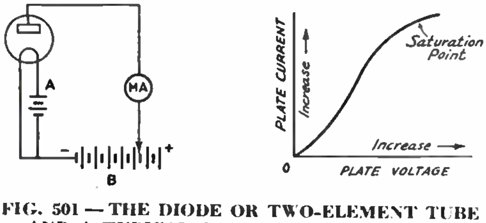


FIG. 501 — THE DIODE OR TWO-ELEMENT TUBE AND A TYPICAL CHARACTERISTIC CURVE

With the cathode temperature fixed, the total number of electrons emitted is always the same regardless of the plate voltage. Fig. 501 shows, however, that less plate current will flow at low plate voltages than when the plate voltage is large. With low plate voltage only those electrons nearest the plate are attracted to the plate. The electrons in the space near the cathode, being themselves negatively charged, tend to repel the similarly-charged electrons leaving the cathode surface and cause them to fall back on the cathode. This is called the *space charge* effect. As the plate voltage is raised, more and more electrons are attracted to the plate until finally the space charge effect is completely overcome and all the electrons emitted by the cathode are attracted to the plate, and a further increase in plate voltage can cause no increase in plate current. This is called the *saturation point*.

HOW VACUUM TUBES AMPLIFY

If a third element, called the *control grid* or simply the *grid*, is inserted between the cathode and plate of the diode the space-charge effect can be controlled. The tube then becomes a *triode* (three-element tube) and is useful for more things than rectification. The grid is usually in the form of an open spiral or mesh of fine wire. With the grid connected externally to the cathode and with a steady voltage from a d.c. supply applied between the cathode and plate (the positive of the "B" supply is always connected to the plate), there will be a constant flow of electrons from cathode to plate, through the openings of the grid, much as in the diode. But if a source of variable voltage is connected between the grid and cathode there will be a variation in the flow of electrons from cathode to plate (a variation in plate current) as the voltage on the grid changes about a mean value. When the grid is made

World Radio History

less negative (more positive) with respect to the cathode, the space charge is partially neutralized and there will be an increase in plate current; when the grid is made more negative with respect to the cathode, the space charge is reinforced and there will be a decrease in plate current. When a resistance or impedance is connected in the plate circuit, the variation in plate current will cause a variation in voltage across this load that will be a magnified version of the variation in grid voltage. In other words there is *amplification* and the tube is an *amplifier*.

The measure of the amplification of which a tube is capable is known as its *amplification factor*, designated by μ (mu). Mu is the ratio of plate-voltage change required for a given change in plate current to the grid-voltage change necessary to produce the same change in plate current. Another important characteristic involving plate current change caused by grid voltage change over a very small range is *mutual conductance*, designated by g_m and expressed either in milliamperes plate current change per volt grid voltage change (ma. per volt), or as the current to voltage ratio in *mhos* (inverse of ohms). Since the plate current changes involved are often very small, the mutual conductance is also expressed in *micromhos*, the ratio of amperes plate current change to volts grid voltage change, multiplied by one million. Still another important characteristic used in describing the properties of a tube is the *plate resistance*, designated r_p. This is the ratio of a small plate voltage change to the plate current change it effects. It is expressed in *ohms*. These tube characteristics are inter-related and are dependent primarily on the tube structure.

AMPLIFIER OPERATION

The operation of a vacuum tube amplifier is graphically represented in elementary form in Fig. 502. The sloping line represents the variation in plate current obtained at a constant plate voltage with grid voltages ranging from a value sufficiently negative to reduce the plate current to zero to a value slightly positive. Bear in mind that grid voltage is with reference to the cathode or filament. Notable facts about this curve are that it is essentially a straight line (is *linear*) over the middle section and that it bends towards the bottom (near *cut off*) and near the top (*saturation*). In other words, the variation in plate current is directly proportional to the variation in grid voltage over the region between the two bends. With a fixed grid voltage (*bias*) of proper value the plate current can be set at any desired value.

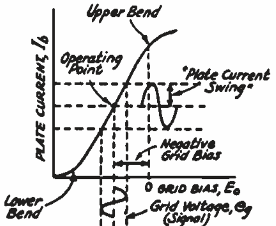


FIG. 502 — OPERATING CHARACTERISTICS OF A VACUUM-TUBE AMPLIFIER
Class-A amplifier operation is depicted.

With negative grid bias as shown in Fig. 502 this point (the *operating point*) comes in the middle of the linear region. If an alternating voltage (*signal*) is now applied to the grid in series with the grid bias, the grid voltage swings more and less negative about the mean bias voltage value and the plate current swings up (positive) and down (negative) about the mean plate current value. This is equivalent to an alternating current superimposed on the steady plate current. At this operating point it is evident that the plate current *wave shapes* are identical reproductions of the grid voltage wave shapes and will remain so as long as the grid voltage amplitude does not reach values sufficient to run into the lower- or upper-bend regions of the curve. If this occurs the output waves will be flattened or *distorted*. If the operating point is set towards the bottom or the top of the curve there will also be distortion of the output wave shapes because part or all of the lower or upper half-cycles will be cut off.

The major uses of vacuum tube amplifiers in radio work are to amplify at audio frequencies (approximately 30 to 15,000 cycles per second) and to amplify at radio frequencies (up to 60,000 kc. or higher). The audio-frequency amplifier is generally used to amplify without discrimination at all frequencies in a wide range (say from 100 to 3000 cycles for voice communication), and is therefore associated with non-resonant or untuned circuits. The radio-frequency amplifier, on the other hand, is generally used to amplify selectively at a single radio frequency, or over a small band of frequencies at most, and is therefore associated with resonant circuits tunable to the desired frequency.

The circuit arrangement of a typical audio-frequency amplifier using a triode is shown in Fig. 503. The alternating grid voltage is applied through the transformer T_1 to the grid circuit, in series with negative grid bias furnished by a battery. The a.c. component of the plate current induces an alternating voltage in the secondary of the output transformer, T_2. This output might go on to another similar audio amplifier for further amplification. In

World Radio History

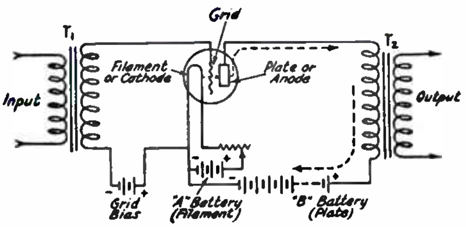


FIG. 503 — A TYPICAL AUDIO-FREQUENCY AMPLIFIER USING A TRIODE TUBE

lieu of the transformer, a pair of head 'phones could be connected in the plate circuit, in which case the alternating plate current component would be reproduced immediately as sound.

STATIC AND DYNAMIC CHARACTERISTICS

Tube characteristics of the type shown in Fig. 502 may be of either the *static* or *dynamic* type. Static characteristics show the plate current that will flow at specified grid and plate voltages in the absence of any output device in the plate circuit for transferring the plate current variation to an external circuit.

Dynamic characteristics are more useful. In plotting this form of curve a resistance, R_p, is connected in series with the battery and plate-cathode circuit of the tube; it represents a *load* or output circuit. Plate current flowing through R_p, causes a voltage drop in the resistor; if the grid voltage is varied, causing a variation in plate current, the voltage drop across R_p likewise will vary. If an alternating voltage is applied to the grid-cathode circuit the alternating plate current causes an alternating voltage to be developed across R_p. This voltage is the useful output of the tube.

The *load impedance* or *load resistance*, R_p, may be an actual resistor or a device such as a headset or loud-speaker having a self-impedance, at the frequency being amplified, of a value suitable for the plate circuit of the tube. In general, there will be one value of R_p which will give optimum results for a given type of tube and set of operating voltages; its value also depends upon the type of service for which the amplifier is designed. If the impedance of the actual device used is considerably different from the optimum load impedance, the tube and output device must be coupled through a transformer having a turns ratio such that the impedance reflected into the plate circuit of the tube is the optimum value.

DISTORTION — HARMONICS

If the output wave shape is not an exact reproduction of the signal applied to the grid-cathode circuit, the wave-shape is said to be *distorted*, as already described. It can be shown that any periodic wave, regardless of its shape, can be resolved into a number of simple sine waves of various amplitudes and phase relationships, but all in harmonic frequency relationship. If the exciting signal is a sine wave, the output wave, when distortion is present, will consist of a fundamental plus second and higher harmonics. In triode amplifiers the second harmonic is the one of most importance.

PARALLEL AND PUSH-PULL AMPLIFIERS

When it is necessary to obtain more power output than one tube is capable of giving, without going to a larger tube structure, two or more tubes may be connected in *parallel*, in which case the similar elements in all tubes are connected together. The power output will then be in proportion to the number of tubes used; the exciting voltage required, however, is the same as for one tube.

An increase in power output also can be secured by connecting two tubes in *push-pull*, the grids and plates of the two tubes being connected to opposite ends of the circuit, respectively. Parallel and push-pull operation are illustrated in Fig. 504. A "balanced" circuit, in which the cathode returns are made to the midpoint of the input and output devices, is necessary with push-pull operation. An alternating current flowing through the primary of the input transformer in the push-pull diagram will cause an alternating voltage to be induced in the secondary winding; since the ends of the winding will be at opposite potentials with respect to the cathode connection the grid of one tube is swung positive at the same instant that the grid of the other is swung negative. The plate current of one tube therefore is rising while the plate current of the other is falling, hence the name "push-pull."

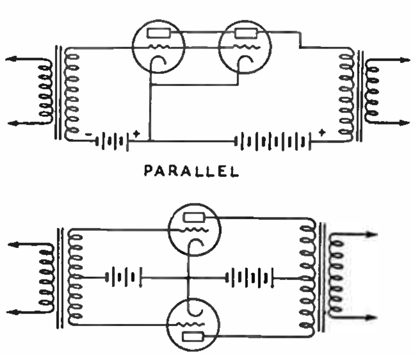


FIG. 504 — PARALLEL AND PUSH-PULL AMPLIFIER CONNECTIONS

World Radio History

In push-pull operation the second-harmonic distortion is cancelled in the symmetrical plate circuit, so that for the same output the distortion will be less than with parallel operation. It follows that for a given degree of distortion the push-pull amplifier is capable of delivering somewhat more power than a parallel amplifier.

VOLTAGE AND POWER AMPLIFIERS

Amplifiers may be divided broadly into two general types, those whose chief purpose is to give a greatly magnified reproduction of the input signal voltage with regard to power, and those intended to deliver a relatively large amount of power to a load (a loud-speaker, in the case of an audio amplifier, or an antenna, in the case of a radio-frequency amplifier). The former is a *voltage amplifier*, while the latter is a *power amplifier*.

In audio circuits, the power tube or output tube in the last stage usually is designed to deliver a considerable amount of audio power, while requiring but negligible power from the input or exciting signal. The *power amplification* — ratio of output power to power supplied the grid circuit — is consequently very high. Such tubes generally require a large grid voltage swing for full power output, however, so that the *voltage amplification* — ratio of output voltage to signal voltage — is quite low. To get the voltage swing required for the grid of such a tube voltage amplifiers are used, employing tubes of high μ which will greatly increase the voltage amplitude of the signal. Although such tubes are capable of relatively high voltage output, the power obtainable from them is small. Voltage amplifiers are used in the radio-frequency stages of receivers as well as in audio amplifiers.

THREE FUNDAMENTAL AMPLIFIER CLASSIFICATIONS

Class-A Amplifiers

An amplifier operated as shown in Fig. 502 in which the output wave shape is a faithful reproduction of the input wave shape, is known as a *Class-A* amplifier.

Certain operating conditions distinguish the Class-A amplifier. As generally used, the grid never is driven positive with respect to the cathode by the exciting signal, and never is driven so far negative that plate-current cut-off is reached. The plate current is constant both with and without an exciting signal. The chief characteristics of the Class-A amplifier are low distortion, low power output for a given size of tube, and a high power-amplification ratio. The plate efficiency — ratio of a.c. output power to steady d.c. input power — is relatively low, being in the vicinity of 20 to 35 percent at full output, depending upon the design of the tube and the operating conditions.

Class-A amplifiers of the power type find application as output amplifiers in audio systems, operating loud speakers in radio receivers and public-address systems, and as modulators in radiotelephone transmitters. Class-A voltage amplifiers are found in the stages preceding the power stage in such applications, and as radio-frequency amplifiers in receivers.

Class-B Amplifiers

The Class-B amplifier is primarily one in which the output current, or alternating component of the plate current, is proportional to the amplitude of the exciting grid voltage. Since power is proportional to the square of the current, the power output of a Class-B amplifier is proportional to the square of the exciting grid voltage.

The distinguishing operating condition in Class-B service is that the grid bias is set so that the plate current is very nearly zero or cut-off; the exciting signal amplitude can be such that the entire linear portion of the tube's characteristic is used. Fig. 505 illustrates Class-B operation. Plate current flows only during the positive half-cycle of excitation voltage. Since the plate current is set practically to zero with no excitation, no plate current flows during the negative swing of the excitation voltage. The shape of the plate current pulse is essentially the same as that of the positive swing of the signal voltage. Since the plate current is driven up toward the saturation point, it is usually necessary for the grid to be driven positive with respect to the cathode during part of the grid swing. Grid current flows, therefore, and the driving source must furnish power to supply the grid losses.

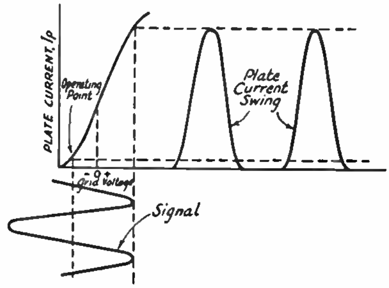


FIG. 505 — OPERATION OF THE CLASS-B AMPLIFIER

Class-B amplifiers are characterized by medium power output, medium plate efficiency (50% to 60% at maximum signal) and a moderate ratio of power amplification. They are used for both audio and radio-frequency amplification. As radio frequency amplifiers they are used as *linear amplifiers* to raise the output power level in radiotelephone transmitters after modulation has taken place.

For audio-frequency amplification, two tubes must be used to permit Class-B operation. A second tube, working alternately with the first, must be included so that both halves of the cycle will be present in the output. A typical method of arranging the tubes and circuit to this end is shown in Fig. 506. The circuit resembles that of the push-pull Class-A amplifier; the difference lies in the method of operation. The signal is fed to a transformer T_1, whose secondary is divided into two equal parts, with the tube grids connected to the outer terminals and the grid bias fed in at the center. A transformer T_2 with a similarly-divided primary is connected to the plates of the tubes. When the signal swing in the upper half of T_1 is positive, Tube No. 1 draws plate current while Tube No. 2 is idle; when the lower half of T_1 becomes positive, Tube No. 2 draws plate current while Tube No. 1 is idle. The corresponding voltages induced in the halves of the primary of T_2 combine in the secondary to produce an amplified reproduction of the signal wave-shape with negligible distortion. The Class-B amplifier is capable of delivering much more power for a given tube size than a Class-A amplifier.

Class-C Amplifiers

The third type of amplifier is that designated as Class C. Fundamentally, the Class-C amplifier is one operated so that the alternating component of the plate current is directly proportional to the plate voltage. The output power is therefore proportional to the square of the plate voltage. Other characteristics inherent to Class-C operation are high plate efficiency, high power output, and a relatively low power-amplification ratio.

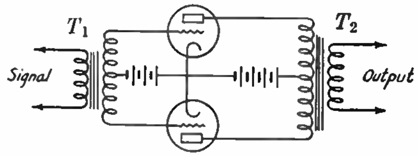
The grid bias for a Class-C amplifier is ordinarily set at approximately twice the value required for plate current cut-off without grid excitation. As a result, plate current flows during only a fraction of the positive excitation cycle. The exciting signal should be of sufficient amplitude to drive the plate current to the saturation point, as shown in Fig. 507. Since the grid must be driven far into the positive region to cause saturation, considerable numbers of electrons are attracted to the grid at the peak of the cycle, robbing the plate of some that it would normally attract. This causes the droop at the upper bend of the characteristic, and also causes the plate current pulse to be indented at the top, as shown. Although the output wave-form is badly distorted, at radio frequencies the distortion is largely eliminated by the filtering or flywheel effect of the tuned output circuit.

Class-C amplifiers are used principally as radio-frequency power amplifiers, and have very little audio-frequency application. Although requiring considerable driving power because of the relatively large grid swing and grid-current flow, the high plate efficiency of the Class-C amplifier makes it an effective generator of radio-frequency power.

OTHER AMPLIFIER CLASSIFICATIONS

SINCE the three fundamental amplifier classifications represent three distinct steps in the operation of vacuum tubes, there are intermediate steps which partake of the nature of two of the classifications although not adhering strictly to either. Such "midway" methods of operation can be classified as "AB" and "BC." Only the "AB" type of operation is in general use. The Class-AB amplifier is a push-pull amplifier in which each tube operates during more than half but less than all the exciting-voltage cycle. Its bias is set so that the tubes draw more plate current than in Class-B operation, but less than they would for Class-A. The plate current of the amplifier varies with the signal voltage, but not as much as in Class-B.

The efficiency and output of the Class-AB amplifier lie between those obtainable with pure Class-A or Class-B operation. Class-AB amplifiers tend to operate Class-A with low signal voltages and Class-B with high signal voltages, thus overcoming the chief objection to Class-B operation — the distortion present with low-input-signal voltages. The Class-AB amplifier is widely used where it is necessary to obtain a power output of considerable magnitude with a minimum of distortion.



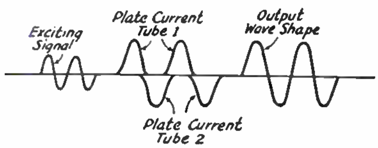


FIG. 506 — THE CLASS-B AUDIO AMPLIFIER, SHOWING HOW THE OUTPUTS OF THE TWO TUBES ARE COMBINED TO GIVE DISTORTIONLESS AMPLIFICATION

World Radio History

GENERATING RADIO FREQUENCY POWER

Because of its ability to amplify, the vacuum tube can oscillate, or generate alternating current power. To make it do this, it is only necessary to couple the plate (output) circuit to the grid (input) circuit so that the alternating voltage supplied to the grid of the tube is opposite in phase to the voltage on the plate. Typical circuits for this condition are shown in Fig. 508. In *A* the feed-back coupling between the plate and grid circuits is inductive (by means of coils), while in *B* the coupling is capacitive (through a condenser). In the circuit of *A* the frequency of oscillation will be very nearly the resonant frequency of the tuned circuit L_1C_1, while in *B* the frequency of oscillation will be determined jointly by L_1C_1 and L_2C_2. At high radio frequencies the inherent plate-grid capacitance of the usual triode tube is sufficient for feed-back in the tuned-grid tuned-plate type circuit of *B*, so the feed-back condenser shown connected between grid and plate is not necessary.

There are many other arrangements of oscillator circuits but all utilize either inductive or capacitive feed-back. They will be treated in following chapters.

DETECTION

Since the frequencies used in radio transmission are merely carriers bearing modulation, it is necessary to provide a means for making the signals intelligible. The process for doing this is called *detection* or *demodulation* — the latter because the modulation envelope is

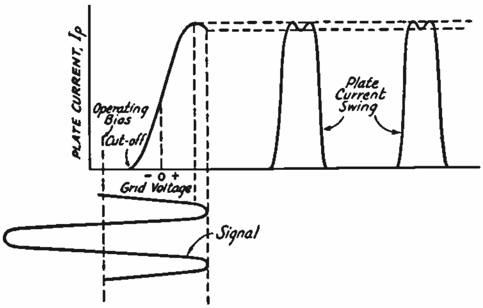


FIG. 507 — CLASS-C AMPLIFIER OPERATION

in effect detached from the carrier wave and made audible. Taking the case of a modulated wave, such as in radiotelephone transmission, we find there are three ways of operating tubes to perform the function of demodulation. All are essentially the process of *rectification*, in which the radio-frequency input is converted into direct current which in turn varies in accordance with the audio-frequency modulation envelope. The first type of detector is the diode, or simple rectifier, the operation of which already has been explained. Multi-element tubes can be operated either as "grid" or "plate" detectors, depending upon whether the rectification takes place in the grid or plate circuits.

Plate Detectors

The circuit arrangement of a typical plate detector is shown at *A* of Fig. 509. Its operating characteristics are illustrated at *A* of Fig. 510. The circuit L_1C_1 is tuned to resonance with the radio frequency and the voltage developed

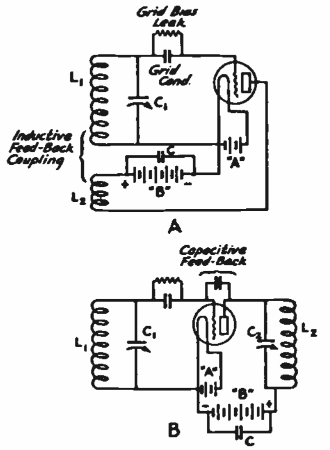


FIG. 508 — TWO GENERAL TYPES OF OSCILLATOR CIRCUITS

across it is applied between the grid and cathode in series with the grid-bias battery. A headset or the primary of a transformer is connected in the plate circuit, a small fixed condenser *C* being connected across the plate load to by-pass radio frequency. As shown at *A* in Fig. 510, the negative grid bias voltage is such that the operating point is in the lower-bend region of the curve, near cut-off. With a modulated signal as shown there will be a variation in plate current conforming to the average value of the positive half-cycles of radio frequency. This variation corresponds to the envelope, representing an audio-frequency current super-imposed on the steady plate current of the tube, and constitutes the useful audio output of the detector. When this pulsating current flows through the 'phones their diaphragms vibrate in accordance with it to give a reproduction of the modulation put on the signal at the transmitter.

Grid Detectors

The circuit arrangement of a triode used as a *grid detector* (also called *grid leak detector*) is shown in *B* of Fig. 509. An input circuit tuned

World Radio History

to the frequency of the radio wave is connected so that the r.f. voltage developed across it is applied between the grid and cathode. However, there is no fixed negative grid bias, as in the case of the plate detector. Instead a small fixed capacity (*grid condenser*) and resistor of high value (*grid leak*) are connected between tuned circuit and grid. The plate circuit is the same as for the plate detector.

The action of the grid detector is illustrated by the grid voltage — grid current curve of Fig. 510-B. A modulated radio-frequency voltage applied to the grid swings it alternately positive and negative about the operating point. The grid attracts electrons from the cathode, the consequent grid current increasing more during the positive half cycles than it decreases during the negative half cycles of grid swing. Hence there is a rectified grid current flow at modulation frequency whose average value develops a voltage across the grid leak. This audio-frequency variation in voltage across the grid leak causes corresponding variations in plate current reproduced in the 'phones.

Regenerative Detectors

With both the grid and plate detectors just described it will be noted that a condenser is connected across the plate load circuit to by-pass radio-frequency components in the output. This radio-frequency can be fed back into the grid circuit, as shown in *C* of Fig. 509, and re-amplified a number of times. This *regeneration* gives a tremendous increase in detector sensitivity. If the regeneration is sufficiently great the circuit will break into oscillation, which would be expected since the circuit arrangement is almost identical with that of the

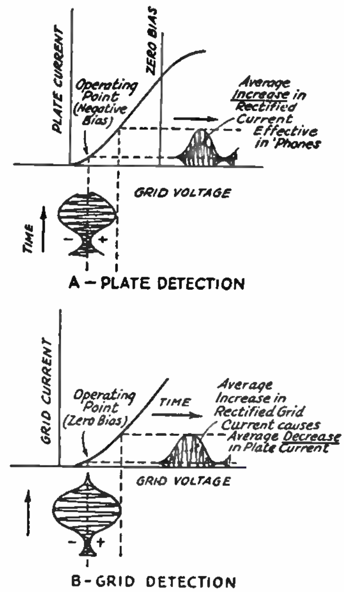


FIG. 510 — OPERATING CHARACTERISTICS OF PLATE AND GRID DETECTORS

oscillator shown in Fig. 508-A. Therefore a control is necessary so that the detector can be operated either regenerating to give large amplification without oscillation, or to oscillate and regenerate simultaneously. Methods of doing this are described in Chapter Seven.

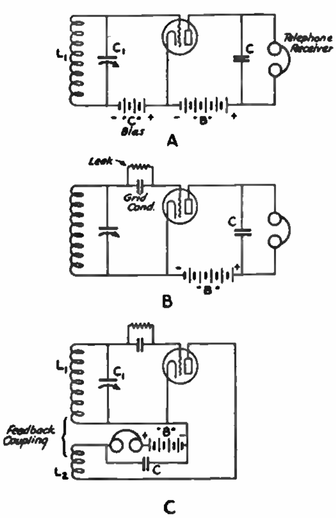


FIG. 509 — DETECTOR CIRCUITS OF THREE TYPES

A, plate detection; B, grid detection; C, regenerative grid detection.

SUPERREGENERATION

THE limit to which regenerative amplification can be carried is the point at which the tube starts to oscillate, because when oscillations commence, further regenerative amplification ceases. To overcome this limitation and give still greater amplification, the *superregenerative* circuit has been devised. Essentially, the superregenerative detector is similar to the ordinary regenerative type but with a comparatively low-frequency super-audible (above audibility) signal introduced in such a way as to vary the detector's operating point at a uniform rate. As a consequence of the introduction of this *quench* or *interruption frequency* the detector can oscillate at the signal frequency only when the moving operating point is in a region suitable for the production of oscillations. Because the oscillations are constantly being interrupted, the signal can build up to relatively tremendous proportions, and the superregenerative detector therefore is extremely sensitive. See Fig. 511. The circuit finds its

World Radio History

chief field in the reception of ultra-high-frequency signals, for which purpose it has proved eminently successful.

MULTI-ELEMENT TUBES

MORE than three elements may be used to make a tube particularly suitable for certain

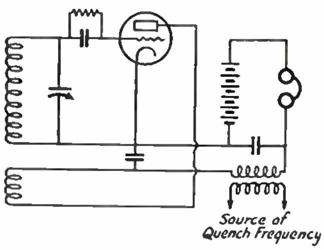


FIG. 511 — AN ELEMENTARY SUPERREGENERATIVE CIRCUIT

specialized applications; likewise two or more sets of elements may be combined in one bulb so that a single tube may be used to perform two or three separate functions.

Tubes having four elements are called *tetrodes,* while if a fifth element is added the tube is known as a *pentode.* Many element combinations and structures become possible as the number of electrodes is increased, but only a few have practical applications.

TETRODES—BEAM TUBES

IN THE section on tube oscillators it was explained that oscillations could be sustained through transfer of energy from the plate to the grid through the electrostatic capacity existing between plate and grid, the circuit of Fig. 508-B being used as an illustration. This circuit without the feed-back condenser is the one which would also be used if the tube is intended to amplify, but not oscillate, at radio frequencies; that is, the input and output circuits must be tuned to the same frequency. However, the grid plate capacity of the triode returns so much energy to the grid circuit from the plate that it is impossible to prevent the tube from oscillating.

If a second grid, in the form of an electrostatic shield between the control grid and plate, is added the grid-plate capacity can be reduced to a value which will not permit oscillations to occur. The *screen grid,* as it is called, increases the amplification factor and plate resistance of the tube to values much higher than are attainable in triodes of practicable construction, although the mutual conductance is about the same as that of an equivalent triode. The screen grid is ordinarily operated at a positive potential about one-third that placed on the plate, and is by-passed back to the cathode so that it has essentially the same a.c. potential as the cathode.

Large screen-grid tubes of the power type are used as amplifiers in transmitting installations. The screen-grid tube can be used as both plate and grid detector, generally showing greater sensitivity than the triode types.

Another type of tetrode, in which the electrostatic shielding provided by the second grid is purely incidental, is built for audio power output work. The second grid (usually called the "screen" although not actually a screen grid) accelerates the flow of electrons from cathode to plate, and the structure gives a higher *power sensitivity* — ratio of power output to grid-voltage swing causing it — than is possible with triodes. "Beam" power tubes are tetrodes with special element structure so that the electrons are concentrated in desired paths to the plate. The beam principle results in relatively high plate efficiency and power sensitivity, with the effects of secondary emission (described in the following section) overcome. Beam tubes are used both in audio amplifiers and radio-frequency transmitting circuits.

PENTODES

THE addition of the screen grid in the ordinary tetrode causes an undesirable effect which limits the usefulness of the tube. Electrons striking the plate at high speeds dislodge other electrons which "splash" from the plate, this phenomenon being known as *secondary emission.* In the triode, ordinarily operated with the grid negative with respect to cathode, these secondary electrons are repelled back into the plate and cause no disturbance. In the screen-grid tube, however, the positively charged screen grid attracts the secondary electrons, causing a reverse current to flow between screen and plate. The effect is particularly marked when the plate and screen potentials are nearly equal, which may be the case during part of the a.c. cycle when the instantaneous plate current is large.

To overcome the effects of secondary emission a third grid, called the *suppressor grid,* is inserted between the screen and plate. This grid, being connected directly to the cathode, repels the relatively low-velocity secondary electrons back to the plate without obstructing to any appreciable extent the regular plate-current flow. Larger undistorted outputs therefore can be secured from the pentode.

Pentode-type screen-grid tubes are used as radio-frequency voltage amplifiers, and in addition can be used as audio-frequency voltage amplifiers to give high voltage gain per stage. Pentode tubes also are suitable as audio-frequency power amplifiers, having greater

World Radio History

plate efficiency than triodes and requiring less grid swing for maximum output.

MULTI-PURPOSE TYPES

A GREAT many types of tubes have been developed to do special work in receiving circuits. Among the simplest of these are full-wave rectifiers, combining two separate diodes of the power type in one bulb, and twin-triodes, consisting of two triodes in one bulb for Class-B audio amplification. To add the functions of diode detection and automatic volume control — described in Chapter Seven on receivers — to that of amplification, a number of types are made in which two small diode plates are placed near the cathode, but not in the amplifier-portion structure. These types are known as duplex-diode triodes or duplex-diode pentodes, depending upon the type of amplifier.

The pentagrid converter is a special tube serving as both oscillator and mixer, used in superheterodyne receivers. There are five grids between cathode and plate in this tube; the two inner grids serve as control grid and plate of a small oscillator triode, while the fourth grid is the detector control grid. The third and fifth grids are connected together to form a screen-grid which shields the detector control grid electrostatically from the other elements. The pentagrid converter eliminates the need for special coupling between oscillator and detector circuits.

Another type consists of a triode and pentode in one bulb, for use where the oscillator and first detector are preferably separately coupled; while still another type (the 6L7) is a pentode with a separate grid for connection to an external oscillator circuit. This "injection" grid provides a means for introducing the oscillator voltage into the detector circuit by electronic means.

Receiving screen-grid tetrodes and pentodes for radio-frequency voltage amplification are made in two types, known as "sharp cut-off" and "variable-μ" or "super-control" types. In the sharp cut-off type the amplification factor is practically constant regardless of grid bias, while in the variable-μ type the amplification factor decreases as the negative bias is increased. The purpose of this design is to permit the tube to handle large signal voltages without distortion in circuits in which grid-bias control is used to vary the amplification, and to reduce interference from stations on adjacent frequencies by preventing cross-modulation. Cross-modulation is modulation of the desired signal by an undesired one, and is practically the same thing as detection. The variable-μ type of tube is a poor detector in circuits used for r.f. amplification, hence cross-modulation is reduced by its use.

TYPES OF CATHODES

CATHODES are of two types, directly and indirectly heated. Directly-heated cathodes or filaments used in receiving tubes are of the oxide-coated type, consisting of a wire or ribbon of tungsten coated with certain rare metals and earths which form an oxide capable of emitting large numbers of electrons with comparatively little cathode-heating power. Directly-heated cathodes are used in older audio power-output tubes, power rectifiers, tubes intended for operation from dry-cell batteries where economy of filament current is important, and in all but the smallest transmitting tubes.

When directly-heated cathodes are operated on alternating current, the cyclic variation of current causes electrostatic and magnetic effects which vary the plate current of the tube at supply-frequency rate and thus produce hum in the output. Hum from this source is eliminated by the indirectly-heated cathode, consisting of a thin metal sleeve or thimble, coated with electron-emitting material, enclosing a tungsten wire which acts as a heater. The heater brings the cathode thimble to the proper temperature to cause electron emission. This type of cathode is also known as the equipotential cathode, since all parts are at the same potential. The cathode ordinarily is not connected to the heater inside the tube, the terminals being brought out to separate base pins.

RATINGS AND CHARACTERISTICS

THE tables give maximum ratings for the various types of tubes listed. For long tube life, filament or heater voltages should be maintained as nearly as possible at the ratings given (varying not more than 5% either above or below rated voltage) and the maximum plate-supply voltage indicated should not be exceeded. It is important, of course, that the tube be operated with the proper negative bias, as indicated by the tables, applied to the grid.

The important characteristics of the tubes, such as amplification factor, mutual conductance, etc., also are given. In addition, the *interelectrode capacitances* are listed in the tables of transmitting tubes. Since transmitting tubes often are large in physical structure, these capacities are quite high in some types of tubes, limiting their application in very high frequency transmitters, since the tube capacity acts as a shunt across the tuning condenser. The important tube capacities are those between grid and cathode (*input capacity*), grid and plate, and plate and cathode (*output capacity*). Input and output capacities of receiving tubes usually are quite small — a few micromicrofarads for most tubes.

World Radio History

Descriptions	*Metal Octal*	*Glass 6.3 V. Octal*	*Glass 6.3 V. Old*	*Glass 2.5 V. Old*	*Glass 2.0 V. Octal*	*Glass 2.0 V. Old*
General-Purpose Triode	6C5 6J5	6C5G 6J5G 6L5G	76	56	1H4G	30
High-μ Triode	6F5 6SF5	6F5G 6K5G	....	....	....	....
Twin Triodes	....	6C8G 6F8G	....	....	....	....
R.F. Amplifier, sharp cutoff	6J7 6SJ7 6W7G	6J7G	6C6 77	57	1E5G	1B4 15
R.F. Amplifier, variable-μ	6K7 6S7	6K7G 6S7G 6SK7 6U7G	6D6	58	1D5G	1A4 34
Twin Diode	6H6	6H6G	....	....	....	....
Duplex-Diode Pentode	6B8	6B8G	6B7	2B7	1F7G	1F6
Duplex-Diode G.P. Triode	6R7	6R7G 6V7G	85	55	1H6G	1B5
Duplex-Diode High-μ Triode	6Q7 6SQ7	6Q7G 6B6G 6T7G	75	2A6	....	....
Pentagrid Converter	6A8	6A8G 6D8G	6A7	2A7	1D7G 1C7G	1A6 1C6
Pentagrid Mixer-Amplifier	6L7	6L7G	....	....	....	....
Pentode Power Amplifier	6F6	6F6G 6G6G 6K6G	42 (41)	2A5	1G5G 1F5G 1E7G	1F4 33
Triode Power Amplifier	....	6B4G 6A5G	6A3	45 2A3	....	31
Triode Power Amplifier, High-μ	....	6AC5G	....	46	....	49
Twin Triode Power Amplifier	6N7	6N7G 6Z7G	6A6 79	53	1J6G	19
Direct-Coupled Power Amplifier	6N6MG	6N6G	6B5	....	....	....
Beam-Type Power Amplifier	6L6 6V6	6L6G 6V6G 6Y6G	....	....	....	....

FIG. 512 — PREFERRED RECEIVING TUBE TYPES BY FUNCTIONS

BASE CONNECTIONS AND PIN NUMBERING

Tube bases have from four to eight pins for element connections. In all except the five- and eight-prong types, the two filament or heater pins are heavier than the others, making them readily distinguishable. The pins of all except the 8-pin or octal base are numbered according to the following system: Looking at the bottom of the base or the bottom of the socket, the left-hand cathode pin is No. 1, and the others are numbered consecutively in the clockwise direction, ending with the right-hand cathode pin. In the octal base, No. 1 pin is to the left of the key, as shown in Fig. 513.

In indicating which element is connected to which base pin, it is customary to use the letters F F or H H for filament or heater, C or K for cathode, P for plate, etc. In multi-grid tubes the grids are numbered according to the position they occupy, the grid nearest the cathode being No. 1, the next No. 2, etc. Some tubes are provided with a cap connection on top, especially when it is desired that the elements connected to the cap have very low capacity to other tube elements.

World Radio History

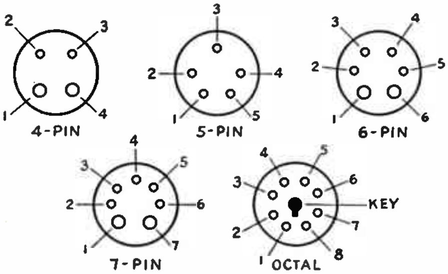
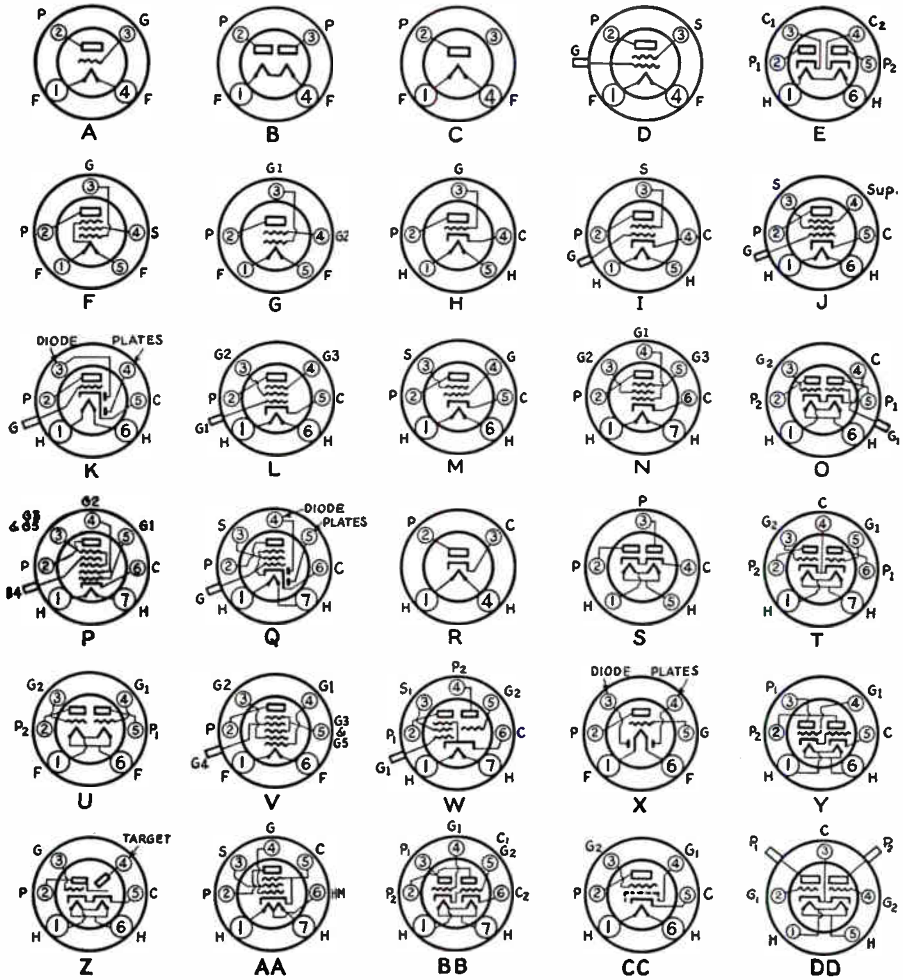


FIG. 513 — TUBE-BASE PIN NUMBERING SYSTEM

These drawings show the pins looking at the bottom of a tube base or socket. Pins are numbered in the clockwise direction, starting with the left-hand cathode pin as No. 1 with glass tubes; with the shield pin as No. 1 with metal tubes. On the 4-, 6- and 7-pin bases the filament or heater pins are heavier than the others; on the 5-pin and octal bases the No. 1 pin is readily identified from the drawings.



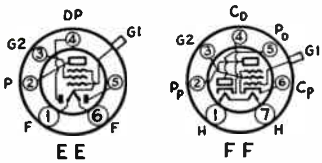


FIG. 514 — BASE DIAGRAMS OF GLASS RECEIVING TUBES

These views are of the bottoms of the bases or sockets. F, filament; H, heater; C, cathode; G, grid; S, screen; Sup, suppressor; P, plate. G1, G2, G3, etc., denotes grids numbered in order from the cathode outward; G_1, G_2, P_1, P_2, etc., denote grids and plates of multi-purpose or twin tubes having separate sets of elements; elements having the same subscripts belong together. A top cap on the tube is shown by an external unnumbered connection.

World Radio History

"G" TUBES AND PREFERRED TYPES

PRACTICALLY all the now-used glass tubes can be obtained with octal bases. Such tubes have the suffix "G" attached to the type number. In some cases these tubes duplicate in characteristic types in the metal series; when this is so, the tube carries the same number as the corresponding metal tube, but with the suffix "G". For example, the glass equivalent of the 6K7 metal tube is known as the 6K7G. Other "G" tubes duplicate existing types of glass tubes; in still other cases the tube is a new type equipped with an octal base.

There are some seventeen tube designs most popularly in use in present-day receivers. These seventeen occur more or less completely in six series: metal, 6.3-volt glass with octal bases, 6.3-volt glass with old bases, 2.5-volt glass with old bases, 2.0-volt (battery) glass with octal bases, and 2.0-volt glass with old bases. The currently-used types under these classifications have been arranged in a table of "preferred types," which gives the set designer and constructor a list of the tubes most worthy of consideration.

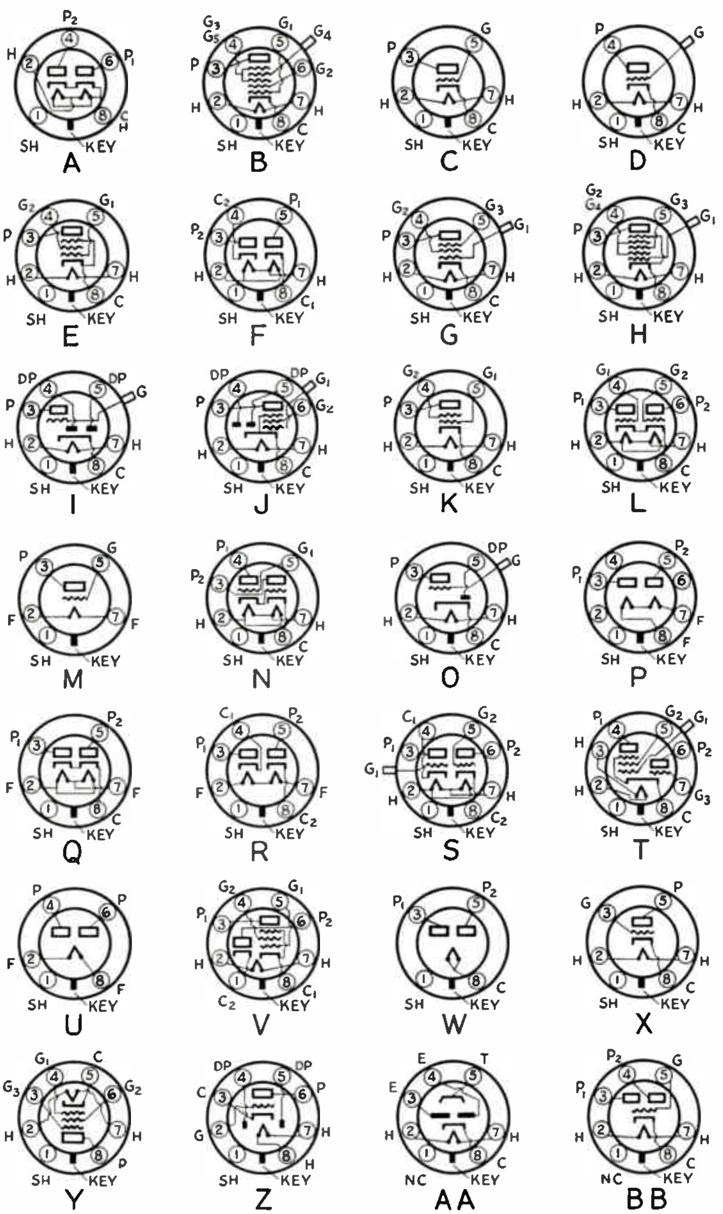


FIG. 515 — BASE DIAGRAMS OF METAL AND GLASS OCTAL-BASED RECEIVING TUBES

Legends have the same significance as in Fig. 514. SH denotes shield, or metal envelope, connection in metal tubes; it is "NC" or "no connection" in G-type tubes. DP signifies diode plate; T, target. Views are of bottoms of tube bases or sockets.

RECTIFIERS

RECTIFIERS for receiving purposes are made with both directly and indirectly-heated cathodes, and are provided with one or two plates depending upon whether the tube is designed for half-wave or full-wave rectification. The tubes may be either of the high-vacuum or mercury-vapor type. The latter type has a small quantity of mercury added after the air is removed from the tube; when the cathode is heated the mercury vaporizes. When the tube is in operation electrons striking the mercury-vapor molecules dislodge other electrons, "ionizing" the gas. This in-

World Radio History

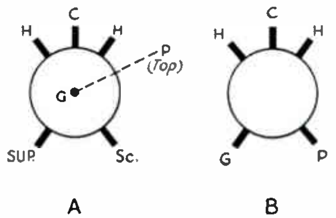


FIG. 517 — CONNECTIONS FOR ACORN TYPE TUBES, BOTTOM VIEWS — LOOKING AT SHORT END

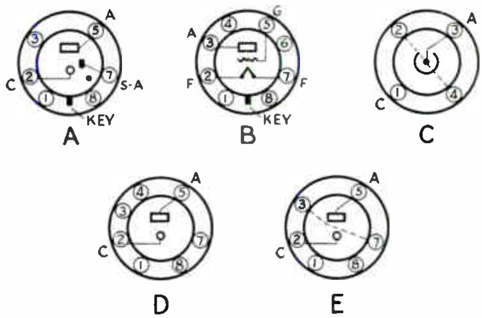
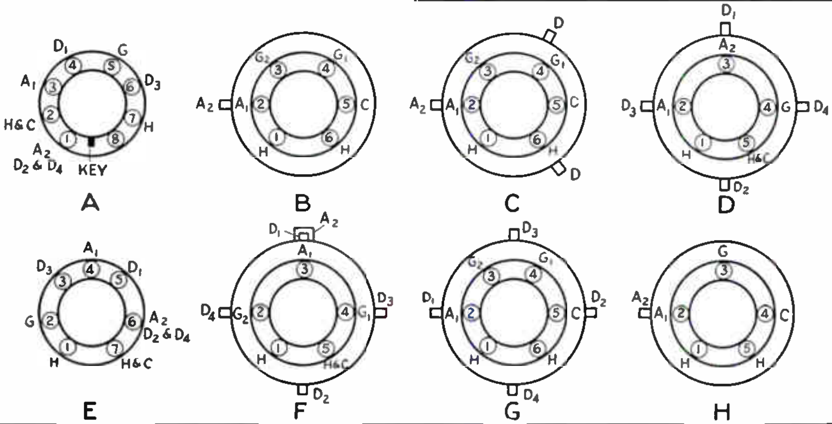


FIG. 518 — BASE DIAGRAMS OF CONTROL AND REGULATOR TUBES

A denotes anode; C, cathode; F, filament; G, grid; S-A, starter-anode. All are octal sockets except C, which is 4-pin M. Dashed lines indicate jumper connection inside tube, which can be wired to cut off power when tube is removed. Views are of bottoms of sockets.

FIG. 519 — SOCKET CONNECTIONS FOR CATHODE-RAY TUBES

H, C and G legends have customary significance; A denotes anode; D, deflecting plate. Inner rings of base diagram indicate socket connections; connections on outer ring indicate bulb cap-type terminals. Views are from bottoms of tubes.



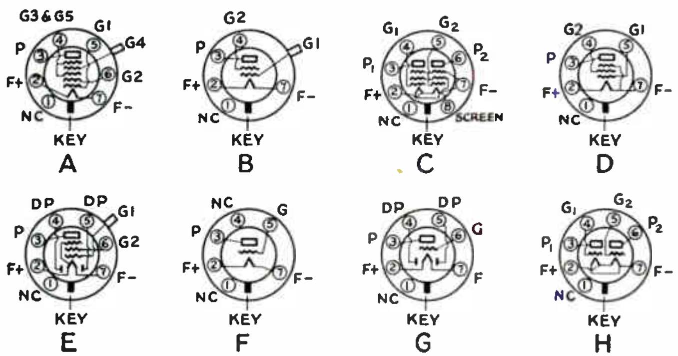
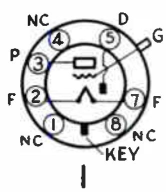


FIG. 516 — SOCKET-CONNECTION DIAGRAMS FOR OCTAL-BASED 2.0-VOLT TUBES

These views are of the bottom of tube sockets or bases. Nomenclature same as in Figs. 514 and 515; NC on No. 1 pin indicates no connection to this pin inside the tube; it is suggested that this socket connection be grounded, however, to provide for possible metal-shell tubes in this series. (Note: In some cases the tube may be provided with more pins than are indicated in the above diagrams. This is a manufacturing convenience; the extra pins have no connections and can be ignored.)



creases the conductivity and results in a lower voltage drop in the rectifier. Mercury-vapor rectifiers are likely to cause noise in the receiver, however, so are seldom used for receiving purposes.

High-voltage rectifiers for transmitters are nearly all of the mercury-vapor type, since voltage regulation and efficiency are more important than in receiving applications. Rectifiers which are designed to handle voltages up to about 500 usually are made with two plates and are called full-wave rectifiers; tubes for higher voltages, however, almost always have but one plate and are known as half-wave rectifiers.

World Radio History

TRANSMITTING TUBES

Transmitting tubes are simply larger versions of the smaller receiving tubes, adapted for the handling of large amounts of power and for operation at high plate voltages. Receiving tubes of the audio power-amplifier type are in fact often used in low-power transmitters — and also in the low-power stages of high-power transmitters — hence some receiving types will be found to have transmitting ratings in the tables. Tubes intended particularly for the generation of radio-frequency power are of more rugged construction, and when built for operation at voltages above 750 are universally provided with thoriated tungsten filaments.

Transmitting tubes are generally rated by plate dissipation, which is the amount of power that can be radiated safely as heat by the plate. The power output obtainable depends upon the efficiency of the circuit used. Maximum plate voltage and maximum plate current ratings also are given for the various types.

The characteristics and typical r.f. operating conditions of transmitting tubes suitable for amateur use are given in Tables XIII and XIV. The selection of types for various purposes is discussed in detail in later chapters on transmitter design and construction. In the tables, the tubes have been listed according to plate dissipation ratings. Generally speaking, the higher the plate dissipation rating the greater the power output the tube can deliver. It should be understood, however, that the power output obtainable depends considerably on the way in which the tube is operated; also that at the higher frequencies certain types of tubes give better performance than others.

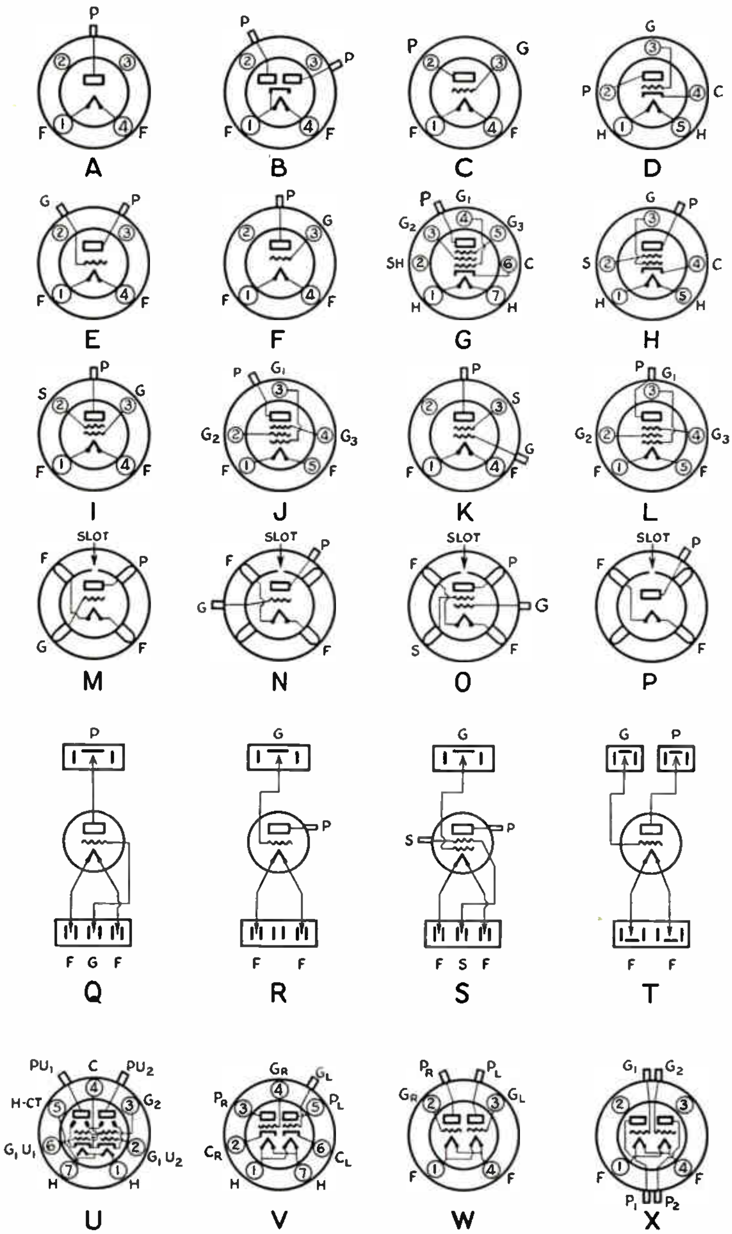


FIG. 520 — SOCKET CONNECTIONS FOR TRANSMITTING TUBES, VIEWED FROM BOTTOM

Legends have same significance as in previous diagrams. Views are of *bottoms* of sockets.

World Radio History

TABLE I — METAL RECEIVING TUBES[1]

Type	Name	Socket Connections[2]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps.	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
6A8	Pentagrid Converter	B	Htr.	6.3	0.3	Converter	250	− 3.0 min.	100	3.2	3.3	Anode-grid (No. 2) 250 volts max. thru 20,000-ohm dropping resistor, 4.0 ma.					6A8
6B8	Duplex-Diode Pentode	J	Htr.	6.3	0.3	Pentode R.F. Amplifier	250	− 3.0	125	2.3	9.0	650000	1125	730	—	—	6B8
						Pentode A.F. Amplifier	250	− 4.5	50	—	0.65	—	—	—	—	—	
6C5	Triode Detector Amplifier	C	Htr.	6.3	0.3	Class-A Amplifier	250	− 8.0	—	—	8.0	10000	2000	20	—	—	6C5
						Bias Detector	250	−17.0	—	—	Plate current adjusted to 0.2 ma. with no signal						
6F5	High-μ Triode	D	Htr.	6.3	0.3	Class-A Amplifier	250	− 1.3	—	—	0.2	66000	1500	100	—	—	6F5
6F6	Pentode Power Amplifier	E	Htr.	6.3	0.7	Class-A Pentode	250 315	−16.5 −22.0	250 315	6.5 8.0	34 42	80000 75000	2500 2650	200 200	7000 7000	3.0 5.0	6F6
						Class-A Triode[3]	250	−20	—	—	31	2600	2700	7.0	4000	0.85	
						Push-Pull Class-AB Amp. Pentode Connection Triode Connection[3]	375 350	−26 −38	250 —	2.5[4] —	17[4] 22.5[4]	Power output for 2 tubes at stated load, plate-to-plate			10000 6000	19 18	
6H6	Twin Diode	F	Htr.	6.3	0.3	Rectifier	Max. a.c. voltage per plate = 100 r.m.s. Max. output current 4.0 ma. d.c.										6H6
6J5	Detector Amplifier Triode	C	Htr.	6.3	0.3	Class-A Amplifier	250	− 8	—	—	9	7700	2600	20	—	—	6J5
6J7	Triple-Grid Detector Amplifier	G	Htr.	6.3	0.3	Screen-Grid R.R. Amplifier	250	− 3.0	100	0.5	2.0	exceeds 1.5 meg.	1225	exceeds 1500	—	—	6J7
						Bias Detector	250	− 4.3	100	Cathode current 0.43 ma.			—	—	0.5 meg.	—	
6K7	Triple-Grid Variable-μ Amplifier	G	Htr.	6.3	0.3	Screen-Grid R.F. Amplifier	250	− 3.0	125	2.6	10.5	600000	1650	990	—	—	6K7
						Mixer	250	−10	100	—	—	—	Oscillator peak volts = 7.0				
6K8	Triode Hexode Converter	B	Htr.	6.3	0.3	Converter	250	− 3	100	6	2.5	Anode-grid (No. 2) 100 volts max., 3.8 ma.					6K8
6L6	Beam Power Amplifier	K	Htr.	6.3	0.9	Single-Tube Class-A$_1$[5] Amp. Fixed Bias	250 375 375	−14.0 − 9.0 −17.5	250 125 250	5.0[4] 0.7[4] 2.5[4]	72[4] 24[4] 57[4]	22500	6000	135	2500 14000 4000	6.5 4.2 11.5	6L6
						Single-Tube Class-A$_1$[5] Amp. Self Bias	250 300 375	−13.5 −11.8 − 9.0	250 200 125	5.4[4] 3.0[4] 0.7[4]	75[4] 51[4] 24[4]				2500 4500 14000	6.5 6.5 4.0	
						Push-Pull A$_1$[5] Fixed Bias Self Bias	250 250	−16 −16	250 250	10[6] 10[6]	120[6] 120[6]	Power Output for 2 tubes. Load plate-to-plate			5000 5000	14.5 13.8	
						Push-Pull AB$_1$[5] Fixed Bias	400 400	−25 −20	300 250	6[6] 4[6]	102[6] 88[6]				6600 8500	34 26.5	
						Push-Pull AB$_1$[5] Self-Bias	400 400	−23.5 −19.0	300 250	7.0[6] 4.6[6]	112[6] 96[6]				6600 8500	32 24	
						Push-Pull AB$_2$[5] Fixed Bias	400 400	−25 −20	300 250	6[6] 4[6]	102[6] 88[6]				3800 6000	60 40	
6L7	Pentagrid Mixer Amplifier	H	Htr.	6.3	0.3	Screen-Grid R.F. Amplifier	250	− 3.0	100	5.5	5.3	800000	1100	—	—	—	6L7
						Mixer	250	− 6.0	150	8.3	3.3	exceeds 1.0 meg.	Oscillator-grid (No. 3) voltage = −15.0				
6N6 MG	Direct-Coupled Power Amplifier	N	Htr.	6.3	0.8	Class-A Amplifier	300	0	—	6[5]	45	24100	2400	58	7000	4.0	6N6 MG
						Push-Pull Amplifier	400	−13	—	4.5[5]	40	—	—	—	10000	20	
6N7	Twin Triode Amplifier	L	Htr.	6.3	0.8	Class-B Amplifier	250 300	0 0	—	—	Power output is for one tube at stated load, plate-to-plate				8000 10000	8.0 10.0	6N7

World Radio History

TABLE I — METAL RECEIVING TUBES — *Continued*

Type	Name	Socket Connections [1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps.	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
6Q7	Duplex-Diode Triode	I	Htr.	6.3	0.3	Triode Amplifier	250	−3	—	—	1.1	58000	1200	70	—	—	6Q7
6RJ	Duplex-Diode Triode	I	Htr.	6.3	0.3	Triode Amplifier	250	−9	—	—	9.5	8500	1900	16	10000	0.28	6R7
6S7	Triple-Grid Variable-μ Amplifier	G	Htr.	6.3	0.15	R.F. Amplifiera	135 250	−3.0 −3.0	67.5 100.0	0.9 2.0	3.7 8.5	—	1250 1750	850 1100	— —	— —	6S7
6S7	Triple-Grid Variable-μ	G	Htr.	6.3	0.15	Class-A Amplifier	250	−3	100	2	8.5	1000000	1750	1750	—	—	6S7
6SF5	High-μ Triode	X	Htr.	6.3	0.3	Class-A Amplifier	250	−2	—	—	0.9	66000	1500	100	—	—	6SF5
6SJ7	Triple-Grid Amplifier	Y	Htr.	6.3	0.3	Class-A Amplifier	250	−3	100	0.8	3	1500000	1650	2500	—	—	6SJ7
6SK7	Triple-Grid Variable-μ	Y	Htr.	6.3	0.3	Class-A Amplifier	250	−3	100	2.4	9.2	800000	2000	1600	—	—	6SK7
6SQ7	Duplex-Diode Triode	Z	Htr.	6.3	0.3	Class-A Amplifier	250	−2	—	—	0.8	91000	1100	100	—	—	6SQ7
6T7	Duplex-Diode Triode	I	Htr.	6.3	0.15	Class-A Amplifier	250	−3	—	—	1.2	62000	1050	65	—	—	6T7
6V6	Beam Power Amplifier	K	Htr.	6.3	0.45	Class-A Amplifier	250	−12.5	250	4.5–6.5	46	52000	4100	218	5000	4.25	6V6
						Class-AB Amplifier 2 Tubes	250	−15	250	5–12	75	—	—	—	10000	8.5	
							300	−20	300	5–13.5	85	—	—	—	8000	13.0	
1612	Pentagrid Amplifier	G	Htr.	6.3	0.3	Class-A Amplifier	250	−3	100	6.5	5.3	800000	1100	880	—	—	1612
1851	Television Amp. Pentode	G	Htr.	6.3	0.45	Class-A Amplifier	300	−2 [7]	150 [8]	2.5	10	750000	9000	6750	—	—	1851
1852	Television Amp. Pentode	Y	Htr.	6.3	0.45	Class-A Amplifier	Characteristics same as Type 1851 above										1852
1853	Television Amp. Pentode	Y	Htr.	6.3	0.45	Class-A Amplifier	300	−3	200 [8]	3.2	12.5	700000	5000	3500	—	—	1853

[1] Characteristics also apply to "G" tubes.
[2] Refer to Fig. 515.
[3] Screen tied to plate.
[4] Zero signal currents per tube.
[5] Subscript 1 indicates no grid-current flow. Subscript 2 indicates grid-current flow over part of input cycle.
[6] Zero-signal currents, two tubes.
[7] Cathode bias resistor should be adjusted for plate current of 10 ma.; minimum value 160 ohms.
[8] Series screen resistor 60,000 ohms for 1851–52 and 30,000 ohms for 1853 with 300-volt supply. Series resistor gives variable-μ characteristic, fixed screen supply gives sharp cut-off.

TABLE II — 6.3-VOLT GLASS TUBES WITH OCTAL BASES

(For "G"-Type Tubes Not Listed Here, See Equivalent Type in Table I; Characteristics and Connections Will Be Identical)

Type	Name	Socket Connections [1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps.	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
6A5G	Triode Power Amplifier	D	Htr.	6.3	1.0	Class A Amplifier	250	−45	—	—	60	800	5250	4.2	2500	3.75	6A5G
						Push-Pull Class AB	325	−68	—	—	80 [2]	—		—	3000	15	
						Push-Pull Class AB	325	850 Ohm Cathode Resistor			80 [4]	—		—	5000	10	
6AC5G	High-μ Power Amplifier Triode	C	Htr.	6.3	0.4	Push-Pull Class-B	250	0	—	—	5 [2]	36700	3400	125	10000	8	6AC5G
						Dynamic-Coupled Amp.	250	—	—	—	32				7000	3.7	
6AD6G	Electron-Ray Tube	AA	Htr.	6.3	0.15	Indicator Tube	100	0 for 90°; −23 for 135°; 45 for 0°. Target current 1.5 ma.									6AD6G
6AE6G	Control Tube	BB	Htr.	6.3	0.15	Indicator Control	250	−1.5	—	—	6.5 [4]	—	1000	25	—	—	6AE6G
							250	−1.5	—	—	4.5 [5]	—	950	33	—	—	
6AF6G	Electron-Ray Tube	AA	Htr.	6.3	0.15	Indicator Tube	100	0 for 100°; 60 for 0°. Target current 0.9									6AF6G
6B4G	Triode Power Amplifier	M	Fil.	6.3	1.0	Power Amplifier	Characteristics same as Type 6A3 — Table III							—	—	—	6B4G
6B6G	Duplex-Diode High-μ Triode	I	Htr.	6.3	0.3	Detector-Amplifier	Characteristics same as Type 75 — Table III							—	—	—	6B6G
6C8G	Amplifier Inverter	S	Htr.	6.3	0.3	Amp. 1 Section	250	−4.5	—	—	3.1	26000	1450	38	—	—	6C8G
						Inv. 2 Sections	250	−3.0	—	—	1.7 [3]	Output — 60v. R.M.S.					
							250	−3.0	—	—	1.0 [3]	Output — 80v. R.M.S.					

World Radio History

TABLE II — 6.3-VOLT GLASS TUBES WITH OCTAL BASES — *Continued*

Type	Name	Socket Connections[1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps.	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
6D8G	Pentagrid Converter	B	Htr.	6.3	0.15	Converter	135 250	−3.0 −3.0 min.	67.5 100	Cathode current 8.0 Ma. Cathode current 13.0 Ma.			Anode grid (No. 2) Volts = 135 Anode grid (No. 2) Volts = 250 through 20,000-ohm dropping resistor				6D8G
6F8G	Twin Triode	S	Htr.	6.3	0.6	Amplifier	250	− 8	—	—	9[3]	7700	2600	20	—	—	6F8G
6G6G	Pentode Power Amplifier	E	Htr.	6.3	0.15	Class-A Amplifier	180 135	− 9 − 6	180 135	2.5 2	15 11.5	175000 170000	2300 2100	400 360	10000 12000	1.1 .6	6G6G
6J8G	Triode Heptode	B	Htr.	6.3	0.3	Converter	250	− 3	100	2.8	1.2	Anode-grid (No. 2) 250 volts max. through 20,000-ohm dropping resistor, 5 ma.					6J8G
6K5G	High-μ Triode	D	Htr.	6.3	0.3	Class-A Amplifier	100 250	−1.5 −3.0	— —	— —	0.35 1.1	78000 53000	900 1400	70 70	— —	— —	6K5G
6K6G	Pentode Power Amplifier	E	Htr.	6.3	0.4	Class-A Amplifier	Characteristics same as Type 41 — Table III										6K6G
6L5G	Triode Amplifier	C	Htr.	6.3	0.15	Class-A Amplifier	135 250	−5.0 −9.0	— —	— —	3.5 8.0	—	1500 1900	17 17	— —	— —	6L5G
6N6G	Direct-Coupled Amplifier	N	Htr.	6.3	0.8	Power Amplifier	Characteristics same as Type 6B5—Table III							—	—	—	6N6G
6P7G	Triode-Pentode	T	Htr.	6.3	0.3	Triode-Pentode	Characteristics same as Type 6F7 — Table III										6P7G
6U7G	Triple Grid Variable-μ Amplifier	G	Htr.	6.3	0.3	R.F. Amplifier	Characteristics same as Type 6D6 — Table III										6U7G
6V7G	Duplex Diode-Triode	I	Htr.	6.3	0.3	Detector-Amplifier	Characteristics same as Type 85 — Table III										6V7G
6W7G	Triple-Grid Det. Amp.	G	Htr.	6.3	0.15	Class-A Amplifier	250	− 3	100	2	0.5	1500000	1225	1850	—	—	6W7G
6Y6G	Beam Power Amplifier	K	Htr.	6.3	1.25	Class-A Amplifier	135	−13.5	135	3	60	—	7000	—	2000	3.6	6Y6G
6Y7G	Twin Triode Amplifier	L	Htr.	6.3	0.3	Class-B Amplifier	Characteristics same as Type 79 — Table III										6Y7G
6Z7G	Twin Triode Amplifier	L	Htr.	6.3	0.3	Class-B Amplifier	180 135	0 0	— —	— —	8.4[2] 6[2]	— —	— —	— —	12000 9000	4.2 2.5	6Z7G
7000	Low-Noise Amplifier	G	Htr.	6.3	0.3	Class-A Amplifier	Characteristics same as Type 6J7 — Table I										7000

[1] Refer to Fig. 515. No connection to Pin No. 1. [2] No-signal value for 2 tubes. [3] Per plate. [4] Plate No. 1, remote cut-off. [5] Plate No. 2, sharp cut-off.

TABLE III — 6.3-VOLT GLASS RECEIVING TUBES

Type	Name	Base[4]	Socket Connections[1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
6A3	Triode Power Amplifier	4-pin M.	A	Fil.	6.3	1.0	Class-A Amplifier	250	− 4.5	—	—	6.0	800	5250	4.2	2500	3.2	6A3
							Push-Pull Amplifier	325 325	− 6.8	Fixed Bias Self Bias		4.0 4.0	Power output for 2 tubes load plate-to-plate			3000 5000	1.5 1.0	
6A4[5]	Pentode Power Amplifier	5-pin M.	F	Fil.	6.3	0.3	Class-A Amplifier	100 180	− 6.5 −12.0	100 180	1.6 3.9	9.0 22.0	83250 45500	1200 2200	100 100	11000 8000	0.31 1.40	6A4
6A6	Twin Triode Amplifier	7-pin M.	T	Htr.	6.3	0.8	Class-B Amplifier	250 300	0 0	—	—	Power output is for one tube at stated load, plate-to-plate				8000 10000	8.0 10.0	6A6
6A7	Pentagrid Converter	7-pin S.	P	Htr.	6.3	0.3	Converter	250	− 3.0 min.	100	2.2	3.5	360000	Anode grid (No. 2) 200 volts max., 4.0 ma. Grid leak, 50000 ohms.				6A7
6AB5	Electron-Ray Tube	6-pin S.	Z	Htr.	6.3	0.15	Indicator Tube	135	0	Cut-off Grid bias 7.5 v.		0.5	Target current 4.5 ma.					6AB5
6B5	Direct-Coupled Power Amplifier	6-pin M.	Y	Htr.	6.3	0.8	Class-A Amplifier	300	0		6[5]	45	241000	2400	58	7000	4.0	6B5
							Push-Pull Amplifier	400	−13		4.5[5]	40	—	—	—	10000	20	

World Radio History

TABLE III—6.3-VOLT GLASS RECEIVING TUBES—*Continued*

Type	Name	Base [4]	Socket Connec-tions [1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resist-ance, Ohms	Mutual Conduct-ance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
6B7	Duplex-Diode Pentode	7-pin S.	Q	Htr.	6.3	0.3	Pentode R.F. Amplifier	250	−3.0	125	2.3	9.0	650000	1125	730	—	—	6B7
							Pentode A.-F. Amplifier	250	−4.5	50	—	0.65	—	—	—	—	—	
6C6	Triple-Grid Detector Amplifier	6-pin S.	J	Htr.	6.3	0.3	Screen-Grid R.F. Amplifier	250	−3.0	100	0.5	2.0	exceeds 1.5 meg.	1225	exceeds 1500	—	—	6C6
							Bias Detector	250	−1.95	50	Cathode current 0.65 ma.		—	Plate coupling resistor 250000 ohms				
6D6	Triple-Grid Variable-μ Amplifier	6-pin S.	J	Htr.	6.3	0.3	Screen-Grid R.F. Amplifier	250	−3.0	100	2.0	8.2	800000	1600	1280	—	—	6D6
							Mixer	250	−10.0	100	—	—	—	Oscillator peak volts = 7.0				
6E5	Electron-Ray Tube	6-pin S.	Z	Htr.	6.3	0.3	Indicator Tube	250	0	Cut-off Grid Bias = −8.0 v.		0.25	Target Current 4 ma.				—	6E5
6E6	Twin Triode Amplifier	7-pin M.	T	Htr.	6.3	0.6	Class-A Push-Pull Amplifier	180 250	−20 −27.5	Per plate — 11.5 Per plate — 18.0			4300 3500	1400 1700	6.0 6.0	15000 14000	0.75 1.6	6E6
6F7	Triode Pentode	7-pin S.	W	Htr.	6.3	0.3	Triode Unit Amplifier	100	−3.0	—	—	3.5	16000	500	8	—	—	6F7
							Pentode Unit Amplifier	250	−3.0	100	1.5	6.5	850000	1100	900	—	—	
							Pentode Unit Mixer	250	−10.0	100	0.6	2.8	Oscillator peak volts = 7.0				—	
6G5	Electron-Ray Tube	6-pin S.	Z	Htr.	6.3	0.3	Indicator Tube	250	0	Cut-off Grid Bias = 22 v.		0.24	Target Current 4 ma.				—	6G5
6H5	Electron-Ray Tube	6-pin S.	Z	Htr.	6.3	0.3	Indicator Tube	Same characteristics as Type 6G5—Circular Pattern										6H5
6N5	Electron-Ray Tube	6-pin S.	Z	Htr.	6.3	0.15	Indicator Tube	180	0	Cut-off Grid Bias = −12 v.		0.5	Target Current 2 ma.				—	6N5
6U5	Electron-Ray Tube	6-pin S.	Z	Htr.	6.3	0.3	Indicator Tube	Same characteristics as Type 6G5—Tubular Bulb										6U5
36	Tetrode R.F. Amplifier	5-pin S.	I	Htr.	6.3	0.3	Screen Grid R.F. Amplifier	100 180 250	−1.5 −3.0 −3.0	55 90 90	— — 1.7	1.8 3.1 3.2	550000 500000 550000	850 1050 1080	470 525 595	—	—	36
							Bias Detector	100 250	−5.0 −8.0	55 90	— —	Plate Current to be adjusted to 0.1 ma. with no signal					— —	
37	Triode Detector Amplifier	5-pin S.	H	Htr.	6.3	0.3	Class-A Amplifier	90 180 250	−6.0 −13.5 −18.0	—	—	2.5 4.3 7.5	11500 10200 8400	800 900 1100	9.2 9.2 9.2	—	—	37
							Bias Detector	90 250	−10.0 −28.0	—	—	Plate Current to be adjusted to 0.2 ma. with no signal					—	
38	Pentode Power Amplifier	5-pin S.	I [2]	Htr.	6.3	0.3	Class-A Amplifier	100 180 250	−9.0 −18.0 −25.0	100 180 250	1.2 2.4 3.8	7.0 14.0 22.0	140000 115000 100000	875 1050 1200	120 120 120	15000 11600 10000	0.27 1.00 2.50	38
39 44	Variable-μ R.F. Amplifier Pentode	5-pin S.	I [2]	Htr.	6.3	0.3	Screen-Grid R.F. Amplifier	90 180 250	−3.0 min.	90 90 90	1.6 1.4 1.4	5.6 5.8 5.8	375000 750000 1000000	960 1000 1050	360 750 1050	—	—	39 44
41	Pentode Power Amplifier	6-pin S.	M [2]	Htr.	6.3	0.4	Class-A Amplifier	100 180 250	−7.0 −13.5 −18.0	100 180 250	1.6 3.0 5.5	9.0 18.5 32.0	103500 81000 68000	1450 1850 2200	150 150 150	12000 9000 7600	0.33 1.50 3.40	41
42	Pentode Power Amplifier	6-pin M.	M [2]	Htr.	6.3	0.7	Class-A Amplifier	250	−16.5	250	6.5	34.0	100000	2200	220	7000	3.0	42
75	Duplex-Diode High-μ Triode	6-pin S.	K	Htr.	6.3	0.3	Triode Amplifier	250	−1.35	—	—	0.4	91000	1100	100	—	—	75
76	Triode Detector Amplifier	5-pin S.	H	Htr.	6.3	0.3	Class-A Amplifier	250	−13.5	—	—	5.0	9500	1450	13.8	—	—	76
							Bias Detector	250	−20.0	Plate current to be adjusted to 0.2 ma. with no signal								

TABLE III — 6.3-VOLT GLASS RECEIVING TUBES — *Continued*

Type	Name	Base[4]	Socket Connections[1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
77	Triple-Grid Detector Amplifier	6-pin S.	J	Htr.	6.3	0.3	Screen-Grid R.F. Amplifier	100 250	−1.5 −3.0	60 100	0.4 0.5	1.7 2.3	650000 1500000	1100 1250	715 1500	—	—	77
							Bias Detector	250	−1.95	50	Cathode current = 0.65 ma. Plate coupling resistor 250000 ohms							
78	Triple-Grid Variable-μ Amplifier	6-pin S.	J	Htr.	6.3	0.3	Screen-Grid R.F. Amplifier	90 180 250 250	−3.0 min.	90 75 100 125	1.3 1.0 1.7 2.6	6.4 4.0 7.0 10.5	315000 1000000 800000 600000	1275 1100 1450 1650	400 1100 1160 990	—	—	78
79	Twin Triode Amplifier	6-pin S.	O	Htr.	6.3	0.6	Class-B Amplifier	180 250	0 0	—	—	Power output is for one tube at stated load, plate-to-plate				7000 14000	5.5 8.0	79
85	Duplex Diode Triode	6-pin S.	K	Htr.	6.3	0.3	Triode Unit as Class-A Amplifier	135 180 250	−10.5 −13.5 −20.0	—	—	3.7 6.0 8.0	11000 8500 7500	750 975 1100	8.3 8.3 8.3	25000 20000 20000	0.075 0.160 0.350	85
89	Triple-Grid Power Amplifier	6-pin S.	L	Htr.	6.3	0.4	Class-A Triode Amplifier[6]	160 180 250	−20.0 −22.5 −31.0	—	—	17.0 20.0 32.0	3300 3000 2600	1425 1550 1800	4.7 4.7 4.7	7000 6500 5500	0.300 0.400 0.900	89
							Class-A Pentode Amplifier[7]	100 180 250	−10.0 −18.0 −25.0	100 180 250	1.6 3.0 5.5	9.5 20.0 32.0	104000 80000 70000	1200 1550 1800	125 125 125	10700 8000 6750	0.33 1.50 3.40	
							Class-B Triode Amplifier[8]	180	0	—	—	Power output is for 2 tubes at stated load, plate-to-plate				13600 9400	2.50 3.50	
1603	Triple-Grid Detector Amplifier (Low Noise)	6-pin M.	J	Htr.	6.3	0.3	Class-A Pentode Amplifier	100 250	−3 −3	100 100	0.5 0.5	2.0 2.0	1000000 1500000	1185 1225	1185 1500	— —	— —	1603
							Class-A Triode Amplifier[8]	180 250	−5.3 −8.0	— —	— —	5.3 6.5	11000 10500	1800 1900	20 20	— —	— —	
7700	Low-Noise Amplifier	6-pin S.	J	Htr.	6.3	0.3	Class-A Amplifier	Characteristics same as 6C6										7700
RK34	Twin Triode Amplifier	5-pin M. 7-pin M.	DD[9]	Htr.	6.3	0.8	Class-B Amplifier	180 300	−6 −15	—	—	—	Power output for one tube at stated load, plate-to-plate			6000 10000	7.2 12.0	RK34
RK100	Mercury-vapor Triode	6-pin M.	CC	Htr.	6.3	0.6	Amplifier	100	−2.5	Cathode (G1) current 250 ma.				20000	50	—	—	RK100

[1] Refer to Fig. 514.
[2] Suppressor grid, connected to cathode inside tube, not shown on base diagram.
[3] Also known as Type LA.
[4] S.—small; M.—medium.
[5] Current to input plate (P_1).
[6] Grids Nos. 2 and 3 connected to plate.
[7] Grid No. 2, screen; grid No. 3, suppressor.
[8] Grids Nos. 1 and 2 tied together; grid No. 3 connected to plate.
[9] Early models; later tubes have 7-pin bases. Connections same as Fig. 514-T except that pins 2 and 6 are unconnected; plate leads brought out to top caps.

TABLE IV — 2.5-VOLT RECEIVING TUBES

Type	Name	Base[3]	Socket Connections[1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
2A3	Triode Power Amplifier	4-pin M.	A	Fil.	2.5	2.5	Class-A Amplifier	250	−45	—	—	60.0	800	5250	4.2	2500	3.5	2A3
							Push-Pull Amplifier	300 300	−62 −62	Self-Bias Fixed-Bias		40.0 40.0	Power Output for 2 tubes Load Plate-to-Plate			5000 3000	10.0 15.0	
2A5	Pentode Power Amplifier	6-pin M.	M[2]	Htr.	2.5	1.75	Class-A Amplifier	250	−16.5	250	6.5	34.0	80000	2500	200	7000	3.0	2A5
2A6	Duplex-Diode Triode	6-pin S.	K	Htr.	2.5	0.8	Triode as Class-A Amp.	250	−1.35	—	—	0.4	91000	1100	100	—	—	2A6
2A7	Pentagrid Converter	7-pin S.	P	Htr.	2.5	0.8	Converter	250	−3.0 min.	100	2.2	3.5	360000	Anode grid (No. 2) 200 max. volts, 4.0 ma. Grid leak, 50000 ohms				2A7
2B6	Special Power Amplifier	7-pin M.	BB	Htr.	2.5	2.25	Amplifier	250	−24.0	—	—	40.0	5150	3500	18.0	5000	4.0	2B6

World Radio History

TABLE IV—2.5 VOLT RECEIVING TUBES—*Continued*

Type	Name	Base [3]	Socket Connections [1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
2B7	Duplex-Diode Pentode	7-pin S.	Q	Htr.	2.5	0.8	Pentode Amplifier	Characteristics same as Type 6B7—Table III										2B7
2E5	Electron-Ray Tube	6-pin S.	Z	Htr.	2.5	0.8	Indicator Tube	Characteristics same as Type 6E5—Table III										2E5
24-A	Tetrode R.F. Amplifier	5-pin M.	I	Htr.	2.5	1.75	Screen-Grid R.F. Amp.	250	−3.0	90	1.7	4.0	600000	1050	630	——	——	24-A
							Bias Detector	250	−5.0	20	Plate current adjusted to 0.1 ma. with no signal							
27	Triode Detector-Amplifier	5-pin M.	H	Htr.	2.5	1.75	Class-A Amplifier	250	−21.0	——	——	5.2	9250	975	9.0	——	——	27
							Bias Detector	250	−30.0	——	Plate current adjusted to 0.2 ma. with no signal							
35	Variable-μ Amplifier	5-pin M.	I	Htr.	2.5	1.75	Screen-Grid R.F. Amp.	250	−3.0	90	2.5	6.5	400000	1050	420	——	——	35
45	Triode Power Amplifier	4-pin M.	A	Fil.	2.5	1.5	Class-A Amplifier	180 250 275	−31.5 −50.0 −56.0	180 250 275	——	31.0 34.0 36.0	1650 1610 1700	2125 2175 2050	3.5 3.5 3.5	2700 3900 4600	0.82 1.60 2.00	45
46	Dual-Grid Power Amplifier	5-pin M.	G	Fil.	2.5	1.75	Class-A Amplifier [4]	250	−33.0	——	——	22.0	2380	2350	5.6	6400	1.25	46
							Class-B Amplifier [5]	300 400	0 0	——	——	Power output for 2 tubes at stated load, plate-to-plate				5200 5800	16.0 20.0	
47	Pentode Power Amplifier	5-pin M.	F	Fil.	2.5	1.75	Class-A Amplifier	250	−16.5	250	6.0	31.0	60000	2500	150	7000	2.7	47
53	Twin Triode Amplifier	7-pin M.	T	Htr.	2.5	2.0	Class-B Amplifier	250 300	0 0	——	——	Power output for 1 tube at stated load, plate-to-plate				8000 10000	8.0 10.0	53
55	Duplex-Diode Triode	6-pin S.	K	Htr.	2.5	1.0	Class-A Amplifier	250	−20.0	——	——	8.0	7500	1100	8.3	20000	0.350	55
56	Triode Amplifier, Detector	5-pin S.	H	Htr.	2.5	1.0	Class-A Amplifier	250	−13.5	——	——	5.0	9500	1450	13.8	——	——	56
							Bias Detector	250	−20.0	——	Plate current adjusted to 0.2 ma. with no signal							
57	Triple-Grid Detector Amplifier	6-pin S.	J	Htr.	2.5	1.0	Screen-Grid R.F. Amplifier	250	−3.0	100	0.5	2.0	exceeds 1.5 meg.	1225	exceeds 1500	——	——	57
							Bias Detector	250	−1.95	50	Cathode current = 0.65 ma.			Plate resistor = 250000 ohms				
58	Triple-Grid Variable-μ Amplifier	6-pin S.	J	Htr.	2.5	1.0	Screen-Grid R.F. Amp.	250	−3.0	100	2.0	8.2	800000	1600	1280	——	——	58
							Mixer	250	−10.0	100	——	——	Oscillator peak volts = 7.0				——	
59	Triple-Grid Power Amplifier	7-pin M.	N	Htr.	2.5	2.0	Class-A Triode [6]	250	−28.0	——	——	26.0	2300	2600	6.0	5000	1.25	59
							Class-A Pentode [7]	250	−18.0	250	9.0	35.0	40000	2500	100	6000	3.0	
							Class-B Triode [8]	300 400	0 0	——	——	Power output for 2 tubes at stated load, plate-to-plate				4600 6000	15.0 20.0	
RK15	Triode Power Amplifier	4-pin M.	A [9]	Fil.	2.5	1.75	Characteristics same as Type 46 with Class-B connections											RK15
RK16	Triode Power Amplifier	5-pin M.	H	Htr.	2.5	2.0	Characteristics same as Type 59 with Class-A triode connections											RK16
RK17	Pentode Power Amplifier	5-pin M.	I [2]	Htr.	2.5	2.0	Characteristics same as Type 2A5											RK17

[1] Refer to Fig. 514.
[2] Suppressor grid, connected to cathode inside tube, not shown on base diagram.
[3] S.—small; M.—medium.
[4] Grid No. 2 tied to plate.
[5] Grids Nos. 1 and 2 tied together.
[6] Grids Nos. 2 and 3 connected to plate.
[7] Grid No. 2, screen; grid No. 3, suppressor.
[8] Grids Nos. 1 and 2 tied together; grid No. 3 connected to plate.
[9] Grid connection to cap; no connection to No. 3 pin.

TABLE V—2.0-VOLT BATTERY RECEIVING TUBES

Type	Name	Base [3]	Socket Connections [1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
1A4	Variable-μ Pentode	4-pin S.	D	Fil.	2.0	0.06	R.F. Amplifier	180	−3.0	67.5	0.8	2.3	1000000	750	750	——	——	1A4
1A6	Pentagrid Converter	6-pin S.	V	Fil.	2.0	0.06	Converter	180	−3.0 min.	67.5	2.4	1.3	500000	Anode grid (No. 2) 135 max. volts; 2.3 ma. Grid Leak 50000 ohms				1A6

World Radio History

TABLE V — 2.0-VOLT BATTERY RECEIVING TUBES — *Continued*

Type	Name	Base[3]	Socket Connections[1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
1B4	Pentode R.F. Amplifier	4-pin S.	D	Fil.	2.0	0.06	R.F. Amplifier	180	−3.0	67.5	0.6	1.7	1500000	650	1000	—	—	1B4
1B5	Duplex-Diode Triode	6-pin S.	X	Fil.	2.0	0.06	Triode Class-A Amplifier	135	−3.0	—	—	0.8	35000	575	20	—	—	1B5
1C6	Pentagrid Converter	6-pin S.	V	Fil.	2.0	0.12	Converter	180	−3.0 min.	67.5	2.0	1.5	750000	Anode grid (No. 2) 135 max. volts; 3.3 ma. Grid Leak 50000 ohms				1C6
1F4	Pentode Power Amplifier	5-pin M.	F	Fil.	2.0	0.12	Class-A Amplifier	135	−4.5	135	2.6	8	200000	1700	340	16000	0.34	1F4
1F6	Duplex-Diode Pentode	6-pin S.	EE	Fil.	2.0	0.6	R.F. Amplifier	180	−1.5	67.5	0.6	2.0	1000000	650	650	—	—	1F6
							A.F. Amplifier	135	−1.0	135	Plate resistor 0.25 megohm Screen resistor 1.0 megohm					Voltage Amp. = 48		
15	R.F. Pentode Amplifier-Oscillator	5-pin S.	I	Htr.	2.0	0.22	R.F. Amplifier	135	−1.5	67.5	0.3	1.85	800000	750	600	—	—	15
								67.5	−1.5	67.5	0.3	1.85	630000	710	450	—	—	
19	Twin-Triode Amplifier	6-pin S.	U	Fil.	2.0	0.26	Class-B Amplifier	135	0	—	—	Load plate-to-plate				10000	2.1	19
30	Triode Detector Amplifier	4-pin S.	A	Fil.	2.0	0.06	Class-A Amplifier	90 135 180	−4.5 −9.0 −13.5	—	—	2.5 3.0 3.1	11000 10300 10300	850 900 900	9.3 9.3 9.3	—	—	30
31	Triode Power Amplifier	4-pin S.	A	Fil.	2.0	0.13	Class-A Amplifier	135 180	−22.5 −30.0	—	—	8.0 12.3	4100 3600	925 1050	3.8 3.8	7000 5700	0.185 0.375	31
32	Tetrode R.F. Amplifier	4-pin M.	D	Fil.	2.0	0.06	Screen-Grid R.F. Amplifier	135 180	−3.0 −3.0	67.5 67.5	0.4 0.4	1.7 1.7	950000 1200000	640 650	610 780	—	—	32
							Bias Detector	180	−6.0	67.5	—	Plate current adjusted to 0.2 ma. with no signal						
33	Pentode Power Amplifier	5-pin M.	F	Fil.	2.0	0.26	Class-A Amplifier	180 135	−18.0 −13.5	180 135	5.0 3.0	22.0 14.5	55000 50000	1700 1450	90 70	6000 7000	1.4 0.7	33
34	Variable-μ Pentode R.F. Amplifier	4-pin M.	D[2]	Fil.	2.0	0.06	Screen-Grid R.F. Amplifier	135 180	−3.0 min.	67.5 67.5	1.0 1.0	2.8 2.8	600000 1000000	600 620	360 620	—	—	34
49	Dual-Grid Power Amplifier	5-pin M.	G	Fil.	2.0	0.12	Class-A Amplifier[4]	135	−20.0	—	—	6.0	4175	1125	4.7	11000	0.17	49
							Class-B Amplifier[5]	180	0	—	—	Power output for 2 tubes at indicated load, plate-to-plate				12000	3.5	
840	R.F. Pentode	5-pin S.	GG	Fil.	2.0	0.130	Class-A Amplifier	180	−3	67.5	0.7	1.0	1000000	400	400	—	—	840
950	Pentode Power Amplifier	5-pin M.	F	Fil.	2.0	0.12	Class-A Amplifier	135	−16.5	1.35	2.0	7.0	100000	1000	100	13500	0.45	950
RK24	Triode Amplifier	4-pin M.	A	Fil.	2.0	0.12	Class-A Amplifier	180	−13.5	—	—	8.0	5000	1600	8.0	12000	0.25	RK24

[1] Refer to Fig. 514.
[2] Suppressor grid connected to filament inside tube, not shown on base diagram.
[3] S.—small; M.—medium.
[4] Grid No. 2 tied to plate.
[5] Grids Nos. 1 and 2 tied together.

TABLE VI — 2.0-VOLT BATTERY TUBES WITH OCTAL BASES

Type	Name	Socket Connections[1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
1C7G	Pentagrid Converter	A	Fil.	2.0	0.06	Converter	—	—	Characteristics same as Type 1C6 — Table V					—	—	—	1C7G
1D5G	Variable-μ R.F. Pentode	B	Fil.	2.0	0.06	R.F. Amplifier	—	—	Characteristics same as Type 1A4 — Table V					—	—	—	1D5G
1D7G	Pentagrid Converter	A	Fil.	2.0	0.06	Converter	—	—	Characteristics same as Type 1A6 — Table V					—	—	—	1D7G

World Radio History

TABLE VI—2.0-VOLT BATTERY TUBES WITH OCTAL BASES—*Continued*

Type	Name	Socket Connections [1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
1E5G	R.F. Amplifier Pentode	B	Fil.	2.0	0.06	R.F. Amplifier	—	—	Characteristics same as Type 1B4—Table V					—	—	—	1E5G
1E7G	Double Pentode Power Amp.	C	Fil.	2.0	0.24	Class-A Amplifier	135	−7.5	135	2.0 [2]	6.5 [2]	220000	1600	350	24000	0.65	1E7G
1F5G	Pentode Power Amplifier	D	Fil.	2.0	0.12	Class-A Amplifier	—	—	Characteristics same as Type 1F4—Table V					—	—	—	1F5G
1F7GV	Duplex-Diode Pentode	E	Fil.	2.0	0.06	Detector-Amplifier	—	—	Characteristics same as Type 1F6—Table V					—	—	—	1F7GV
1G5G	Pentode Power Amplifier	D	Fil.	2.0	0.12	Class-A Amplifier	90 135	−6 13.5	90 135	2.7 2.5	8.5 8.7	133000 1600000	1500 1550	200 250	8500 9000	0.3 0.55	1G5G
1H4G	Triode Amplifier	F	Fil.	2.0	0.06	Detector-Amplifier	—	—	Characteristics same as Type 30—Table V					—	—	—	1H4G
1H6G	Duplex-Diode Triode	G	Fil.	2.0	0.06	Detector-Amplifier	—	—	Characteristics same as Type 1B5—Table V					—	—	—	1H6G
1J5G	Pentode Power Amplifier	D	Fil.	2.0	0.12	Class-A Amplifier	135	−16.5	135	2.0	7.0	—	950	100	13500	0.45	1J5G
1J6G	Twin Triode	H	Fil.	2.0	0.24	Class-B Amplifier	—	—	Characteristics same as Type 19—Table V					—	—	—	1J6G

[1] Refer to Fig. 516.

[2] Total current for both sections; no signal.

TABLE VII—1.5-VOLT FILAMENT DRY-CELL TUBES

Type	Name	Socket Connections [1]	Filament Volts	Filament Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
1A5G	Pentode Power Amplifier	D [2]	1.4	0.05	Class-A Amplifier	85 [3]	−4.5 [3]	85	0.7	3.5	300000	800	240	25000	0.1	1A5G
1A7G	Pentagrid Converter	A	1.4	0.05	Converter	90	0	45 [4]	0.6	0.55	600000	Anode-grid volts 90				1A7G
1C5G	Pentode Power Amplifier	D [2]	1.4	0.10	Class-A Amplifier	83 [3]	−7 [3]	83	1.6	7.0	110000	1500	165	9000	0.2	1C5G
1H5G	Diode High-μTriode	I	1.4	0.05	Class-A Amplifier	90	0	—	—	0.14	240000	275	65	—	—	1H5G
1N5G	Pentode R.F. Amplifier	B [2]	1.4	0.05	Class-A Amplifier	90	0	90	0.3	1.2	1500000	750	1160	—	—	1N5G
RK42	Triode Amplifier	A [5]	1.5	0.6	Class-A Amplifier	Characteristics same as Type 30—Table V										RK42
RK43	Twin Triode Amplifier	U [5]	1.5	0.12	Twin Triode Amplifier	135	−3	—	—	4.5	14500	900	13	—	—	RK43

[1] Refer to Fig. 516.

[2] G3 connected to Pin 7 inside tube.

[3] Grid bias obtained from 90-volt "B" supply through self-biasing resistor.

[4] Obtained from 90-volt supply through 70,000-ohm dropping resistor.

[5] Refer to Fig. 514.

TABLE VIII—HIGH-VOLTAGE HEATER TUBES

Type	Name	Base [3]	Socket Connections [1]	Heater Volts	Heater Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
12A5	Pentode Power Amplifier	7-pin M.	AA	12.6 6.3	0.3 0.6	Class-A Amplifier	100 180	−15 −27	100 180	4.0 9.0	18 40	— —	— —	— —	5000 4500	0.7 2.8	12A5
12A7	Rectifier-Pentode Power Amplifier	7-pin M.	FF	12.6	0.3	Class-A Amplifier	135	−13.5	135	2.5	9.0	102000	975	100	13500	0.55	12A7
						Half-Wave Rectifier	125 Max. Volts R.M.S. Output current 30 ma. Max.										
18	Pentode Power Amplifier	6-pin M.	M [2]	14	0.3	Class-A Amplifier	Characteristics same as Type 2A5—Table IV										18
25A6 25A6G	Pentode Power Amplifier	7-pin O.	E [4]	25	0.3	Class-A Amplifier	95 135 180	−15 −20 −20	95 135 135	4 8 7.5	20 37 38	45000 35000 40000	2000 2450 2500	90 85 100	4500 4000 5000	0.9 2.0 2.75	25A6 25A6G

TABLE VIII—HIGH-VOLTAGE HEATER TUBES—*Continued*

Type	Name	Base [3]	Socket Connections [1]	Heater Volts	Heater Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
25A7G	Rectifier-Amplifier	8-pin O.	V [4]	25	0.3	Class-A Amplifier	100	−15	100	4.0	20.5	50000	1800	90	4500	0.77	25A7G
						Rectifier	125 v. R.M.S.—75 ma. max. output										
25B5	Direct-Coupled Triodes	6-pin S.	Y	25	0.3	Class-A Amplifier	110	0	110	7	45	11400	2200	25	2000	2.0	25B5
25B6G	Pentode Power Amplifier	7-pin O.	E [4]	25	0.3	Class-A Amplifier	95	−15	95	4	45	—	4000	—	2000	1.75	25B6G
25L6	Beam Power Amplifier	7-pin O.	K [4]	25	0.3	Class-A Amplifier	110	− 8	110	3.5–10.5	45–48	10000	8000	80	2000	2.2	25L6
25L6G	Beam Power Amplifier	7-pin O.	K [4]	25	0.3	Class-A Amplifier	Characteristics same as Type 25L6										25L6G
25N6G	Direct-Coupled Triodes	7-pin O.	N [4]	25	0.3	Class-A Amplifier	110	0	110	7	45	11400	2200	25	2000	2.0	25N6G
43	Pentode Power Amplifier	6-pin M.	M [2]	25.0	0.3	Class-A Amplifier	95 135	−15.0 −20.0	95 135	4.0 7.0	20.0 34.0	45000 35000	2000 2300	90 80	4500 4000	0.90 2.00	43
48	Tetrode Power Amplifier	6-pin M.	M	30.0	0.4	Class-A Amplifier	96 125	−19.0 −20.0	96 100	9.0 9.5	52.0 56.0	— —	3800 3900	— —	1500 1500	2.0 2.5	48

[1] Refer to Fig. 514. [2] Suppressor grid connected to filament inside tube, not shown on base diagram. [3] M.—medium; S.—small; O.—octal. [4] Refer to Fig. 515.

TABLE IX—MISCELLANEOUS RECEIVING TUBES

Type	Name	Base [2]	Socket Connections [1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
00-A	Triode Detector	4-pin M.	A	Fil.	5.0	0.25	Grid Leak Detector	45	—	—	—	1.5	30000	666	20	—	—	00-A
01-A	Triode Detector Amplifier	4-pin M.	A	Fil.	5.0	0.25	Class-A Amplifier	90 135	− 4.5 − 9.0	—	—	2.5 3.0	11000 10000	725 800	8.0 8.0	—	—	01-A
10	Triode Power Amplifier	4-pin M.	A	Fil.	7.5	1.25	Class-A Amplifier	350 425	−31.0 −39.0	—	—	16.0 18.0	5150 5000	1550 1600	8.0 8.0	11000 10200	0.9 1.6	10
11-12	Triode Detector Amplifier	4-pin M.	A	Fil.	1.1	0.25	Class-A Amplifier	90 135	− 4.5 −10.5	—	—	2.5 3.0	15500 15000	425 440	6.6 6.6	—	—	11–12
20	Triode Power Amplifier	4-pin S.	A	Fil.	3.3	0.132	Class-A Amplifier	90 135	−16.5 −22.5	—	—	3.0 6.5	8000 6300	415 525	3.3 3.3	9600 6500	0.045 0.110	20
22	Tetrode R.F. Amplifier	4-pin M.	D	Fil.	3.3	0.132	Screen-Grid R.F. Amplifier	135 135	− 1.5 − 1.5	45.0 67.5	0.6 1.3	1.7 3.7	725000 325000	375 500	270 160	—	—	22
26	Triode Amplifier	4-pin M.	A	Fil.	1.5	1.05	Class-A Amplifier	90 180	− 7.0 −14.5	—	—	2.9 6.2	8900 7300	935 1150	8.3 8.3	—	—	26
40	Triode Voltage Amplifier	4-pin M.	A	Fil.	5.0	0.25	Class-A Amplifier	135 180	− 1.5 − 3.0	—	—	0.2 0.2	150000 150000	200 200	30 30	—	—	40
4A6G	Twin Triode Amplifier	8-pin O. [6]	L [3]	Fil.	4 [3]	0.06	Class-A Amplifier [4]	90	− 1.5	—	—	2.2	13300	1500	20	—	—	4A6G
					2 [3]	0.12	Class-B Amplifier	90	0	—	—	4.6 [5]	—	—	—	8000	1.0	
50	Triode Power Amplifier	4-pin M.	A	Fil.	7.5	1.25	Class-A Amplifier	300 400 450	−54.0 −70.0 −84.0	—	—	35.0 55.0 55.0	2000 1800 1800	1900 2100 2100	3.8 3.8 3.8	4600 3670 4350	1.6 3.4 4.6	50
71-A	Triode Power Amplifier	4-pin M.	A	Fil.	5.0	0.25	Class-A Amplifier	90 180	−19.0 −43.0	—	—	10.0 20.0	2170 1750	1400 1700	3.0 3.0	3000 4800	0.125 0.790	71-A
99	Triode Detector Amplifier	4-pin S.	A	Fil.	3.3	0.063	Class-A Amplifier	90	− 4.5	—	—	2.5	15500	425	6.6	—	—	99
112A	Triode Detector Amplifier	4-pin M.	A	Fil.	5.0	0.25	Class-A Amplifier	90 180	− 4.5 −13.5	—	—	5.0 7.7	5400 4700	1575 1800	8.5 8.5	—	—	112A

World Radio History

TABLE IX — MISCELLANEOUS RECEIVING TUBES — *Continued*

Type	Name	Base [2]	Socket Connections [1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps.	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
183	Power Triode	4-pin M.	A	Fil.	5.0	1.25	Class-A Amplifier	250	60	—	—	25	18000	1800	3.2	4500	2.0	183
257	Power Pentode	5-pin M.	F	Fil.	5.0	0.30	Class-A Amplifier	110	21.5	110	7	20	41000	1350	55	6000	0.8	257
485	Triode	5-pin S.	H	Htr.	3.0	1.30	Class-A Amplifier	180	9.0	—	—	6.0	9300	1350	12.5	—	—	485
864	Triode Amplifier	4-pin S.	A	Fil.	1.1	0.25	Class-A Amplifier	90 135	−4.5 −9.0	— —	— —	2.9 3.5	13500 12700	610 645	8.2 8.2	— —	— —	864
954 [7]	Pentode Detector, Amplifier	Special	A [7]	Htr.	6.3	0.15	Class-A Amplifier	250	−3	100	0.7	2.0	Exceeds 1.5 megohms	1400	Exceeds 2000	—	—	954
							Bias Detector	250	−6	100		Plate current to be adjusted to 0.1 ma. with no signal						
955 [7]	Triode Detector, Amplifier	Special	B [7]	Htr.	6.3	0.16	Class-A Amplifier	180	−5	—	—	4.5	12500	2000	25	20000	0.135	955
							Oscillator	180	−35	—	—	7	D.C. Grid Current App. 1.5 ma.				0.5	
956 [7]	Triple-Grid Variable-μ R.F. Amplifier	Special	A [7]	Htr.	6.3	0.15	Screen Grid R.F. Amplifier	250	−3	100	1.8	5.5	800000	1800	1440	—	—	956
							Mixer	250	−10	100	—	—	Oscillator peak volts—7 min.					
1609	Pentode Amplifier	5-pin S.	F	Fil.	1.1	0.25	Class-A Amplifier	135	2.5		—	—	400000	735	300	—	—	1609

[1] Refer to Fig. 514.
[2] M.—medium; S.—small.
[3] Cathode terminal is mid-point of filament; use series connection with 4 volts, parallel with 2 volts.
[4] Triodes connected in parallel.
[5] Idling current, bcth plates.
[6] Refer to Fig. 515.
[7] "Acorn" type; miniature unbased tubes for ultra-high frequencies. See Fig. 517.

TABLE X — CONTROL AND REGULATOR TUBES

Type	Name	Base [1]	Socket Connections [2]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps.	Use	Peak Anode Voltage	Peak Anode Current [3]	Minimum Starting Voltage	Operating Voltage	Operating Current [3]	Grid Resistor	Tube Voltage Drop	Type
0A4G	Gas Triode	6-pin O.	A	Cold	—	—	Cold-Cathode Starter-Anode Relay Tube	With 105–120-volt a.c. anode supply, peak starter-anode a.c. voltage is 70, peak r.f. voltage 55							0A4G
2A4G	Thyratron	8-pin O.	B	Fil.	2.5	2.5	Control Tube	200	100	—	—	—	—	15	2A4G
874	Voltage Regulator	4-pin M.	C	—	—	—	Voltage Regulator [5]	—	—	125	90	10–50	—	—	874
876	Current Regulator	Mogul	—	—	—	—	Current Regulator [5]	—	—	—	40–60	1.7	—	—	876
884	Gas Triode	6-pin O.	C [10]	Htr.	6.3	0.6	Sweep Circuit Oscillator	300	300	—	—	2	25000 [4]	—	884
							Grid-Controlled Rectifier	350	300	—	—	75	25000 [4]	—	
885	Gas Triode	5-pin S.	H [11]	Htr.	2.5	1.4	Same as Type 884	Characteristics same as Type 884							885
886	Current Regulator	Mogul	—	—	—	—	Current Regulator [5]	—	—	—	40–60	2.05	—	—	886
KY21	Gas Triode	4-pin M.	—	Fil.	2.5	10.0	Grid-Controlled Rectifier	—	—	—	3000	500	—	—	KY21
RK62	Gas Triode	4-pin S.	A [11]	Fil.	1.4	0.05	Relay Tube [6]	45	1.5	—	30–45	0.1–1.5	—	15	RK62
RM208	Permatron	4-pin M.	—	Fil.	2.5	5.0	Controlled Rectifier [7]	7500 [8]	1000	—	—	—	—	15	RM208
RM209	Permatron	4-pin M.	—	Fil.	5.0	10.0	Controlled Rectifier [7]	7500 [8]	5000	—	—	—	—	15	RM209
VR90	Voltage Regulator	7-pin O.	D	—	—	—	Voltage Regulator	—	—	125	90	10–30 [9]	—	—	VR90
VR105	Voltage Regulator	6-pin O.	E	—	—	—	Voltage Regulator	—	—	137	105	5–30 [9]	—	—	VR105
VR150	Voltage Regulator	6-pin O.	E	—	—	—	Voltage Regulator	—	—	180	150	5–30 [9]	—	—	VR150

[1] M.—Medium; S.—Small; O.—Octal.
[2] Refer to Fig. 518.
[3] In ma.
[4] Not less than 1000 ohms per grid volt; 500,000 ohms max.
[5] For use in series with power transformer primary.
[6] For use as self-quenching super-regenerative detector with high-resistance relay (5000–10000 ohms) in anode circuit.
[7] For use as grid-controlled rectifier or with external magnetic control. RM-208 has characteristics of 866, RM-209 of 872.
[8] When under control peak inverse rating is reduced to 2500.
[9] Sufficient resistance must be used in series with tube to limit current to 30 ma.
[10] Refer to Fig. 515.
[11] Refer to Fig. 514.

World Radio History

TABLE XI—CATHODE-RAY TUBES AND KINESCOPES

Type	Name	Socket Connections[1]	Heater Volts	Heater Amps.	Use	Size	Anode No. 2 Voltage	Anode No. 1 Voltage	Cut-Off Grid Voltage[2]	Grid No. 2 Voltage	Signal-Swing Voltage	Max. Input Voltage[3]	Screen Input Power[4]	Deflection Sensitivity[5] D_1 D_2	Deflection Sensitivity[5] D_3 D_4	Screen Persistence	Pattern Color[6]	Type
902	Electrostatic Cathode-Ray	A	6.3	0.6	Oscillograph	2″	600	150	−80	—	—	350	5	0.19	0.22	Med.	Green	902
							400	100		—	—			0.28	0.33			
903	Electromagnetic Cathode-Ray	B	2.5	2.1	Oscillograph	9″	7000	1360	−120	250	—	—	10	—	—	Med.	Green	903
							4600	900		250	—	—		—	—			
							3000	580		250	—	—		—	—			
							1000	195		100	—	—		—	—			
904	Electrostatic-Magnetic Cathode-Ray	C	2.5	2.1	Oscillograph	5″	4600	970	−140	250	—	4000	10	0.09	—	Med.	Green	904
							3000	630		100	—			0.13	—			
							1000	210		100	—			0.40	—			
905	Electrostatic Cathode-Ray	D	2.5	2.1	Oscillograph	5″	2000	450	−60	—	—	1000	10	0.19	0.23	Med.	Green	905
							1000	225		—	—			0.38	0.46			
906	Electrostatic Cathode-Ray	E	2.5	2.1	Oscillograph	3″	1500	475	−70	—	—	600	10	0.22	0.23	Med.	Green	906
							1200	345		—	—			0.27	0.29			
							1000	285		—	—			0.33	0.35			
							800	230		—	—			0.41	0.44			
							600	170		—	—			0.55	0.58			
							400	128		—	—			0.81	0.87			
907	Electrostatic Cathode-Ray	D	2.5	2.1	Oscillograph	5″	Characteristics same as Type 905							—	—	Short	Blue	907
908	Electrostatic Cathode-Ray	E	2.5	2.1	Oscillograph	3″	Characteristics same as Type 906							—	—	Short	Blue	908
909	Electrostatic Cathode-Ray	D	2.5	2.1	Oscillograph	5″	Characteristics same as Type 905							—	—	Long	Blue	909
910	Electrostatic Cathode-Ray	E	2.5	2.1	Oscillograph	3″	Characteristics same as Type 906							—	—	Long	Blue	910
911	Electrostatic Cathode-Ray	E	2.5	2.1	Oscillograph	3″	Characteristics same as Type 906[7]							—	—	Med.	Green	911
912	Electrostatic Cathode-Ray	F	2.5	2.1	Oscillograph	5″	15000	3000	−125	250	—	7000	10	0.028	0.034	Med.	Green	912
							10000	2000		250	—			0.041	0.051			
							5000	1000		250	—			0.083	0.102			
913	Electrostatic Cathode-Ray	A	6.3	0.6	Oscillograph	1″	500	100	−90	—	—	250	5	0.07	0.10	Med.	Green	913
							250	50		—	—			0.15	0.21			
914	Electrostatic Cathode-Ray	G	2.5	2.1	Oscillograph	9″	7000	1500	−125	250	—	3000	10	0.073	0.093	Med.	Green	914
							5000	915		250	—			0.102	0.130			
							2500	460		250	—			0.204	0.260			
1800	Electromagnetic Kinescope	B	2.5	2.1	Television	9″	6000	1250	−75	250	25	—	10	—	—	Med.	Yellow	1800
							4500	925		250	25	—		—	—			
							3000	625		200	20	—		—	—			
1801	Electromagnetic Kinescope	H	2.5	2.1	Television	5″	3000	450	−35	—	20	—	10	—	—	Med.	Yellow	1801
							2500	375		—	15	—		—	—			
2002	Electrostatic Cathode-Ray	A	6.3	0.6	Oscillograph	2″	600	120	—	—	—	—	—	0.16	0.17	Med.	Green	2002
							500	100	—	—	—	—	—	0.18	0.20			
							400	80	—	—	—	—	—	0.24	0.26			

[1] Refer to Fig. 519.
[2] For current cut-off. Control grid should never be allowed to go positive.
[3] Between Anode No. 2 and any deflecting plate.
[4] In mw./sq. cm., max.
[5] In mm. volt d.c.
[6] Long-persistence screen is distinguished from short-persistence screen by bluish-white tinge.
[7] The 911 is identical to 906 except for the gun material, which is designed to be especially free from magnetization effects.

World Radio History

TABLE XII — RECTIFIERS — RECEIVING AND TRANSMITTING

Type No.	Name	Base [2]	Socket Connec-tions [1]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps.	Max. A.C. Voltage Per Plate	Max. D.C. Output Current Ma.	Max. Inverse Peak Voltage	Max. Peak Plate Current Ma.	Type [7]
OZ4	Full-Wave Rectifier	6-pin O.	W [4]	Cold	—	—	350	30–75	1250	200	G
OZ4G	Full-Wave Rectifier	6-pin O.	W [4]	Cold	Characteristics same as Type OZ4						G
5T4	Full-Wave Rectifier	5-pin O.	U [4]	Fil.	5.0	3.0	450	250	1250	800	V
5U4G	Full-Wave Rectifier	8-pin O.	U [4]	Fil.	5.0	3.0	Same as Type 5Z3				V
5V4G	Full-Wave Rectifier	8-pin O.	A [4]	Htr.	5.0	2.0	Same as Type 83V				V
5W4	Full-Wave Rectifier	5-pin O.	A [4]	Fil.	5.0	1.5	350	110	1000	—	V
5X4G	Full-Wave Rectifier	8-pin O.	P [4]	Fil.	5.0	3.0	Same as 5Z3				V
5Y3G	Full-Wave Rectifier	5-pin O.	A [4]	Fil.	5.0	2.0	Same as Type 80				V
5Y4G	Full-Wave Rectifier	8-pin O.	P [4]	Fil.	5.0	2.0	Same as Type 80				V
5Z3	Full-Wave Rectifier	4-pin M.	B	Fil.	5.0	3.0	500	250	1400	—	V
5Z4	Full-Wave Rectifier [3]	5-pin O.	A [4]	Htr.	5.0	2.0	400	125	1100	—	V
6W5G	Full-Wave Rectifier	6-pin O.	Q [4]	Htr.	6.3	0.9	350	100	1250	350	V
6X5 6X5G	Full-Wave Rectifier	6-pin O.	Q [4]	Htr.	6.3	0.5	350	75	—	—	V
6ZY5G	Full-Wave Rectifier	6-pin O.	Q [4]	Htr.	6.3	0.3	350	35	1000	150	V
12Z3	Half-Wave Rectifier	4-pin S.	R	Htr.	12.6	0.3	250	60	700	—	V
25Z5	Rectifier-Doubler	6-pin S.	E	Htr.	25.0	0.3	125	100	—	500	V
25Z6 25Z6G	Rectifier-Doubler	7-pin O.	R [4]	Htr.	25.0	0.3	125	100	—	500	V
1 [5]	Half-Wave Rectifier	4-pin S.	R	Htr.	6.3	0.3	350	50	1000	400	M
1-V [5]	Half-Wave Rectifier	4-pin S.	R	Htr.	6.3	0.3	350	50	—	—	V
80	Full-Wave Rectifier	4-pin M.	B	Fil.	5.0	2.0	350 400 550 [6]	125 110 135	—	—	V
81	Half-Wave Rectifier	4-pin M.	C	Fil.	7.5	1.25	700	85	—	—	V
82	Full-Wave Rectifier	4-pin M.	B	Fil.	2.5	3.0	500	125	1400	400	M
83	Full-Wave Rectifier	4-pin M.	B	Fil.	5.0	3.0	500	250	1400	800	M
83-V	Full-Wave Rectifier	4-pin M.	B	Htr.	5.0	2.0	400	200	1100	—	V
84/6Z4	Full-Wave Rectifier	5-pin S.	S	Htr.	6.3	0.5	350	60	1000	—	V
RK60	Full-Wave Rectifier	4-pin M.	B [8]	Fil.	5	3	750	250	2120	—	V
RK19	Full-Wave Rectifier	4-pin M.	B [8]	Htr.	7.5	2.5	1250	200 [10]	3500	600	V
RK21	Half-Wave Rectifier	4-pin M.	A [8]	Htr.	2.5	4.0	1250	200 [10]	3500	600	V
RK22	Full-Wave Rectifier	4-pin M.	B [8]	Htr.	2.5	8.0	1250	200 [10]	3500	600	V
836	Half-Wave Rectifier	4-pin M.	A [8]	Htr.	2.5	5.0	—	—	5000	1000	V
866	Half-Wave Rectifier	4-pin M.	A [8]	Fil.	2.5	5.0	—	250 [10]	7500	1000	M
866-A	Half-Wave Rectifier	4-pin M.	A [8]	Fil.	2.5	5.0	—	250 [10]	10000	1000	M
866B	Half-Wave Rectifier	4-pin M.	A [8]	Fil.	5.0	5.0	—	—	8500	1000	M
866Jr.	Half-Wave Rectifier	4-pin M.	C	Fil.	2.5	2.5	1250	250 [9]			M
871	Half-Wave Rectifier	4-pin M.	A [8]	Fil.	2.5	2.0	1750	250	5000	500	M
878 [11]	Half-Wave Rectifier	4-pin M.	A [8]	Fil.	2.5	5.0	7100	5	20000	—	V
879 [11]	Half-Wave Rectifier	4-pin S.	A [8]	Fil.	2.5	1.75	2650	7.5	7500	100	V
872	Half-Wave Rectifier	4-pin J.	P [8]	Fil.	5.0	10.0	—	—	7500	5000	M
872-A	Half-Wave Rectifier	4-pin J.	P [8]	Fil.	5.0	10.0	—	—	10000	5000	M

[1] Refer to Fig. 514 except as noted otherwise.
[2] M.—medium; S.—small; O.—small octal; J.—jumbo.
[3] Metal tube series.
[4] Refer to Fig. 518.
[5] Types 1 and 1-V interchangeable.
[6] With input choke of at least 20 henrys.
[7] M.—Mercury-vapor type; V.—high-vacuum type.
[8] Refer to Fig. 518.
[9] Per pair with choke input.
[10] Condenser input.
[11] For use with cathode-ray tubes.

World Radio History

TABLE XIII — TETRODE AND PENTODE TRANSMITTING TUBES

Type	Max. Plate Dissipation Watts	Cathode Volts	Cathode Amps.	Max. Plate Voltage	Max. Screen Voltage	Max. Screen Dissipation Watts	Interelectrode Capacitances (μμfd.) Grid to Fil.	Grid to Plate	Plate to Fil.	Base [2]	Socket Connections [1]	Typical Operation	Plate Voltage	Screen Voltage	Suppressor Voltage	Grid Voltage	Plate Current Ma.	Screen Current Ma.	Grid Current Ma.	Screen [6] Resistor Ohms	Approx. Grid Driving Power Watts	Approx. Carrier Output Power Watts	Type
1610	6	2.5	1.75	400	200	2	8.6	1.2	13	5-pin M.	F [5]	Class-C Amp.-Oscillator	400	150	—	−50	22.5	7.0	1.5	—	0.1	5.0	1610
RK56	8	6.3	0.55	300	300	4.5	10	0.2	9.0	5-pin M.	H	Class-C Amp. (Telegraphy)	300	300	—	−40	62	12	1.6	—	0.1	12.5	RK56
												Class-C Amp. (Telephony)	250	200	—	−40	50	10	1.6	5000	0.1	8.5	
												Grid-Modulated Amplifier	300	300	—	−60	27	4.0	2.0	—	0.11	3.0	
												Class-B Amp. (Telephony)	300	300	—	−38	30	4.5	4.0	—	0.2	8.5	
802	10	6.3	0.9	500	250	6	12	0.15	8.5	7-pin M.	G	Class-C Amp. (Telegraphy)	500	250	40	−100	45	12	2.0	—	0.25	16	802
												Grid-Modulated Amplifier	500	200	0	−130	25	8.0	1.0	—	0.8	4.0	
												Suppressor-Mod. Amp.	500	200	−45	−90	22	28	4.5	10700	0.5	3.5	
												Class-B Amp. (Telephony)	500	200	0	−28	25	7.0	—	—	0.18	3.5	
												Class-C Amp. (Telephony)	400	200	40	−40	35	17	1.5	12000	0.1	8.0	
RK23 RK25 RK25B RK45	10	2.5 6.3 12.6	2.0 0.9 0.45	500	250	8	10	0.2	10	7-pin M.	G	Class-C Amp. (Telegraphy)	500	200	45	−90	55	38	4.0	—	0.5	22	RK23 RK25 RK25B RK45
												Class-C Amp. (Telephony)	400	150	0	−90	43	30	6.0	8300	0.8	13.5	
												Suppressor-Modulated Amp.	500	200	−45	−90	31	39	4.0	—	0.5	6.0	
												Grid-Modulated Amplifier	500	200	45	−125	34	20	4.0	—	1.3	6.5	
												Class-B Amp. (Telephony)	500	250	0	−38	30	12	—	—	0.24	5.0	
837 RK44	12	12.6	0.7	500	300	8	16	0.2	10	7-pin M.	G	Class-C Amp. (Telegraphy)	500	200	40	−75	60	15	4.0	20000	0.4	22	837 RK44
												Class-C Amp. (Telephony)	400	140	40	−40	45	20	5.0	13000	0.3	11	
												Suppressor-Modulated Amp.	500	—	−65	−20	30	23	3.5	14000	0.1	5.0	
												Grid-Modulated Amplifier	500	200	40	−43	30	6.0	0	—	0.15	5.5	
												Class-B Amp. (Telephony)	500	200	40	−25	30	12	0	—	0.1	5.5	
844	15	2.5	2.5	500	180	3	9.5	0.15	7.5	5-pin M.	H	Class-C Amp. (Telegraphy)	500	175	—	−125	25	—	5.0	—	—	9.0	844
												Class-C Amp. (Telephony)	500	150	—	−100	20	—	—	—	—	4.0	
												Class-B Amp. (Telephony)	500	180	—	−40	20	—	—	—	—	3.0	
307A	15	5.5	1.0	500	250	6	15	0.55	12	5-pin M.	J	Class-C Amp. (Telegraphy)	500	250	0	−35	60	13	1.4	20000	—	20	307A
												Suppressor-Modulated Amp.	500	200	−50	−35	40	20	1.5	14000	—	6.0	
832	15	6.3	0.8	400	250	5	7.5	0.05	3.8	Special	T	Class-C Amp. (Telegraphy)	400	250	—	−60	90	18	0.3	8300	0.18	22	832
												Class-C Amp. (Telephony)	325	210	—	−50	68	15	1.2	7500	0.06	12	
												Grid-Modulated Amplifier	400	250	—	−60	55	6.0	0	—	0.1	7.6	
HY60	15	6.3	0.5	425	200	2.5	11	0.19	10.2	5-pin M.	H	Class-C Amp. (Telegraphy)	425	200	—	−62.5	55	7.0	2.5	32000	0.25	16	HY60
												Class-C Amp. (Telephony)	325	200	—	−45	45	8.5	2.0	15000	0.2	10	
865	15	7.5	2.0	750	175	3	8.5	0.1	8.0	4-pin M.	I	Class-C Amp. (Telegraphy)	750	125	—	−80	40	—	5.5	—	1.0	16	865
												Class-C Amp. (Telephony)	500	125	—	−120	40	—	9.0	—	2.5	10	
												Class-B Amp. (Telephony)	750	125	—	−30	22	—	3.0	—	1.5	4.5	
254A	20	5.0	3.25	750	175	5	4.6	0.1	9.4	4-pin M.	I	Class-C Amplifier	750	175	—	−90	60	—	—	—	—	25	254A
RK49	21	6.3	0.9	400	300	3.5	11.5	1.4	10.6	6-pin M.	M [5]	Class-C Amp. (Telegraphy)	400	250	—	−50	95	8.0	3.0	—	0.2	25	RK49
												Class-C Amp. (Telephony)	300	200	—	−45	60	15	5.0	6700	0.34	12	
												Grid-Modulated Amplifier	400	250	—	−40	55	4.0	0.5	—	0.15	7.0	
												Class-B Amp. (Telephony)	400	250	—	−30	52	5.0	0.1	—	0.5	7.0	

World Radio History

TABLE XIII — TETRODE AND PENTODE TRANSMITTING TUBES — *Continued*

Type	Max. Plate Dissipation Watts	Cathode Volts	Cathode Amps.	Max. Plate Voltage	Max. Screen Voltage	Max. Screen Dissipation Watts	Interelectrode Capacitances (μμfd.) Grid to Fil.	Grid to Plate	Plate to Fil.	Base [2]	Socket Connections [1]	Typical Operation	Plate Voltage	Screen Voltage	Suppressor Voltage	Grid Voltage	Plate Current Ma.	Screen Current Ma.	Grid Current Ma.	Screen [5] Resistor Ohms	Approx. Grid Driving Power Watts	Approx. Carrier Output Power Watts	Type
RK41	25	2.5	2.4	600	300	3.5	13	0.2	10	5-pin M.	H	Class-C Amp. (Telegraphy)	600	300	—	−90	93	10	3.0	—	0.38	36	RK41
RK39		6.3	0.9									Class-C Amp. (Telephony)	475	250	—	−50	85	9.0	2.5	25000	0.2	26	RK39
												Grid-Modulated Amplifier	600	300	—	−70	60	3.0	0.2	—	0.54	12	
												Class-B Amp. (Telephony)	600	300	—	−25	63	4.0	9.0	—	0.4	12.5	
807 HY61	25	6.3	0.9	600	300	3.5	11	0.2	7.0	5-pin M.	H	Class-C Amp. (Telegraphy)	600	250	—	−50	100	9.0	3.0	39000	0.22	37.5	807 HY61
												Class-C Amp. (Telephony)	475	225	—	−50	83	9.0	2.0	25000	0.13	24	
												Class-B Amp. (Telephony)	600	250	—	−25	62.6	3.0	0	—	0.2	12.5	
254B	25	7.5	3.25	750	150	5.0	11.2	0.085	5.4	4-pin M.	I	Class-C Amplifier	750	150	—	−135	75	—	—	—	—	30	254B
RK20 RK20A RK46	40	7.5 7.5 12.6	3.0 3.25 2.5	1250	300	15	14	0.01	12	5-pin M.	J	Class-C Amp. (Telegraphy)	1250	300	45	−100	92	36	11.5	—	1.6	84	RK20 RK20A RK46
												Class-C Amp. (Telephony)	1000	300	0	−100	75	30	10	23000	1.3	52	
												Suppressor-Modulated Amp.	1250	300	−45	−100	48	44	11.5	—	1.5	21	
												Grid-Modulated Amp.	1250	300	45	−142	40	7.0	1.8	—	1.5	20	
												Class-B Amp. (Telephony)	1250	300	0	−30	43	15	—	—	0.5	16	
804	40	7.5	3.0	1250	300	15	16	0.01	14.5	5-pin M.	J	Class-A Amp. (Telegraphy)	1250	300	45	−100	92	27	7.0	14300	0.95	80	804
												Class-A Amp. (Telephony)	1000	220	50	−90	75	21	6.0	37000	0.65	50	
												Suppressor-Modulated Amp.	1250	—	−50	−100	48	35.5	7.0	27000	0.85	21	
												Grid-Modulated Amp.	1250	300	45	−115	45	11	2.0	—	0.85	21	
												Class-B Amp. (Telephony)	1250	300	45	−20	45	11	1.0	—	0.25	16	
814	50	10	3.25	1250	300	10	13.5	0.1	13.5	5-pin M.	J [4]	Class-C Amp. (Telegraphy)	1250	300	—	−80	144	22.5	10	—	1.5	130	814
												Class-C Amp. (Telephony)	1000	300	—	−150	120	17.5	10	40000	2.0	87	
												Grid-Modulated Amplifier	1250	200	—	−100	60	1.4	2.8	—	2.3	29	
												Class-B Amp. (Telephony)	1250	200	—	−28	60	1.0	1.8	—	0.65	25	
RK47	50	10	3.25	1250	300	10	13	0.12	10	5-pin M.	J [4]	Class-C Amp. (Telegraphy)	1250	300	—	−70	138	14	7.0	—	1.0	120	RK47
												Class-C Amp. (Telephony)	900	250	—	−120	90	23	7.5	28000	1.2	55	
												Grid-Modulated Amplifier	1250	300	—	−135	60	9.0	1.6	—	1.43	28.5	
												Class-B Amp. (Telephony)	1250	300	—	−30	60	2.0	0.9	—	4.0	25	
305A	60	10	3.1	1000	200	6	10.5	0.14	5.4	4-pin M.	A [3]	Class-C Amp. (Telegraphy)	1000	200	—	−200	125	—	—	—	—	85	305A
												Class-C Amp. (Telephony)	800	200	—	−270	125	—	—	—	—	70	
												Class-B Amp. (Telephony)	1000	200	—	−135	90	—	—	—	—	30	
282A	70	10	3.0	1000	250	5	12.2	0.2	6.8	4-pin M.	I	Class-C Amplifier	1000	250	—	−150	100	—	—	—	—	60	282A
850	100	10	3.25	1250	175	10	17	0.25	25	4-pin J.	O	Class-C Amp. (Telegraphy)	1250	175	—	−150	160	—	35	—	10	130	850
												Class-C Amp. (Telephony)	1000	140	—	−100	125	—	40	—	10	65	
												Grid-Modulated Amplifier	1250	175	—	−13	110	—	—	—	—	40	
RK28 RK28A	100	10	5.0	2000	400	35	15	0.02	15	5-pin J.	L	Class-B Amp. (Telephony)	2000	400	45	−100	150	55	13	—	2.0	210	RK28 RK28A
												Class-C Amp. (Telegraphy)	1500	400	45	−100	135	52	13	21000	2.0	155	
												Class-C Amp. (Telephony)	2000	400	−45	−100	85	65	13	—	1.8	60	
												Suppressor-Modulated Amp.	2000	400	45	−140	80	20	4.0	—	3.5	75	
												Grid-Modulated Amplifier	2000	400	0	−38	75	30	—	—	0.9	50	

World Radio History

TABLE XIII—TETRODE AND PENTODE TRANSMITTING TUBES—*Continued*

Type	Max. Plate Dissipation Watts	Cathode Volts	Cathode Amps.	Max. Plate Voltage	Max. Screen Voltage	Max. Screen Dissipation Watts	Interelectrode Capacitances (μμfd.) Grid to Fil.	Grid to Plate	Plate to Fil.	Base [2]	Socket Connections [1]	Typical Operation	Plate Voltage	Screen Voltage	Suppressor Voltage	Grid Voltage	Plate Current Ma.	Screen Current Ma.	Grid Current Ma.	Screen Resistor Ohms [6]	Approx. Grid Driving Power Watts	Approx. Carrier Output Power Watts	Type
813	100	10	5.0	2000	400	22	16.3	0.2	14	7-pin J.	U	Class-C Amp. (Telegraphy)	2000	400	—	−90	180	15	3.0	107000	0.5	260	813
												Class-C Amp. (Telephony)	1600	400	—	−130	150	20	6.0	21600	1.2	175	
												Grid-Modulated Amplifier	2000	400	—	−120	75	3.0	—	—	—	50	
												Class-B Amp. (Telephony)	2000	400	—	−75	75	3.0	—	—	—	50	
RK48	100	10	5.0	2000	400	22	17	0.13	13	5-pin J.	L [4]	Class-C Amp. (Telegraphy)	2000	400	—	−100	180	40	6.5	—	1.0	250	RK48
												Class-C Amp. (Telephony)	1500	400	—	−100	148	50	6.5	22000	1.0	165	
												Grid-Modulated Amplifier	1500	400	—	−145	77	10	1.5	—	1.6	40	
												Class-B Amp. (Telephony)	2000	400	—	−35	76	6.0	0.35	—	0.22	60	
803	125	10	5.0	2000	600	30	17.5	0.15	29	5-pin J.	L	Class-C Amp. (Telegraphy)	2000	500	40	−90	160	45	12	—	2.0	210	803
												Class-C Amp. (Telephony)	1600	500	100	−80	150	20	4.0	20000	4.0	155	
												Suppressor-Modulated Amp.	2000	—	−110	−100	80	48	15	35000	2.5	53	
												Grid-Modulated Amplifier	2000	600	40	−80	80	20	4.0	—	2.0	53	
												Class-B Amp. (Telephony)	2000	600	40	−40	80	20	3.0	—	1.5	53	
861	400	11	10	3500	750	35	14.5	0.1	10.5	Special	S	Class-C Amp. (Telegraphy)	3500	500	—	−250	300	40	40	—	30	700	861
												Class-C Amp. (Telephony)	3000	375	—	−200	200	—	55	70000	35	400	
												Class-B Amp. (Telephony)	3500	500	—	−60	150	—	4.0	—	15	175	

[1] Refer to Fig. 520.
[2] M.—medium; J.—jumbo.
[3] Plate, grid and screen connections brought out through bulb.
[4] Terminal 4 connects to beam-forming plates—connect to ground.
[5] Refer to Fig. 514.
[6] In plate-and-screen modulated Class-C amplifiers, connect screen dropping resistor direct to plate and by-pass for r.f. only.

TABLE XIV—TRIODE TRANSMITTING TUBES

Type	Max. Plate Dissipation Watts	Cathode Volts	Cathode Amps.	Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances (μμfd.) Grid to Fil.	Grid to Plate	Plate to Fil.	Base [2]	Socket Connections [1]	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts [5]	Peak Power Output Watts	Approx. Carrier Output Power Watts	Type
RK24	1.5	2.0	0.12	180	20	6.0	8.0	3.5	5.5	3.0	4-pin S.	C	Class-C Amp.-Oscillator	180	−45	16.5	6.0	0.5	—	2.0	RK24
RK33	2.5	6.3	0.6	250	20	6.0	10.5	3–2 [7]	3–2 [7]	2.5	7-pin S.	V	Class-C Amp.-Oscillator	250	−60	20	6.0	0.54	—	3.5	RK33
HY615 *	5.0	6.3	0.15	250	20	4.0	20	1.4	1.8	0.6	5-pin O.	See Note 6	Class-C Amp.-Oscillator	250	−9.0	20	4.0	—	—	2.5	HY615
RK34	10 [8]	6.3	0.8	300	80	20	13	4.2	2.7	0.8	7-pin M.	T [9]	Class-C Amp.-Oscillator	300	−36	80	20	1.8	—	16	RK34
205D	14	4.5	1.6	400	50	10	7.3	5.2	4.8	3.3	4-pin M.	C	Class-C Amp. (Telegraphy)	400	−112	45	10	1.5	—	10	205D
													Class-C Amp. (Telephony)	350	−144	35	10	1.7	28.4	7.1	
843	15	2.5	2.5	450	40	7.5	7.7	4.0	4.5	4.0	5-pin M.	D	Class-C Amp. (Telegraphy)	450	−140	30	5.0	1.0	—	7.5	843
													Class-C Amp. (Telephony)	350	−150	30	7.0	1.6	20	5.0	
RK59	15	6.3	1.0	500	90 [8]	—	25	5.0	9.0	1.0	4-pin M.	W	Class-C Amp.-Oscillator	500	−60	90 [8]	14	1.3	—	32	RK59

World Radio History

TABLE XIV — TRIODE TRANSMITTING TUBES — *Continued*

Type	Max. Plate Dissipation Watts	Cathode Volts	Cathode Amps.	Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances (μμfd.) Grid to Fil.	Grid to Plate	Plate to Fil.	Base [2]	Socket Connections [1]	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts [5]	Peak Power Output Watts	Approx. Carrier Output Power Watts	Type
1602	15	7.5	1.25	450	60	15	8.0	4.0	7.0	3.0	4-pin M.	C	Class-C Amp. (Telegraphy)	450	−115	55	15	3.3	—	13	1602
													Class-C Amp. (Telephony)	350	−135	45	15	3.5	32	8.0	
841	15	7.5	1.25	450	60	20	30	4.0	7.0	3.0	4-pin M.	C	Class-C Amp. (Telegraphy)	450	− 34	50	15	1.8	—	15	841
													Class-C Amp. (Telephony)	350	− 47	50	15	2.0	44	11	
10 RK10	15	7.5	1.25	450	65	15	8.0	3.0	8.0	4.0	4-pin M.	C	Class-C Amp. (Telegraphy)	450	−100	65	15	3.2	—	19	10 RK10
													Class-C Amp. (Telephony)	350	−100	50	12	2.2	48	12	
													Grid-Modulated Amp.	450	−170	40	1.0	2.4	24	6.0	
RK100	15	6.3	0.9	150	250	100	40	23	19	3.0	6-pin M.	CC [9]	Class-C Oscillator [10]	110	—	80	8.0	—	—	3.5	RK100
													Class-C Amplifier [10]	110	—	185	40	2.1	—	12	
1608	20	2.5	2.5	425	95	25	20	8.5	9.0	3.0	4-pin M.	C	Class-C Amp. (Telegraphy)	425	− 90	95	20	3.0	—	27	1608
													Class-C Amp. (Telephony)	350	− 80	85	20	3.0	72	18	
310	20	7.5	1.25	600	70	15	8.0	4.0	7.0	2.2	4-pin M.	C	Class-C Amp. (Telegraphy)	600	−150	65	15	4.0	—	25	310
													Class-C Amp. (Telephony)	500	−190	55	15	4.5	72	18	
801	20	7.5	1.25	600	70	15	8.0	4.5	6.0	1.5	4-pin M.	C	Class-C Amp. (Telegraphy)	600	−150	65	15	4.0	—	25	801
													Class-C Amp. (Telephony)	500	−190	55	15	4.5	72	18	
T20	20	7.5	1.25	750	75	25	20	—	4.0	—	4-pin M.	F	Class-C Amplifier	750	−100	75	15	2.5	—	42	T20
TZ20	20	7.5	1.25	750	75	25	62	—	4.0	—	4-pin M.	F	Class-C Amplifier	750	—	75	15	2.5	—	42	TZ20
809	25	6.3	2.5	750	100	35	50	5.7	6.7	0.9	4-pin M.	F	Class-C Amp. (Telegraphy)	750	− 60	100	20	2.5	—	55	809
													Class-C Amp. (Telephony)	600	−160	83	32	7.2	152	38	
RK11	25	6.3	3.0	750	105	35	20	7.0	7.0	0.9	4-pin M.	F	Class-C Amp. (Telegraphy)	750	−120	105	21	3.2	—	55	RK11
													Class-C Amp. (Telephony)	600	−120	85	24	3.7	152	38	
													Grid-Modulated Amp.	750	−130	38	1.2	2.7	48	12	
RK12	25	6.3	3.0	750	105	40	—	7.0	7.0	0.9	4-pin M.	F	Class-C Amp. (Telegraphy)	750	−100	105	35	5.2	—	55	RK12
													Class-C Amp. (Telephony)	600	−100	85	27	3.8	152	38	
HK24	25	6.3	3.0	1500	75	—	25	—	—	—	4-pin M.	F	Class-C Amplifier	1500	—	75	—	3.8	—	87.5	HK24
316A *	30	2.0	3.65	450	80	12	6.5	1.2	1.6	0.8	None [3]	—	Class-C Amp. (Telegraphy)	450	—	80	12	—	—	7.5	316A
													Class-C Amp. (Telephony)	400	—	80	12	—	—	6.5	
UH35 *	35	5.0	4.0	1500	150	—	30	1.9	1.6	—	4-pin M.	E	Class-C Amplifier	1500	—	150	—	—	—	—	UH35
TT * [11]	35	6.0	4.0	1500	85	—	37	1.9	2.0	—	4-pin M.	X	Class-C Amplifier	1500	—	85	—	—	—	—	TT
800	35	7.5	3.25	1250	80	25	15	2.75	2.5	2.75	4-pin M.	E	Class-C Amp. (Telegraphy)	1250	−175	70	15	4.0	—	65	800
													Class-C Amp. (Telephony)	1000	−200	70	15	4.0	200	50	
													Class-B Amp. (Telephony)	1000	− 55	42	2.0	3.3	56	14	
RK30	35	7.5	3.25	1250	80	25	15	2.75	2.5	2.75	4-pin M.	E	Class-C Amp. (Telegraphy)	1250	−180	90	18	5.2	—	85	RK30
													Class-C Amp. (Telephony)	1000	−200	80	15	4.5	240	60	
													Grid-Modulated Amp.	1250	−140	40	1.5	1.5	72	18	
													Class-B Amp. (Telephony)	1250	− 70	40	1.3	2.5	72	18	
825	40	7.5	2.0	850	110	25	8.0	3.0	7.0	2.7	4-pin M.	C	Class-C Amplifier	850	—	110	25	—	—	—	825
756	40	7.5	2.0	850	110	20	25	3.5	8.0	2.7	4-pin M.	C	Class-C Amplifier	850	—	110	20	—	—	—	756

World Radio History

TABLE XIV — TRIODE TRANSMITTING TUBES — *Continued*

Type	Max. Plate Dissipation Watts	Cathode Volts	Cathode Amps.	Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances (μμfd.) Grid to Fil.	Grid to Plate	Plate to Fil.	Base [2]	Socket Connections [1]	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts [5]	Peak Power Output Watts	Approx. Carrier Output Power Watts	Type
T40	40	7.5	2.5	1000	115	40	25	—	4.5	—	4-pin M.	F	Class-C Amp. (Telegraphy)	1000	−80	115	15	5.0	—	86	T40
													Class-C Amp. (Telephony)	1000	−120	115	22	7.5	346	86	
TZ40	40	7.5	2.5	1000	115	35	62	—	—	—	4-pin M.	F	Class-C Amp. (Telegraphy)	1000	−40	115	15	5.0	—	86	TZ40
													Class-C Amp. (Telephony)	1000	−60	115	22	7.5	346	86	
HY40	40	7.5	2.25	1000	115	25	25	5.8	6.3	1.8	4-pin M.	F	Class-C Amp. (Telegraphy)	1000	−90	115	20	5.0	—	86	HY40
													Class-C Amp. (Telephony)	850	−90	90	15	3.5	208	52	
HY57	40	6.3	2.25	800	110	25	50	4.9	5.1	1.7	4-pin M.	F	Class-C Amp. (Telegraphy)	800	−45	100	15	2.0	—	60	HY57
													Class-C Amp. (Telephony)	700	−45	90	17	5.0	200	50	
RK18	40	7.5	3.0	1250	100	40	18	6.0	4.8	1.8	4-pin M.	F	Class-C Amp. (Telegraphy)	1250	−160	100	12	2.8	—	95	RK18
													Class-C Amp. (Telephony)	1000	−160	80	13	3.1	256	64	
													Grid-Modulated Amp.	1250	−140	38	0.5	3.8	72	18	
RK31	40	7.5	3.0	1250	100	35	—	7.0	10	2.0	4-pin M.	F	Class-C Amp. (Telegraphy)	1250	−80	100	30	3.9	—	90	RK31
													Class-C Amp. (Telephony)	1000	−80	100	28	3.5	280	70	
830	40	10	2.15	750	110	18	8.0	4.9	9.9	2.2	4-pin M.	C	Class-C Amplifier	750	−180	110	18	7.0	—	55	830
													Grid-Modulated Amp.	1000	−200	50	2.0	3.0	60	15	
HK54	50	5.0	5.0	2000	150	30	27	1.9	1.9	0.2	4-pin M.	E	Class-C Amp. (Telegraphy)	2000	−269	130	20	9.0	—	210	HK54
													Class-C Amp. (Telephony)	1500	−150	135	20	7.0	624	156	
HK154	50	5.0	6.5	1500	175	30	6.7	4.3	5.9	1.1	4-pin M.	E	Class-C Amp. (Telegraphy)	1500	−590	167	20	15	—	200	HK154
													Class-C Amp. (Telephony)	1250	−460	170	20	12	648	162	
													Grid-Modulated Amp.	1500	−450	52	—	5.0	112	28	
													Class-B Amp. (Telephony)	1500	−265	52	—	5.0	112	28	
UH51 *	50	5.0	6.5	2000	175	—	10.6	2.2	2.3	—	4-pin M.	E	Class-C Amplifier	2000	—	175	—	—	—	—	UH51
834 *	50	7.5	3.25	1250	100	20	10.5	2.2	2.6	0.6	4-pin M.	E	Class-C Amp. (Telegraphy)	1250	−225	90	15	4.5	—	75	834
													Class-C Amp. (Telephony)	1000	−310	90	17.5	6.5	232	58	
													Class-B Amp. (Telephony)	1250	−115	50	0	3.0	80	20	
RK32*	50	7.5	3.25	1250	100	25	11	2.5	3.4	0.7	4-pin M.	E	Class-C Amp. (Telegraphy)	1250	−225	100	14	4.8	—	90	RK32
													Class-C Amp. (Telephony)	1000	−310	100	21	8.7	280	70	
													Class-B Amp. (Telephony)	1250	−120	50	—	2.5	84	21	
304A	50	7.5	3.25	1250	100	20	11	2.0	2.5	0.7	4-pin M.	E	Class-C Amp. (Telegraphy)	1250	−120	100	—	—	—	85	304A
													Class-C Amp. (Telephony)	1000	−180	100	—	—	—	65	
													Class-B Amp. (Telephony)	1250	−110	50	—	—	84	21	
304B	50	7.5	3.25	1250	100	25	11	2.0	2.5	0.7	4-pin M.	E	Class-C Amp. (Telegraphy)	1250	−200	100	—	—	—	85	304B
													Class-C Amp. (Telephony)	1000	−180	100	—	—	—	65	
													Class-B Amp. (Telephony)	1250	−110	60	—	—	100	25	
UH50 *	50	7.5	3.25	1250	125	—	10.6	2.2	2.6	—	4-pin M.	E	Class-C Amplifier	—	—	—	—	—	—	—	UH50
RK35	50	7.5	4.0	1500	125	20	9.0	3.5	2.7	0.4	4-pin M.	E	Class-C Amp. (Telegraphy)	1500	−250	115	15	5.0	—	120	RK35
													Class-C Amp. (Telephony)	1250	−250	100	14	4.6	372	93	
													Grid-Modulated Amp.	1500	−250	50	0	1.7	100	25	
													Class-B Amp. (Telephony)	1500	−180	37	0	2.0	100	25	

World Radio History

TABLE XIV — TRIODE TRANSMITTING TUBES — *Continued*

Type	Max. Plate Dissipation Watts	Cathode Volts	Cathode Amps.	Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances (μμfd.) Grid to Fil.	Grid to Plate	Plate to Fil.	Base [2]	Socket Connections [1]	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts [5]	Peak Power Output Watts	Approx. Carrier Output Power Watts	Type
RK37	50	7.5	4.0	1500	125	35	—	3.5	3.2	0.2	4-pin M.	E	Class-C Amp. (Telegraphy)	1500	−130	115	30	7.0	—	122	RK37
													Class-C Amp. (Telephony)	1250	−150	100	23	5.6	360	90	
													Grid-Modulated Amp.	1500	−200	44	5.0	6.0	104	26	
													Class-B Amp. (Telephony)	1500	− 50	50	—	2.4	104	26	
808	50	7.5	4.0	1500	150	35	47	5.3	2.8	0.15	4-pin M.	E	Class-C Amp. (Telegraphy)	1500	−200	125	30	9.5	—	140	808
													Class-C Amp. (Telephony)	1250	−225	100	32	10.5	420	105	
													Class-B Amp. (Telephony)	1500	− 35	45	1.0	2.0	88	22	
841SW	50	10	2.0	1000	150	30	14.6	—	9.0	—	4-pin M.	F	Class-C Amplifier	—	—	—	—	—	—	—	841SW
841A	50	10	2.0	1250	150	30	14.6	3.5	9.0	2.5	4-pin M.	F	Class-C Amplifier	—	—	—	—	—	—	85	841A
T55	55	7.5	2.75	1500	150	40	20	4.0	3.75	1.5	4-pin M.	F	Class-C Amp. (Telegraphy)	1500	−136	150	17	7.5	—	168	T55
													Class-C Amp. (Telephony)	1500	−200	150	25	15	652	168	
RK51	60	7.5	3.75	1500	150	40	20	6.0	6.0	2.5	4-pin M.	F	Class-C Amp. (Telegraphy)	1500	−250	150	31	10	—	170	RK51
													Class-C Amp. (Telephony)	1250	−200	105	17	4.5	384	96	
													Grid-Modulated Amp.	1500	−130	60	0.4	2.3	128	32	
													Class-B Amp. (Telephony)	1500	− 75	60	—	3.5	120	30	
RK52	60	7.5	3.75	1500	130	50	—	6.6	12	2.2	4-pin M.	F	Class-C Amp. (Telegraphy)	1500	−120	130	40	7.0	—	135	RK52
													Class-C Amp. (Telephony)	1250	−120	115	47	8.5	420	105	
HY51A HY51B	65	7.5 10	3.5 2.25	1000	155	25	25	6.0	7.5	2.0	4-pin M.	F	Class-C Amplifier	—	—	—	—	—	—	—	HY51A HY51B
35T	70	5–5.1	4.0	2000	150	35	30	2.5	1.9	0.3	4-pin M.	F	Class-C Amp. (Telegraphy)	2000	−150	150	30	30	—	225	35T
													Class-C Amp. (Telephony)	1500	−120	100	30	15	480	120	
HF100	75	10	2.0	1500	150	30	23	3.5	4.5	1.4	4-pin M.	E	Class-C Amp. (Telegraphy)	1500	−200	150	18	6	—	170	HF100
													Class-C Amp. (Telephony)	1250	−250	110	21	8	420	105	
													Grid-Modulated Amp.	1500	−280	72	1.5	6.0	168	42	
													Class-B Amp. (Telephony)	1500	− 55	75	1.5	3.0	168	42	
ZB120	75	10	2.0	1250	160	40	90	5.3	5.2	3.2	4-pin J.	M	Class-C Amp. (Telegraphy)	1250	−135	160	23	5.5	—	145	ZB120
													Class-C Amp. (Telephony)	1000	−150	120	21	5.0	380	95	
													Grid-Modulated Amp.	1250	0	95	8	1.5	180	45	
													Class-B Amp. (Telephony)	1250	− 80	90	7	1.6	168	42	
50T	75	5.0	6.0	3000	100	30	12	2.0	2.0	0.4	4-pin M.	E	Class-C Amplifier	3000	−600	100	25	—	—	250	50T
RK36	100	5.0	8.0	3000	165	35	14	4.5	5.0	1.0	4-pin M.	E	Class-C Amp. (Telegraphy)	2000	−360	150	30	15	—	200	RK36
													Class-C Amp. (Telephony)	2000	−360	150	30	15	800	200	
													Grid-Modulated Amp.	2000	−270	72	1.0	3.5	168	42	
													Class-B Amp. (Telephony)	2000	−180	75	3.0	10	200	50	
RK38	100	5.0	8.0	3000	165	40	—	4.6	4.3	0.9	4-pin M.	E	Class-C Amp. (Telegraphy)	2000	−200	160	30	10	—	225	RK38
													Class C Amp. (Telephony)	2000	−200	160	30	10	900	225	
													Grid-Modulated Amp.	2000	−150	80	2.0	5.5	240	60	
													Class-B Amp. (Telephony)	2000	−100	75	2.0	7.0	220	55	

World Radio History

TABLE XIV — TRIODE TRANSMITTING TUBES — *Continued*

Type	Max. Plate Dissipation Watts	Cathode Volts	Cathode Amps.	Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances (μμfd.) Grid to Fil.	Grid to Plate	Plate to Fil.	Base [2]	Socket Connections [1]	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts [5]	Peak Power Output Watts	Approx. Carrier Output Power Watts	Type
100TH	100	5–5.1	6.5	3000	225	50	30	2.2	2.0	0.3	4-pin M.	E	Class-C Amplifier	3000	−210	135	45	—	—	300	100TH
100TL	100	5–5.1	6.5	3000	225	50	12	2.0	2.3	0.4	4-pin M.	E	Class-C Amplifier	3000	−210	135	45	—	—	300	100TL
HK254	100	5.0	7.5	3000	200	40	25	3.3	3.4	1.1	4-pin J.	M	Class-C Amp. (Telegraphy)	3000	−251	167	40	19	—	400	HK254
													Class-C Amp. (Telephony)	2500	−225	180	40	18	1400	350	
203A	100	10	3.25	1250	175	60	25	6.5	14.5	5.5	4-pin J.	M	Class-C Amp. (Telegraphy)	1250	−125	150	25	7.0	—	130	203A
													Class-C Amp. (Telephony)	1000	−135	150	50	14	400	100	
													Class-B Amp. (Telephony)	1250	− 45	105	3.0	3.0	170	42.5	
211 835	100	10	3.25	1250	175	50	12	6.0 6.0	14.5 9.25	5.5 5.0	4-pin J.	M	Class-C Amp. (Telegraphy)	1250	−225	150	18	7.0	—	130	211 835
													Class-C Amp. (Telegraphy)	1000	−260	150	35	14	400	100	
													Class-B Amp. (Telephony)	1250	−100	106	1.0	7.5	170	42.5	
242A	100	10	3.25	1250	150	—	12.5	6.5	13	4.0	4-pin J.	M	Class-C Amplifier	1000	−150	150	—	—	—	125	242A
													Class-B Amp. (Telephony)	1250	−100	100	—	—	125	31	
838	100	10	3.25	1250	175	70	—	6.5	8.0	5.0	4-pin J.	M	Class-C Amp. (Telegraphy)	1250	− 90	150	30	6.0	—	130	838
													Class-C Amp. (Telephony)	1000	−135	150	60	16	400	100	
													Class-B Amp. (Telephony)	1250	0	106	15	6.0	170	42.5	
RK58	100	10	3.25	1250	175	70	—	8.5	6.5	10.5	4-pin J.	M [1]	Class-C Amp. (Telegraphy)	1250	− 90	150	30	6.0	—	130	RK58
													Class-C Amp. (Telephony)	1000	−135	150	50	16	400	100	
													Class-B Amp. (Telephony)	1250	0	106	15	6.0	170	42.5	
261A	100	10	3.25	1250	175	50	12	6.0	9.0	5.0	4-pin J.	M	Class-C Amp. (Telegraphy)	1250	−225	150	18	7.0	—	130	261A
													Class-C Amp. (Telephony)	1000	−260	150	35	14	400	100	
													Class-B Amp. (Telephony)	1250	−100	160	—	—	170	42.5	
203H	100	10	3.25	1500	175	60	25	6.5	11.5	1.5	4-pin J.	M [1]	Class-C Amp. (Telegraphy)	1500	−200	170	12	3.8	—	200	203H
													Class-C Amp. (Telephony)	1250	−160	167	19	5.0	640	160	
													Class-B Amp. (Telephony)	1500	− 48	100	3.0	2.0	208	52	
852	100	10	3.25	3000	150	40	12	1.9	2.6	1.0	4-pin M.	E	Class-C Amp. (Telegraphy)	3000	−600	85	15	12	—	165	852
													Class-C Amp. (Telephony)	2000	−500	67	30	23	300	75	
													Class-B Amp. (Telephony)	3000	−250	43	0	7.0	240	40	
RK57	125	10	3.25	1500	210	70	—	6.5	8.0	5.0	4-pin J.	M [1]	Class-C Amp. (Telegraphy)	1500	−105	200	40	8.5	—	215	RK57
													Class-C Amp. (Telephony)	1250	−160	160	60	16	560	140	
													Class-B Amp. (Telephony)	1500	− 10	115	15	7.5	230	57.5	
805	125	10	3.25	1500	210	70	40–60	8.5	6.5	10.5	4-pin J.	M [1]	Class-C Amp. (Telegraphy)	1500	−105	200	40	8.5	—	215	805
													Class-C Amp. (Telephony)	1250	−160	160	60	16	560	140	
													Class-B Amp. (Telephony)	1500	− 10	115	15	7.5	230	57.5	
T125	125	10	3.85	2000	200	60	25	—	4.5	—	4-pin J.	N	Class-C Amp. (Telegraphy)	2000	−120	200	30	10	—	300	T125
													Class-C Amp. (Telephony)	2000	−200	200	50	20	1200	300	
150T	150	5.0	10	3000	200	50	13	3.0	3.5	0.5	4-pin J.	N	Class-C Amplifier	3000	−600	200	35	—	—	450	150T
806	150	5.0	10	3000	200	50	12.6	6.1	3.4	1.1	4-pin J.	N	Class-C Amp. (Telegraphy)	3000	−600	195	25	20	—	450	806
													Class-C Amp. (Telephony)	2500	−600	195	40	32	1560	390	
													Class-B Amp. (Telephony)	3000	−340	70	0	5.0	280	70	
HK354								9.0	4.0	0.4		M [4]	Class-C Amp. (Telegraphy)	4000	−700	245	48	46	—	840	HK354
	150	5.0	10	4000	300	50	14				4-pin J.		Class-C Amp. (Telephony)	3000	−550	255	50	40	2512	628	
HK354C								4.5	3.8	1.1		N	Class-B Amp. (Telephony)	3000	−205	78	—	10	328	82	HK354C

World Radio History

TABLE XIV — TRIODE TRANSMITTING TUBES — *Continued*

Type	Max. Plate Dissipation Watts	Cathode Volts	Cathode Amps.	Max. Plate Voltage	Max. Plate Current Ma.	Max. D.C. Grid Current Ma.	Amp. Factor	Interelectrode Capacitances (μμfd.) Grid to Fil.	Grid to Plate	Plate to Fil.	Base [2]	Socket Connections [1]	Typical Operation	Plate Voltage	Grid Voltage	Plate Current Ma.	D.C. Grid Current Ma.	Approx. Grid Driving Power Watts [5]	Peak Power Output Watts	Approx. Carrier Output Power Watts	Type
HK354D	150	5.0	10	4000	300	55	22	4.5	3.8	1.1	4-pin J.	N	Class-C Amplifier	3500	−490	240	50	38	—	690	HK354D
HK354E	150	5.0	10	4000	300	60	35	4.5	3.8	1.1	4-pin J.	N	Class-C Amplifier	3500	−448	240	60	45	—	690	HK354E
MK354F	150	5.0	10	4000	300	75	50	4.5	3.8	1.1	4-pin J.	N	Class-C Amplifier	3500	−368	250	75	50	—	720	HK354F
HD203A	150	10	4.0	2000	250	60	25	—	12	—	4-pin J.	M [4]	Class-C Amplifier	—	—	—	—	—	—	375	HD203A
HF200	150	10–11	3.4	2500	200	50	18	5.2	5.8	1.2	4-pin J.	N	Class-C Amp. (Telegraphy)	2500	−300	200	18	8.0	—	380	HF200
													Class-C Amp. (Telephony)	2000	−350	160	20	9.0	1000	250	
													Class-B Amp. (Telephony)	2500	−140	90	—	4.0	320	80	
T155	155	10.0	4.0	3000	200	60	20	2.5	3.0	1.0	4-pin J.	N	Class-C Amplifier	—	—	—	—	—	—	450	T155
F108A	175	10.0	11.0	3000	200	50	12	3.0	7.0	2.0	4-pin J.	N	Class-C Amplifier	3000	−350	200	—	—	—	400	F108A
RK63	200	5.0	10	3000	250	60	37	2.7	3.3	1.1	4-pin J.	N	Class-C Amplifier	3000	−200	233	45	17	—	525	RK63
T814	200	10	4.0	2500	300	80	12	7.0	13	5.5	4-pin J.	M [4]	Class-C Amplifier	2000	−400	300	55	30	—	400	T814
T822	200	10	4.0	2500	300	60	27	8.0	14	6.0	4-pin J.	M [4]	Class-C Amplifier	2000	−220	300	55	35	—	400	T822
HF300	200	11–12	4.0	3000	275	60	23	6.0	6.5	1.4	4-pin J.	N	Class-C Amp. (Telegraphy)	3000	−400	250	28	16	—	600	HF300
													Class-C Amp. (Telephony)	2000	−300	250	36	17	1540	385	
													Class-B Amp. (Telephony)	2500	−100	120	0.5	6.0	420	105	
250TH	250	5–5.1	10.5	3000	350	100	32	3.5	3.5	0.3	4-pin J.	N	Class-C Amplifier	3000	−210	330	55	—	—	750	250TH
250TL	250	5–5.1	10.5	3000	350	50	13	3.0	3.5	0.3	4-pin J.	N	Class-C Amplifier	3000	−400	330	45	—	—	750	250TL
204A	250	11	3.85	2500	275	80	23	12.5	15	2.3	Special	Q	Class-C Amp. (Telegraphy)	2500	−200	250	30	15	—	450	204A
													Class-C Amp. (Telephony)	2000	−250	250	35	20	1400	350	
													Class-B Amp. (Telephony)	2500	−70	160	—	15	400	100	
654	300	7.5	15	4000	600	100	22	6.2	5.5	1.5	4-pin J.	N	Class-C Amplifier	2000	−380	500	75	57	—	720	654
300T	300	8.0	11.5	3500	350	75	16	4.0	4.0	0.6	4-pin J.	N	Class-C Amplifier	3500	−600	300	60	—	—	800	300T
833 *	300	10	10	3000	500	75	35	12.3	6.3	8.5	Special	T	Class-C Amp. (Telegraphy)	2000	−200	475	65	25	—	740	833
													Class-C Amp. (Telephony)	2500	−300	335	75	30	2540	635	
													Class-B Amp. (Telephony)	3000	−70	150	2.0	10	600	150	
849	400	11	5.0	2500	350	125	19	17	33.5	3.0	Special	Q	Class-C Amp. (Telegraphy)	2500	−250	300	20	8.0	—	560	849
													Class-C Amp. (Telephony)	2000	−300	300	30	14	1700	425	
													Class-B Amp. (Telephony)	2500	−125	216	1.0	12	720	180	
831	400	11	10	3500	350	75	14.5	3.8	4.0	1.4	Special	R	Class-C Amp. (Telegraphy)	3500	−400	275	40	30	—	590	831
													Class-C Amp. (Telephony)	3000	−500	200	60	50	1440	360	
													Class-B Amp. (Telephony)	3500	−220	146	—	—	640	160	
450TH	450	7.5–7.7	12	6000	500	125	30	—	—	—	4-pin J.	N	Class-C Amp. (Telegraphy)	2500	−200	400	80	—	—	750	450TH
													Class-C Amp. (Telephony)	2500	−250	400	75	—	3000	750	
450TL	450	7.5–7.7	12	6000	500	75	16	4.0	4.0	0.6	4-pin J.	N	Class-C Amp. (Telegraphy)	2500	−400	400	70	—	—	750	450TL
													Class-C Amp. (Telephony)	2500	−400	400	65	—	3000	750	
F100	500	11	25	2000	500	—	14	4.0	10	2.0	Special	R	Class-C Amplifier	2000	−300	500	—	—	—	600	F100
500T	500	8.0	20	4000	600	125	13.5	6.0	4.5	0.8			Class-C Amplifier	2000	−400	450	100	—	—	650	500T

1 Refer to Fig. 518.
2 M.—medium; J.—jumbo.
3 All Wire leads. Ratings at 500 Mc.
4 Plate connection to top cap.
5 See Chapter 8 for discussion of grid driving power.
6 Heater and cathode connected to usual pins, grid and plate connected to top caps.

* Indicates that tube is designed especially for u.h.f. work.

7 Twin triodes. Values correspond to left- and right-hand sections.
8 Twin triodes. Values for both sections, in push-pull.
9 Refer to Fig. 514. RK34 has plate leads coming to top caps, pins 2 and 6 having no connection.
10 Gaseous discharge tube for use on 110-volt d.c. Use 500-ohm resistor in series with No. 1 grid. Ionizing current, 150 to 250 ma.
11 Twin triodes. Characteristics per section.

World Radio History

CHAPTER SIX

WORKSHOP PRACTICE

Tools — Constructional Methods — Coil Winding — Benches — Racks — Antenna Masts

In great contrast to the early days of amateur radio, component parts, designed especially for the amateur, for every conceivable purpose, are readily available at reasonable prices. In consideration of this, it is seldom possible to economize in the cost of a transmitter or receiver by attempting the construction of component parts such as transformers, condensers, etc., most of which are impossible to duplicate satisfactorily without special machinery.

TOOLS

The construction of a piece of amateur equipment thus resolves itself chiefly into proper assembly and wiring of the various components. With a few well-chosen tools, an otherwise tedious piece of work may be simplified so that almost anyone may turn out a neat appearing and well working job. To a certain degree, it may be said that the greater the variety of tools available, the easier and, perhaps, the better the job may be done. It is surprising, however, how many fine pieces of equipment are turned out with only a minimum of common hand tools.

For simple breadboard construction, the following tools are the most important:

1 pr. Longnose Pliers (6")
1 pr. Diagonal Cutting Pliers (6")
1 Screwdriver (6" to 7", ¼" blade)
1 Screwdriver (4" to 5", ⅛" blade)
1 pr. Tin Shears (10")
1 Scratch Awl or Ice Pick
1 Combination Square (12")
1 Yardstick or other straightedge
1 Hand Drill (2 speed)
1 Heavy Knife
1 Electric Soldering Iron (100 watts, small pointed tip)
1 Center Punch
1 Flat File (12" medium coarse cut)
Drills; particularly ⅛", ¼" and 3/16" and No. 42
Solder (Rosin Core)
Soldering Paste (Non-corroding)

For more extensive construction and metal working, the following additional tools will be found indispensable:

1 Bench Vise (4" jaws)
1 Ball Peen Hammer (1-lb. head)
1 Hacksaw (12" blades)
1 pr. Slip-joint Pliers (6")
1 Long Shank Screwdriver with screw-holding clip (¼" blade)
1 set Small Stamped Steel Open End Wrenches
1 Wood Chisel (½")
1 Cold Chisel (½")
1 pr. Wing Dividers (8")
1 Carpenter's Plane (8" to 12")
1 Carpenter's Ratchet Brace
1 Countersink for brace
1 Screwdriver Bit for brace
1 Circle Cutter for brace (adjustable)
1 Taper Reamer for brace (½")
1 Taper Reamer for brace (1")
1 Round Bastard File (coarse, ½" or more diam.)
1 Flat File (12" — very coarse for fast cutting)
Several smaller files for smoothing; rat-tail, flat, round, square, triangular and half-round
Several small "C" Clamps
Additional Drills: Nos. 18, 21, 28, 29, 33 and 50
Steel Wool
Sandpaper and Emery Cloth (several grades)
1 Combination Oil Stone for sharpening tools

Several of the pieces of light wood-working machinery often sold in hardware stores and mail order retail stores are ideal for amateur radio work, especially the drill press, grinding head, band and circular saws and joiner. Socket holes may be most easily made by means of punches especially designed for the purpose. However, a complete set of these punches is quite expensive, if those of good quality are selected. Those of inferior quality should be avoided. The idea that machinery is necessary to turn out a good job should be dismissed. Machinery is mentioned here merely as a suggestion to those who are in a position to acquire it.

A few feet of brass or iron strip ½" wide by 1/16" thick, ¼" square brass rod, ¼" diameter brass rod and ½" by ½" by 1/16" brass angle stock always come in handy for making mounting brackets, panel braces, shaft extensions and other small metal objects.

CUTTING AND BENDING SHEET METAL

Sheet metal is normally cut with a hacksaw, following a scratched line as closely as possible, but not so close as to obliterate the line. The rough edge is then trimmed down to the line with a file. Use a square to mark the cutting

World Radio History

line and coarse files for fast cutting. Smooth up the edges with the finer files. A large, coarse round file will cut faster than other types, if used with a combination filing and planing motion. For final finishing of the edges, place a large piece of emery cloth or sandpaper on a flat surface and run the edge of the metal back and forth over the sheet.

The easiest way to cut a wide sheet of aluminum or alloy is to make scratches as deep as possible along the line of the cut on both sides of the sheet. Clamp the sheet in a vise and weave back and forth until the sheet breaks at the line. Do not carry the weaving too far until the break begins to weaken, otherwise the edge of the sheet may become bent. A pair of iron bars or pieces of heavy angle stock, as long or longer than the width of the sheet, used in the vise will make the job easier. "C" clamps may be used to keep the bars from spreading apart at the ends.

Bends are made with a similar arrangement. The sheet should be scratched on both sides, as described above, but not too deeply.

DRILLING AND CUTTING HOLES

HOLES should never be drilled without first using a center punch to locate the center of the holes. Mistakes and a ruined panel or chassis may be avoided by first laying out the components on a sheet of heavy paper on which an exact outline of the panel or chassis has been made. Components may be moved about until the most satisfactory arrangement has been found. The various hole centers are then marked on the paper. The paper is transferred to the chassis or panel and fastened with adhesive tape or gummed paper. The hole centers are then punched through the paper, avoiding scratches on the metal. In laying out dimensions for any piece of work, make the measurements as accurately as possible. Small errors in measurement often spell the difference between well-fitting a job and one which requires filing and trimming.

Holes larger than ⅛″ or 3⁄16″ should first be drilled with a small drill and then enlarged with successively larger drills until the desired size is reached. Be careful of excessive pressure on drills of small size to avoid breaking. Use a taper reamer for holes larger than ¼″ or 5⁄16″, especially if a drill press is not available. A ½″ diameter round tapered file with a coarse cut can be used for reaming by removing the handle and clamping the handle end in the chuck of a brace. Turn the file counter-clockwise with medium pressure.

For holes larger than 1″ diameter, a hole cutter, sometimes called a "fly-cutter," is used. When using the adjustable type, try the setting on a block of wood or piece of scrap metal before cutting the chassis or panel to make sure that the size is right. After a hole for a standard size socket or meter has been cut, the disk which forms the center may be saved and used in setting the cutter to the correct point at some time in the future when the need for a hole of the same size arises. Always back up the metal with a piece of wood in using the hole cutter. This is also advisable when using small drills. If a hole cutter is not available, or if a square or irregular shaped hole is required, it may be cut out by drilling a series of small holes as close together as possible, and as close as possible to the inside of the outline mark of the hole. The center may then be knocked out with a cold chisel. Another method which may be used for cutting rectangular holes is to drill a ½″ hole inside each corner and cut the rectangular hole out with a hacksaw blade. Burrs, which may develop around the edge of a hole when drilling, may be removed by careful use of a large knife or an old wood chisel. Reference should be made to the table showing the drill sizes to be used for clearing or for tapping for various standard size machine screws.

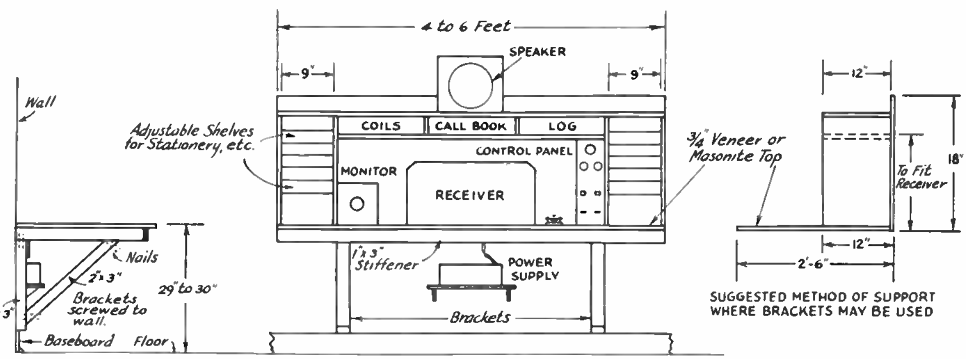


FIG. 601 — A CONVENIENT OPERATING TABLE
It may be supported from the wall or provided with legs as shown in Fig. 602.

World Radio History

Exercise extreme care in using taps, especially in aluminum. Keep the tap at right angles to the surface of the metal surface and reverse the tap whenever it begins to turn hard. Machine oil usually makes tapping much easier. Small taps may very readily be used in the hand drill, if the drill is shifted into slow speed.

NUMBERED DRILL SIZES

Number	*Diameter (mils)*	*Will Clear Screw*	*Drilled for Tapping Iron, Steel or Brass**
1	228.0	—	—
2	221.0	12-24	—
3	213.0	—	14-24
4	209.0	12-20	—
5	205.0	—	—
6	204.0	—	—
7	201.0	—	—
8	199.0	—	—
9	196.0	—	—
10	193.5	10-32	—
11	191.0	10-24	—
12	189.0	—	—
13	185.0	—	—
14	182.0	—	—
15	180.0	—	—
16	177.0	—	12-24
17	173.0	—	—
18	169.5	8-32	—
19	166.0	—	12-20
20	161.0	—	—
21	159.0	—	10-32
22	157.0	—	—
23	154.0	—	—
24	152.0	—	—
25	149.5	—	10-24
26	147.0	—	—
27	144.0	—	—
28	140.5	6-32	—
29	136.0	—	8-32
30	128.5	—	—
31	120.0	—	—
32	116.0	—	—
33	113.0	4-36 4-40	—
34	111.0	—	—
35	110.0	—	6-32
36	106.5	—	—
37	104.0	—	—
38	101.5	—	—
39	099.5	3-48	—
40	098.0	—	—
41	096.0	—	—
42	093.5	—	4-36 4-40
43	089.0	2-56	—
44	086.0	—	—
45	082.0	—	3-48
46	081.0	—	—
47	078.5	—	—
48	076.0	—	—
49	073.0	—	2-56
50	070.0	—	—
51	067.0	—	—
52	063.5	—	—
53	059.5	—	—
54	055.0	—	—

* Use one size larger drill for tapping bakelite and hard rubber.

CLEANING AND FINISHING METAL

Parts made of aluminum or alloy may be cleaned up and given a satin finish, after all holes have been drilled, by placing them in a solution of lye for half to three-quarters of an hour. Three or four tablespoonfuls of lye should be used to each gallon of water. If more than one piece is treated in the same bath, each piece should be separated from the others so as to expose all surfaces to the solution. Overlapping of pieces may result in spots or stains.

SOLDERING

The secret of good soldering is in allowing time for the *joint*, not the solder, to attain sufficient temperature. Sufficient heat should be applied so that the solder will melt when it comes in contact with the wire forming the joint without the necessity for touching the solder to the iron. Soldering paste, if the non-corroding type, is extremely useful when used correctly. In general, it should not be used for radio work except when it is necessary to make the soldered joint with one hand. In this case, the joint should first be warmed slightly and the soldering paste applied with a piece of wire. Only the soldering paste which melts from the warmth of the joint should be used. If the soldering iron is clean, it will be possible to pick up a drop of solder on the tip of the iron which can be applied to the joint with one hand, while the other is used to hold the connecting wires together. The use of excessive soldering paste causes the paste to spread over the surface of adjacent insulation causing leakage or breakdown of the insulation. Except where absolutely necessary, solder should never be depended upon for the mechanical strength of the joint; the wire should be wrapped around the terminals or clamped with soldering terminals.

The tip of a soldering iron should be kept clean and well-tinned. If it is necessary to allow the iron to run for long periods without use, a resistance should be inserted in series to prevent the tip from burning up.

OPERATING TABLES

While any standard table or desk may be used for an operating position, a more convenient and attractive arrangement will result if the operating table is built for the purpose. The drawings of Figs. 601, 602 and 603 show two types which have accommodations for all of the various operating accessories such as control switches, key, receiver and power supply, monitor, stationery, etc.

The one shown in Figs. 601 and 602 was designed by W6HGW. It may be built by anyone possessing a fair degree of mechanical skill and with a minimum number of carpenter's tools. There are no complicated joints to make and, for the most part, it is simply a matter of

World Radio History

cutting the material and nailing it together.

The top may consist of a single sheet of ¾-inch 5-ply Douglas fir veneer or several fairly smooth boards fastened together with cleats covered by a sheet of ⅛-inch masonite or pressed wood. Small holes are drilled about six inches apart along the edges of the masonite which is fastened with small brass escutcheon pins, driving the heads down flush. Brass binding may be used along the edges of the top

The top may be supported in either of two ways. If permissible, the better plan is to build

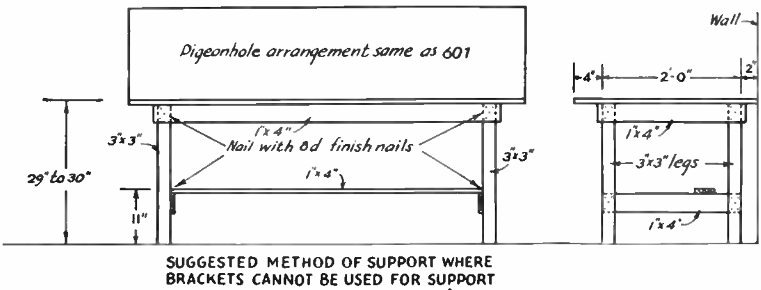


FIG. 602 — LEGS MAY BE PROVIDED WHERE WALL MOUNTING IS IMPOSSIBLE

two brackets of 2″ × 3″ material, as shown in the sketch, and fasten them to the wall by means of large wood screws driven through the plaster and into the studding of the wall. In this way there are no table legs to get in the way of one's feet. The studding in the walls may be located by tapping along the wall with a hammer until it feels solid. The studding is generally on 16″ centers, hence, having located one stud, it is an easy matter to locate the others by measurement.

If the bracket form of construction is used, it will be necessary to stiffen the top between the brackets. This may be done by nailing a 1″ × 3″ piece across the front end of the brackets, and a 1″ × 6″ piece across the front of the vertical legs of the brackets, notching it so as to clear the horizontal bracket members.

The more orthodox method of using four legs is shown in Fig. 602. These may be made of 3″ × 3″ material, fastened at the top with 1″ × 4″ pieces, and with a cross piece at each end about 8″ from the floor and a longitudinal brace between them, as shown by the sketches.

The table should be about 30″ wide, and from 4 to 6 feet long, depending upon one's individual ideas. For best operating convenience the top should be from 29″ to 30″ above the floor.

By buying all lumber surfaced on four sides, the labor of building this table is reduced to a great extent. The greater part of the work will be simply cutting the material and fastening it together. A good grade of pine looks well and, when sandpapered and finished with dark mahogany stain, it will make a table of which no one need be ashamed.

The back panel may be the 18″ piece left over after having cut the four-foot panel down to 30″. The rest of the shelves and pigeonholes may be made of 1″ × 12″ pine, which may be bought at the lumber yard surfaced on four sides, ready to be cut and nailed into place. All joints should be nailed with eight-penny finish nails.

The small shelves may be made of wood, or better, by making saw cuts in the side pieces about an inch apart and ⅛″ deep, to receive pieces of 20 gauge galvanized iron which are slid into them to make shelves that are easily adjustable, to suit one's convenience.

The second type, shown in Fig. 603, was designed by W5CIQ. The entire structure is made of ¾″ × 12″ smooth lumber. Essential dimensions are given in the drawing. The various compartments may be used as follows:

A. Loud speaker.
B. Antenna tuner.
C. Small monitor.
D. Final amplifier.
E. Exciter stages (two or three).
F. Power supplies (receiver supply included).
G. Receiver.
H. Log, call book, writing paper, etc.

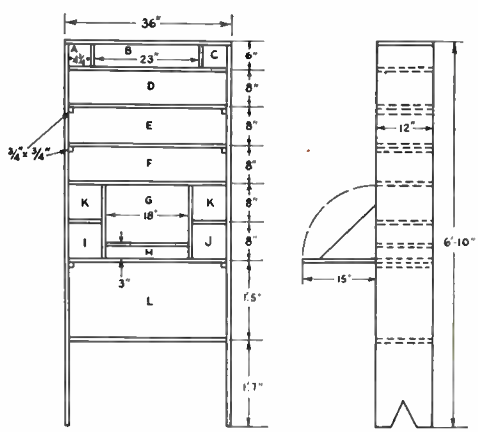


FIG. 603 — ANOTHER TYPE OF OPERATING POSITION PROVIDING SPACE FOR A LOW-POWER TRANSMITTER

I. Panel for switches controlling 110v. a.c. power.
J. Key.
K. Tools, QSL's, neon bulb, plug-in coils, etc.

The shelf at *L* is mainly a support for the bottom of the structure. It can be used for the speech amplifier and its power unit, and also to accommodate magazines, books and the miscellaneous boxes of screws.

The space *H* may be made as a sort of pedestal setting inside the space for the receiver, and the receiver rests upon it. The writing desk is hinged at the bottom and folds up to hide the receiver, etc.

Panels may be used on the shelves that slide out, if so desired. The top and bottom shelves are put in permanently while the ones in between slide out in case repairs to the apparatus become necessary.

TRANSMITTER RACK

THE present trend in amateur transmitter construction is definitely toward the standard rack and panel type. In this type of construction, illustrated in Fig. 604, the transmitter is made up of units of standard dimensions, each one complete in itself, which are grouped together in suitable order in a vertical frame also of standard dimensions. Each unit is composed of a chassis, preferably of metal, on which most of the components are mounted, and a panel which may be of either metal or wood.

A transmitter following this plan of construction usually requires less floor or table space than other types and is attractive and business-like in appearance. The unit feature permits changes, from time to time, without the necessity of disrupting the entire transmitter or working on it in a restricted space. The usual unsightly connecting wiring may be cabled and run down the inside corners of the vertical members.

Each chassis measures 17″ long, 2″ to 3″ deep and 4″ to 13″ wide according to space requirements. All panels are 19″ wide by some multiple of 1¾″ high. One sixty-fourth inch is taken off the height of each panel to compensate for any irregularities which might cause cramping of the panels when they are mounted together on the rack. Mounting holes are spaced so that the individual panels will fit when moved up or down to any desired position on the rack in steps of 1¾″. This

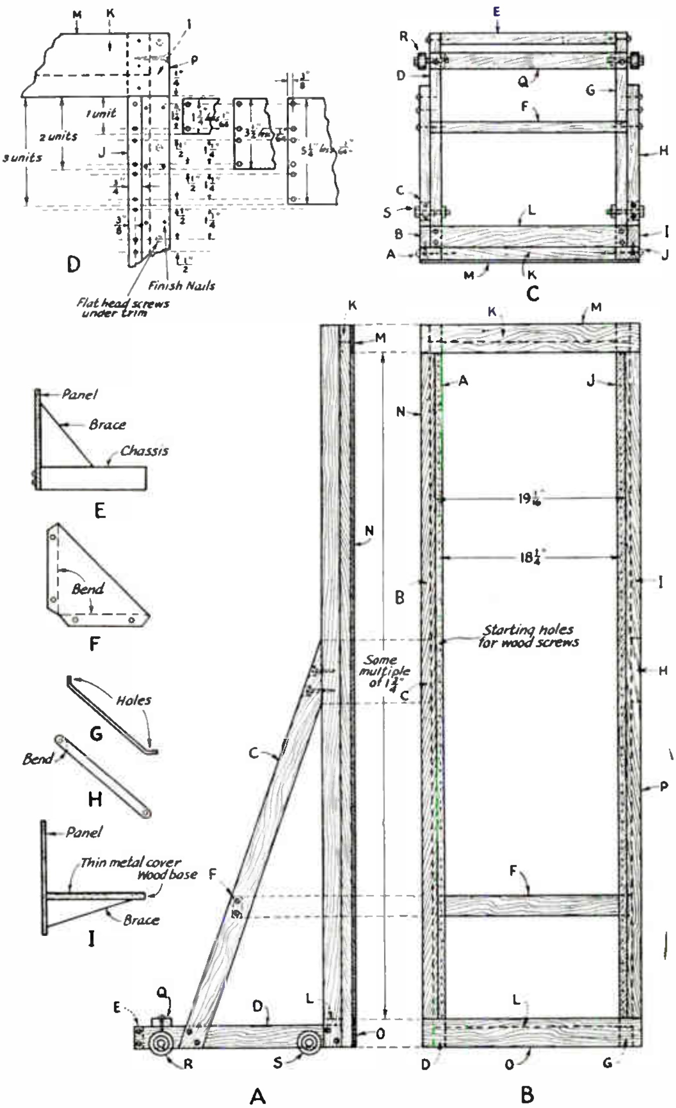


FIG. 604 — THE STANDARD RACK

A — Side view, B — Front view, C — Top view, D — Upper right hand corner detail, E — Panel and chassis assembly, F, G, H — Various types of panel brackets, I — A substitute for the metal chassis.

World Radio History

dimension of 1¾″ is known as a rack unit. The height of the rack will depend upon the number of panels required and their sizes. Small transmitters may be confined to a small table type rack or to the upper portion of a floor type rack. Standard racks of steel are available in various sizes from the larger amateur radio supply houses. Very practical and inexpensive substitutes of wood may be constructed by the amateur, however.

Referring to Fig. 604, the rack is constructed entirely of 1″ × 2″ stock of smooth pine, spruce or redwood, with the exception of the trimming strips, *M*, *N*, *O* and *P*. Since the actual size of standard 1″ × 2″ stock runs appreciably below these dimensions, a much sturdier job will result if pieces are obtained cut to the full dimensions.

The two main vertical supporting members are each comprised of two pieces (*A* and *B*, and *I* and *J*) fastened together at right angles. Each pair of pieces is fastened together by No. 8 flat head screws, countersunk.

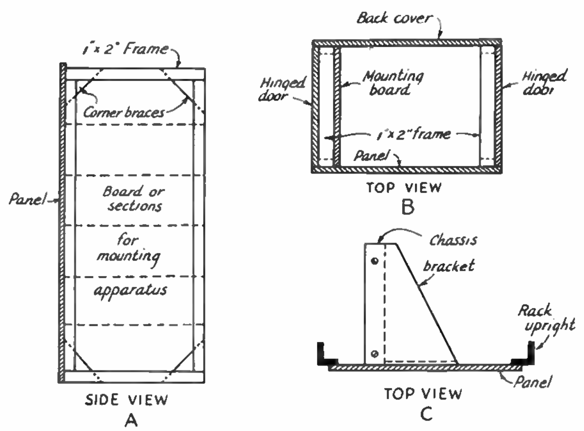


FIG. 605 — CONSTRUCTION WHICH PROVIDES MAXIMUM ACCESSIBILITY

A — Frame of 1″ x 2″ or similar stock mounted at right angles to full-length panel. B — Top view showing how transmitter may be enclosed. C — Adapting vertical construction to standard racks

Before fastening these pairs together, pieces *A* and *J* should be made exactly the same length and drilled in the proper places for the mounting screws using a No. 30 drill. The length of pieces *A*, *J*, *B* and *I* should equal the total height of all panels required for the transmitter plus *twice* the sum of the thickness and width of the material used. If the dimensions of the stock are exactly 1″ × 2″, then 6″ must be added to the sum of the panel heights. An inspection of the top and bottom of the rack in the drawing will reveal the reason for this. The first mounting hole should come at a distance of ¼″ plus the sum of the thickness and width of the material from either end of pieces *A* and *J*. This distance will be 3¼″ for stock exactly 1″ × 2″. The second hole will come 1¼″ from the first, the third ½″ from the second, the fourth 1¼″ from the third and so on, alternating spacings between ½″ and 1¼″ (see detail drawing D, Fig. 604). All holes should be placed ⅜″ from the inside edge of the vertical members.

The two vertical members are fastened together by cross-member *K* at the top and *L* at the bottom. These should be of such a length that the inside edges of *A* and *J* are exactly 17½″ apart at all points. This will bring the lines of mounting holes 18¼″ center to center. Extending back from the bottoms of the vertical members are pieces *G* and *D* connected together by cross-members *L*, *Q* and *E*, forming the base. The length of the pieces *D* and *G* will depend upon space requirements of the largest power supply unit which will rest upon it. The vertical members are braced against the base by diagonal members *C* and *H*. Rear support for heavy units placed above the base may be provided by mounting angles on the insides of *C* and *H*, or by connecting them with cross-members at suitable heights as shown at *F*.

To finish off the front of the rack pieces of ¼″ oak strip (*M*, *N*, *O*, *P*) are fastened around the edges with small-head finishing nails. The heads are set below the surface and the holes plugged with putty or plastic wood. They should be of such a width that the top and bottom edges of *O* and *P* respectively should be ¼″ from the first mounting holes and the distance between the inside edges of the vertical strips, *N* and *P*, $19\frac{5}{16}''$.

To prevent the screw holes from wearing out when panels are changed frequently, ½″ wide × $\frac{1}{16}''$ or $\frac{3}{32}''$ thick iron or brass strip may be used to back up the vertical members of the frame. Clearance holes for the mounting screws may be drilled in the wood and the metal strips may be drilled and tapped for machine screws. Such a metal strip will also serve as a grounding strip between units.

The outside surfaces should be sandpapered thoroughly and given one or two coats of flat black finish, sandpapering between coats. A finishing surface of two coats of glossy black "Duco" is then applied, again sandpapering between coats. It is important to allow each coat to dry thoroughly before applying the next, or sandpapering.

Since the combined weights of power sup-

World Radio History

plies, modulator equipment, etc., may total to a surprising figure, the rack should be provided with rollers or wheels so that it may be moved about when necessary after the transmitter has been assembled. For this purpose, ball bearing roller-skate wheels are excellent.

Rack Units

As mentioned previously, the various units are built upon an assembly consisting of a panel 19″ wide and a chassis or base 17″ long, as shown in drawing E of Fig. 604. Chassis pans of several standard sizes as well as panels are available from most amateur radio supply houses. Chassis are commonly obtainable in soft steel, aluminum or a zinc alloy. Of these, aluminum or zinc alloy, while more expensive, are much easier to work and are definitely recommended where all work must be done with hand tools.

Very acceptable substitutes may be made by covering a piece of wood, such as oak or a special impregnated wood known commercially as "Tempered Masonite" or "Lamtex," with a thin sheet of aluminum or other metal assembled as shown in drawing I, Fig. 604. This special type wood also makes excellent panels since it may be obtained, ¼″ thick, with an attractive black crystalline finish in standard rack sizes with drilled mounting holes or in undrilled sheets 19″ wide. Even inexpensive ¼″ ply-wood panels will be practical and presentable if given a sufficient number of coats of flat black finish to obliterate the grain. No panel or baseboard of any kind should be depended upon for r.f. insulation if it has been finished with black paint or lacquer which conducts r.f. currents quite readily.

Panels are drilled as shown in drawing D, Fig. 604. The holes should be large enough to pass the No. 8 or No. 10 round head nickeled wood screws which are used to fasten the panels in the rack. As the drawings of the two-unit and three-unit panels show, it is not necessary to drill holes in the panels corresponding to all of the mounting holes, but only a sufficient number to provide adequate strength. Commercial panels are usually notched instead of drilled. The simple holes shown are less difficult to make and serve as well. If desired, the notches may be filed out after the holes are drilled.

Since the panel is called upon to bear the weight of the chassis and that of the equipment mounted upon it, metal panels should be not less than ⅛″ thick and wood panels not less than ¼″ thick. In addition to fastening the lower edge of the panel to the chassis with machine screws, braces should be provided for additional support. Triangular shaped pieces such as those shown in drawing F, Fig. 604, may be cut and bent out of metal sheet or may be purchased ready to use. A satisfactory substitute may consist of a simple bracing strip of ½″ × 1⁄16″ stock, drilled at one end for the chassis and bent and drilled at the other for the panel, as shown in drawing H. Where space permits, the strip may be bent flat-wise, as shown at *G*.

Whenever possible, all components should be mounted on the chassis making it necessary to drill the panel only for shaft holes, supporting screws and, possibly, the dials. Condenser shaft holes may be located by taking accurate measurements remembering that the lower edge of the panel and that of the chassis should coincide when assembled.

Vertical Construction

A different type of construction is shown in Fig. 605. A frame of wood, properly braced, is fastened to the panel at right angles. Upon the frame is mounted a vertical breadboard, preferably covered with thin sheet metal upon which the apparatus is mounted. Power-supply apparatus may be placed at the bottom. Tuning condensers are mounted so that the shafts may be extended through the panel. Tubes may be mounted horizontally although vertical mounting by means of brackets usually will permit shorter leads. If desired, the breadboard may be made in removable sections following rack practice. This type of construction has the advantage that both sides of the mounting board are easily accessible and lends itself very well to enclosed cabinet construction as shown at *B*. Similar construction may be employed with standard racks by mounting the chassis vertically instead of horizontally as shown at *C*.

COIL WINDING

Coil forms 1″ to 2½″ in diameter and 1½″ to 4″ long, which may be plugged into standard receiving tube sockets, are standard items of manufacture. These are commonly used for winding coils for low-power transmitters as well as receivers. Some sizes are available with from four to six prongs. The type to be used will depend upon circuit requirements.

Coils for low-power stages, handling twenty-five to thirty watts, can be wound with relatively small wire. When the power to be handled is fairly large, heavier conductors must be used, however, to avoid heating. Number 12 or 14 wire, properly spaced, will carry the output of most medium and high power amplifiers without undue heating, especially when the optimum or higher *L-C* ratio is used. In high-*C* circuits, copper tubing is generally used; sizes of tubing range from ⅛″ to ¼″ in diameter.

The chief requirements for a good transmitting coil are that its resistance be low (large conductor and proper proportioning of dimen-

World Radio History

sions) and that it be mechanically rigid. The turns should not be "floppy" because if vibration occurs, the inductance will change at the same rate, modulating the output of the transmitter. If the coils are plug-in, it should also be possible to handle them a great deal without getting turns out of place or breaking off terminals. Plug-in coils larger than those wound on receiving coil forms usually are provided with G.R. or "banana" type plugs fitting into jacks mounted in a strip of bakelite or in special stand-off insulators.

Coils for transmitters often are wound on grooved ceramic forms available from several manufacturers. Such inductances are easy to make, and if wound with bare wire can readily be tapped at any point.

Another type of coil construction utilizes strips of bakelite or similar material ⅛″ to $\frac{3}{16}$″ thick, ⅜″ to ½″ wide, drilled at proper intervals to give the desired turn spacing, to support the turns. A coil of this type is illustrated in Fig. 606. Wire between sizes 14 and 10 is commonly used, although the same system may be used for copper tubing. The strips should be drilled, one strip having one extra hole to take care of the end of the winding, the others having the same number of holes as the number of turns on the coil. The coil itself is wound separately on a form of the proper diameter. The loose coil is then removed and the wire fed through the strips a turn at a time, starting with the strip with the extra hole. It is not difficult to do, although taking a little time. The holes in the strips should be large enough to pass the wire without binding. After threading through the strips, the turns may be fastened firmly in place with Duco cement. The bottom of the coil may be clamped between two strips of bakelite, as shown in the drawing of Fig. 606 and mounted on a third strip which bears the required number of coil plugs. A mounting base may be made identical to strip *F* except that it should be somewhat wider to take care of the large holes required for the coil jacks, and about 2″ longer to provide for mounting on stand-off insulators. Link windings may be made in a similar manner and may be cemented to the inside edges of the coil strips as shown in the drawing.

A third type of coil is shown in Figs. 607 and 608. In this case the supporting strips are celluloid, cemented to the coil turns. A winding form such as a bakelite tube of proper diameter or a collapsible form made of wood shown in Fig. 608 should be covered with several layers of paper; the wire is fastened at one end with a machine screw and nut through the form and wound on to the desired number of turns, after which three or four celluloid strips are slid under the wire at proper intervals around the form. The turns are then spaced by winding string or wire of the proper diameter between them. After spacing, the turns should be tightened up and the other end of the winding fastened to the form. Duco cement is run in between the turns along the celluloid strips and allowed to dry for an hour or two, when

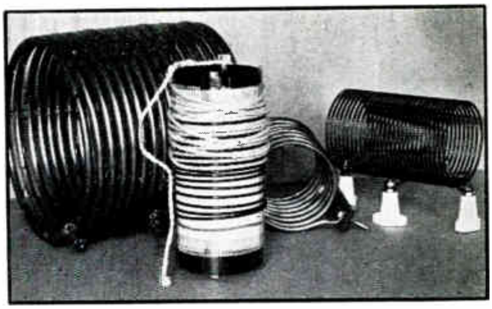


FIG. 607 — COILS WOUND ON CELLULOID STRIPS, SHOWING THE WORKING MATERIALS NEEDED FOR CONSTRUCTION

The coil on the bakelite form is in the middle of the winding process, about to be spaced with the heavy string before tightening and cementing.

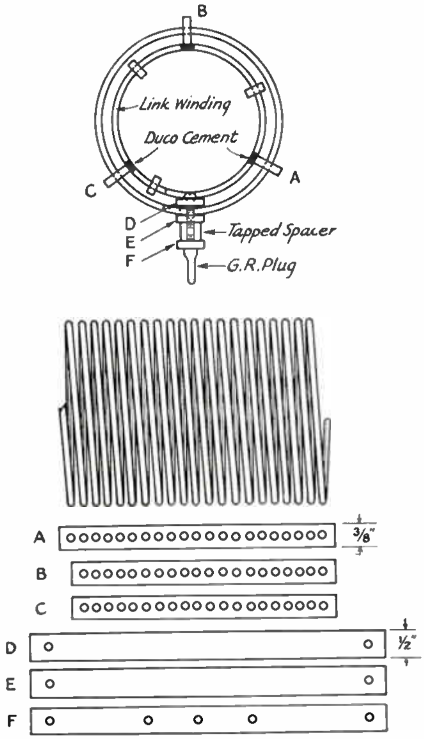


FIG. 606 — COIL ASSEMBLY FOR WIRE OR COPPER TUBING COILS

After the coil is wound the strips A, B and C are threaded on the wire starting with strip A which has an extra hole.

World Radio History

another application of cement is made. The second coat should be allowed to dry overnight, after which the turns will be firmly cemented to the celluloid strips. The paper may then be pulled or cut out and the finished coil slid off the form. The coils are quite strong and rigid. Even large-size copper-tubing coils can be made by this method,

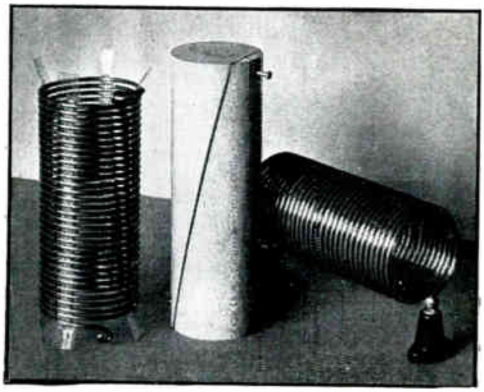


FIG. 608 — THE WOODEN MANDREL SHOWN ABOVE IS CONVENIENT IF MANY COILS ARE TO BE WOUND

A copper tubing coil just as it comes off the winding form is shown at the left; the coil at the right has been "trimmed" and mounted.

although it is generally used with wire coils. Complete coils of the type are available from several manufacturers.

ANTENNA MASTS

A very simple and inexpensive mast is shown in Fig. 609. This design has been very popular and is satisfactory for heights up to 35 or 40 feet. In addition to the 2″ × 2″ lumber, the only materials required are 5/16″ carriage bolts 5½″ long with washers, a few spikes, about 300 ft. No. 12 galvanized iron wire and several small strain insulators. These should be used about every 10 or 12 feet to break the guy wires into sections. Clear, sound lumber should be selected. The mast may be protected by 2 or 3 coats of house paint or, preferably, aluminum paint.

If the mast is to stand on the ground, a couple of stakes should be driven to keep the bottom from slipping. At this point the mast may be "walked up" by a pair of helpers. If it is to go on a roof, first stand it up against the side of the building and then hoist it, from the roof, keeping it vertical. The whole assembly is light enough for two men to perform the complete operation — lifting the mast, carrying it to its permanent berth and fastening the guys — with the mast vertical all the while. It is therefore entirely practicable to put up this kind of mast on a small flat area of roof that would prohibit the erection of one that had to be raised vertical in its final location.

A heavier mast for greater heights is described by W1ALJ and shown in Fig. 610. It can be made forty to sixty feet high, requires only two back guys forming a tripod with the antenna and is cheap to construct.

The material required is as follows:

1 — 6″ × 6″ 9 feet long
2 — 4″ × 4″ 14 feet long
1 — 4″ × 4″ 20 feet long
2 pieces 20 feet long, 1″ thick, 3″ at bottom end, tapered to 2″ at top
1 — Top piece 2″ × 1″ 6 feet long

Lapping bolts:
4 — ⅝″ × 14″
3 — ½″ × 7″
3 — ⅜″ × 3½″

Reinforcement bolts to prevent splitting at ends of sticks:
6 — ½″ × 4½″
1 — ½″ × 7″
2 — ¼″ × 3½″
3 — ¼″ × 2½″

Each bolt requires two washers. Large square washers may be used on the lapping bolts and regular round washers on the rein-

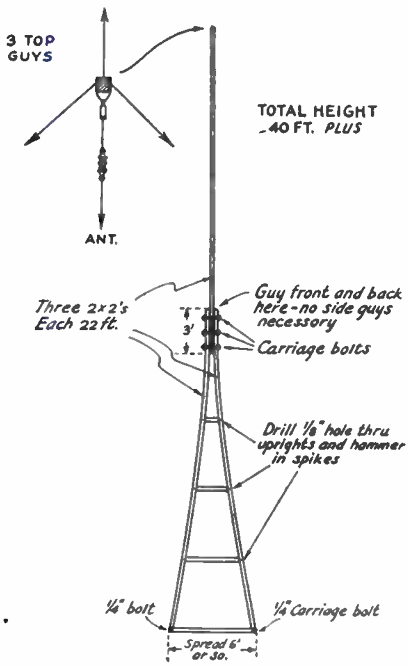
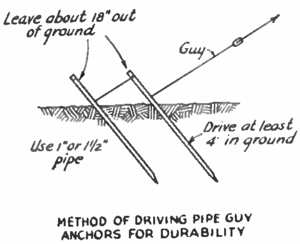


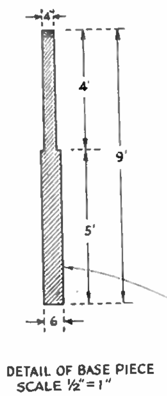
FIG. 609 — DETAILS OF A 40-FOOT MAST SUITABLE FOR ERECTION IN LOCATIONS WHERE SPACE IS LIMITED

World Radio History

forcement bolts. The bolts and washers should preferably be galvanized.

The cost of all material for this mast in this locality (southern Rhode Island) was only about $12.





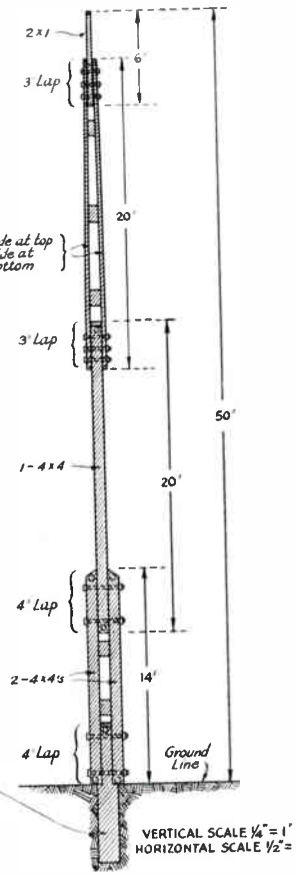


FIG. 610 — A 50-FOOTER OF HUSKY CONSTRUCTION. ONLY TWO GUY WIRES AT THE TOP ARE REQUIRED

Eight Constructional Hints

1. Saw sides of bottom piece (6 × 6) to accommodate lapping of the two 4 × 4's. See Figs. 1 and 2.

Note.—Most so-called 4 × 4's are usually about 3⅝" square.

2. Shed the tops of all pieces to allow rain to run off.

3. Bore necessary bolt holes in all pieces.

4. Install the reinforcement bolts with washers in ends of all pieces where necessary and tighten.

5. Lay all pieces on level ground in mast formation and insert bolts. Tighten all bolts except those for lapping the first two parallel 4 × 4's with the second 4 × 4.

6. Cut and fit the intermediate reinforcement pieces used in the two parallel sections and nail them permanently in place. They should be about one foot long.

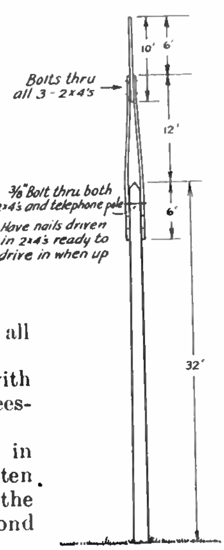
7. Get three or four soap boxes for horses and paint mast if you desire. Light gray makes a fine-looking mast.

8. Use at least ½" rope for raising any antenna and install a good pulley on top stick.

Guying of this type of mast is neither complicated nor costly. No. 14 or 12 steel wire will suffice for an ordinary single wire antenna. Small egg type strain insulators are best for breakers due to lapping of guy wire holes. They should be spaced about 12 feet.

As previously mentioned, only two back guys are necessary, each of these spaced 120 degrees from the antenna.

There are numerous methods of anchoring the guys but the most common are trees, fences and pipes driven in the ground. The latter method is shown. The guy anchors should be installed at least 30 feet from the base of the mast and driven at least four feet into the ground.



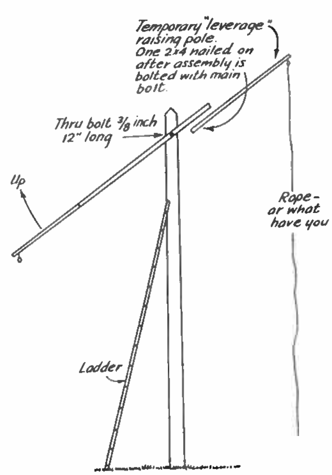


FIG. 611 — THIS TYPE MAY BE CARRIED TO A HEIGHT OF 50 FEET OR MORE. NO GUY WIRES ARE REQUIRED

World Radio History

Installation

Dig hole 5 feet deep for 6 × 6. This piece may be set in cement or reinforced by filling hole with rocks and tamping dirt around them. Use level to make sure base piece is vertical. Raise first two parallel 4 × 4's, and bolt in place to base piece. Raise remaining 40-foot section to vertical position beside the parallel 4 × 4's. It is not heavy and one man can easily accomplish this. While a brother ham holds the 40-foot section in place, climb a stepladder and tie a piece of rugged rope or wire loosely around the whole assembly about 2 feet down from the top of the parallel 4 × 4's. Hold this in place with a staple driven into one of the parallel 4 × 4's. This will serve as a safety guide while raising the 40-foot section vertically. Two men take one guy each and walk in opposite directions from base of pole to a distance of about 40 feet. Get a good hold under bottom of 40-foot section and raise vertically. Men on end of guys should allow plenty of freedom and yet not allow top to sway more than 12 inches or so. When bottom of this section reaches your waist, start walking up stepladder. If you are rugged, you can handle mast with one hand and hang on to stepladder with the other. However, if you are not rugged, someone should help you during this operation. When 40-foot section reaches the proper height, slide its base between the 4 × 4's and insert the two bolts for this lap. Tighten nuts and the mast is complete.

The mast shown in Fig. 611 was put up by W9LM at a cost of no more than $8. Only four persons were needed to put it up and no guy wires were used. It has stood up for a number of years through some strong winds.

A used telephone pole was purchased and delivered for $5. A hole 6 ft. deep was dug for it. About 2 ft. from the top of the pole a ½″ hole was bored. The lower section was raised by hand until ladders could be placed under it which served as gin poles. The top section consisting of 2 × 4's was assembled on the ground and a ½″ hole bored about 5 ft. from the lower end of the top section. The lower end of the top section was loosely bolted to the top of the lower section and swung up into position, as shown in the sketch, and spiked in place.

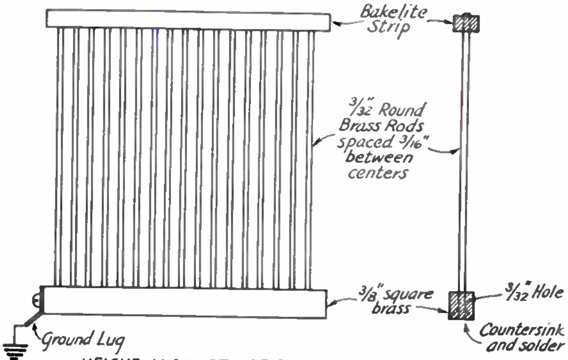


FIG. 612 — CONSTRUCTION OF THE FARADAY-TYPE SHIELD USING BRASS OR COPPER RODS

The upper ends of the rods may be fixed to the bakelite strip with Duco cement.

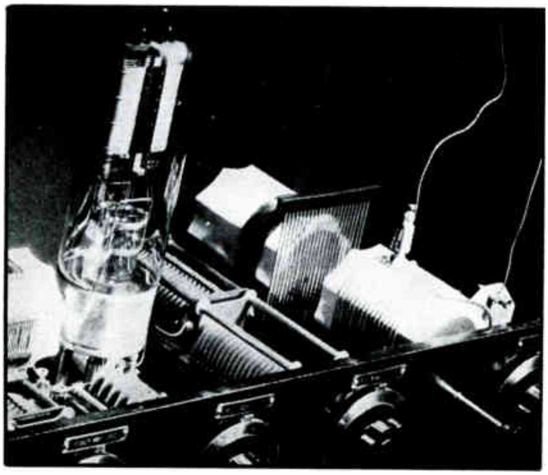


FIG. 613 — SHOWING THE MANNER IN WHICH THE SHIELD IS MOUNTED BETWEEN FINAL TANK AND ANTENNA COUPLING COILS

FARADAY SHIELDS

The use of Faraday or electrostatic shielding between the final amplifier tank and antenna tank circuits is discussed elsewhere. The construction of such a shield will vary with the coil arrangements of the final stage and the antenna circuit. One type which may be used in most cases is shown in Figs. 612 and 613. It consists of a series of closely spaced parallel rods or wires of size No. 12, or larger, connected together at one end by the ¼″ square brass rod in which the wires are mounted and insulated at the other end by a bakelite strip. In push-pull circuits, two shields, one for each end of the coil, are required as illustrated at *B*, Fig. 614. In cases where a shield in close proximity to the coil will interfere with coil changing, the metal strip may be fitted with plugs and plugged in after the coil is in place as shown at *C* and *D*, Fig. 614.

World Radio History

LOW CAPACITY NEUTRALIZING CONDENSERS

Low capacity neutralizing condensers for tubes such as the 35T, 808, T55 and other low capacity tubes are not difficult to construct. Two types are shown in Fig. 615. In *A*, two stand-off insulators are used to support two square or rectangular plates with sufficient spacing to prevent voltage breakdown and of sufficient area to provide somewhat more than the plate-grid capacity of the tube. Values of tube capacity may be taken from the tube tables of Chapter 5 and the capacity may be computed from the formula given in the Appendix. The capacity may be varied by swinging one plate or the other to one side. A spacer of metal or bakelite is used to give proper spacing.

The second type requires insulators of different heights, both of which are standard products. The plates shown are round, although this shape is not strictly necessary. Round plates may be made easily with the hole cutter. A strip of metal ½″ × 3⁄32″ or ⅛″ holds the top plate. It is tapped for the machine screw which provides the adjustment of capacity. The top plate should be countersunk on the under side for a flat head screw 3⁄16″ or ¼″ in diameter. The end of the screw is notched with a hacksaw for an adjusting screwdriver.

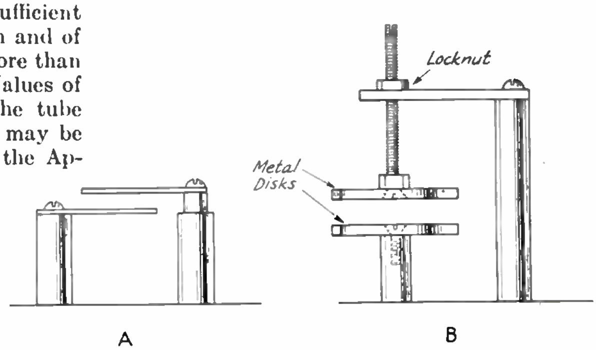


FIG. 615 — TWO TYPES OF LOW-CAPACITY NEUTRALIZING CONDENSERS OF EASY CONSTRUCTION

Refer to the text for dimensions.

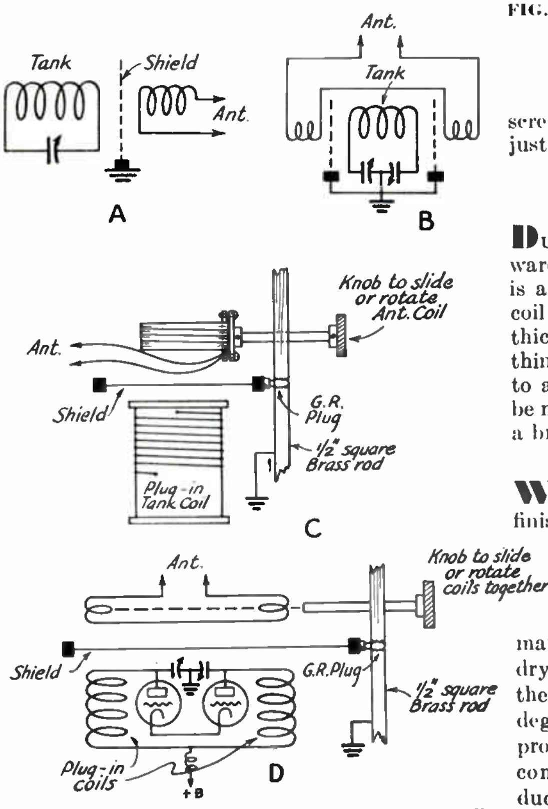


FIG. 614 — ARRANGEMENTS FOR USING THE SHIELDS WITH SINGLE-ENDED AND PUSH-PULL CIRCUITS

COIL CEMENT

Duco cement, obtainable universally at hardware, stationery or five-and-ten-cent stores, is a very satisfactory substance for fastening coil turns. For small coils, however, it is rather thick and a better-looking job will result if it is thinned out with acetone, sometimes referred to as banana oil. If desired, the solution may be made thin enough to permit application with a brush.

CRACKLE FINISH

Wood or metal parts may be given a crackle finish by applying one coat of clear Duco or Tri-Seal and allowing it to dry over night. A coat of Kem Art Metal Finish is then sprayed or put on thickly with a brush, taking care that the brush marks do not show. This should be allowed to dry for two or three hours and the part should then be baked in a household oven at 225 degrees for one and one-half hours. This will produce a regular commercial job. This finish comes in several different colors and is produced by the Sherwin-Williams Paint Co. and should be obtainable through any dealers handling Sherwin-Williams products.

World Radio History

CHAPTER SEVEN

RECEIVER DESIGN AND CONSTRUCTION

Regenerative and Superheterodyne Types — Modern Circuit Developments of Proved Performance

The success of the amateur station is fully as dependent on the receiving equipment as on the transmitter. You can't work stations unless you can hear them. It pays, therefore, to give just as much attention to the choice of a receiver as to the selection of a transmitting layout.

The availability of factory-made communications-type superheterodyne receivers in a wide price range is responsible for the fact that many amateurs prefer to buy rather than build receivers. It must be admitted that the more complicated sets can be purchased nearly as economically as they can be built, and often provide a degree of operating convenience which the home constructor finds it difficult to duplicate. Nevertheless, there is a definite field for home construction, especially where economy is an important consideration. Circuit features not feasible in manufactured sets intended for all types of buyers may be incorporated to increase performance without raising cost. Also, in the home-built receiver it is possible to control those characteristics — the degree of band-spread, for instance, or the type of circuit used — which must be accepted as presented in the manufactured receiver of comparable cost.

The receivers described in this chapter are types adaptable to amateur construction, with proved performance and economy as the keynote. In addition, as much attention as possible has been given to circuits which may be adapted to existing receivers to improve their performance.

TYPES OF RECEIVERS

Receivers for amateur communications frequencies — 1.75 to 30 Mc., inclusive — are of two general types, regenerative (autodyne) and superheterodyne. The basic arrangements are illustrated by the block diagrams of Fig. 701. The regenerative receiver may consist simply of a regenerative detector (described in Chapter Five) with or without an audio amplifier, as at Fig. 701-A, or it may incorporate a radio-frequency amplifier preceding the detector, as in 701-B. The regenerative receiver is used chiefly because of its low cost, particularly in the simpler types, and because it is relatively easy to construct and put into operation. It is therefore a favorite with beginners.

The superheterodyne receiver, depicted in essential form in Fig. 701-C, is capable of a much higher order of performance and hence is preferred by the more experienced amateur. In it, the frequency of the incoming signal is first changed to a value at which high amplification and more selective circuits can be used, then detected and made audible. Frequency changing is made possible because of the phenomenon of heterodyne action, or the generation of beats. If two signals of differing frequency are applied to the input of a detector, the output will contain not only the two original frequencies but also two new frequencies, one equal to the sum of and the other the numerical difference between the original two. In the superheterodyne, the output of a local oscillator of suitable frequency is applied to the *first detector*, or *mixer*, simultaneously with the incoming signal; the resulting beat is then amplified by the *intermediate-frequency (i.f.) amplifier*, and again rectified (see Chapter Five) by the *second detector*. The conventional communications-type superheterodyne uses an intermediate frequency in the neighborhood of 455 kc., and the "difference" frequency or beat is amplified. The local high-frequency oscillator is therefore tuned to a frequency differing from the incoming signal frequency by 455 kc., or whatever i.f. may be used. Common practice is to tune the oscillator 455 kc. higher than the signal, rather than lower, although either tuning may be used.

To make c.w. signals audible, heterodyne action again is used at the second detector through the use of a second local oscillator, the *c.w. beat oscillator*. The beat-oscillator frequency is adjusted so that it differs from the i.f. by some desirable audio frequency, such as 1000 cycles. It may be set, for instance, to 456 kc., if a 455-kc. i.f. is used. The same principle is employed in the reception of c.w. signals by a regenerative detector, the detector being

World Radio History

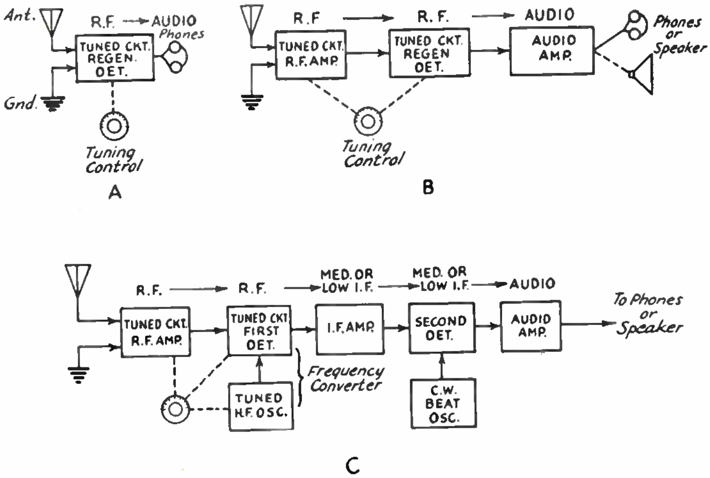


FIG. 701 — BLOCK DIAGRAMS SHOWING THE ESSENTIAL UNITS OF BASIC RECEIVER TYPES. A, SIMPLE REGENERATIVE; B, TUNED R.F. REGENERATIVE; C, SUPERHETERODYNE

made to oscillate at a frequency differing by 1000 cycles or so from the actual frequency of the incoming signal. Without heterodyne action, unmodulated c.w. signals would produce no audio response in the detector but would be heard merely as clicks or thumps.

A radio-frequency amplifier at signal frequency may be incorporated in the superheterodyne receiver to amplify the signal before mixing and to increase the selectivity. Fig. 701-C shows such an amplifier.

RECEIVER PERFORMANCE CHARACTERISTICS

The important general characteristics of a receiver are its selectivity, its sensitivity, its stability and its fidelity. These are interdependent, with selectivity the controlling factor. The *selectivity* is the receiver's ability to discriminate between signals of different frequencies. The *sensitivity* is the minimum r.f. voltage input required to give a specified useful output. The *stability* is the receiver's ability to maintain its output constant over a period of time with constant signal input. The *fidelity* is the proportionate response through the audio-frequency range required for a given type of communication.

Selectivity

The selectivity of a receiver is its most important characteristic, since it not only determines the receiver's ability to separate a desired signal of one radio frequency from undesired signals of other frequencies, but also it affects the sensitivity of the receiver, as will be explained later. The selectivity of a given receiver is determined primarily by the resonance characteristic of its tuned circuits, in accordance with the fundamental principles of resonant circuits described in Chapter Four. It is also affected by the frequency characteristic of the audio-frequency circuits following the final detector; in fact, audio-frequency selectivity may be quite effective in cases where deliberately-tuned audio combinations are used for c.w. telegraph reception.

The selectivity of a receiver is usually described by an overall resonance curve such as that shown in Fig. 702. This curve shows how many times stronger than the desired signal an interfering signal off resonance must be to give receiver output equal to that given by the on-resonance desired signal. It should be noted that the response scale of microvolt input ratios is in logarithmic steps. The curve is plotted this way because the logarithmic scale enlarges the input-ratio steps near resonance, where the selectivity characteristic is most important. The logarithmic microvoltage scale also corresponds with a uniform scale of decibel steps, the latter being noted at the right in Fig. 702. (Refer to the decibel chart and explanation in the Appendix.) This selectivity curve is for a standard amateur-type communication superheterodyne having 5 or 6 tuned i.f. circuits with transformer coupling, and represents typical selectivity for 'phone reception. It shows that an interfering signal 1.6 kc. off resonance would have to have twice the strength of the desired signal to give equal output, the curve being twice 1.6 kc. or 3.2 kc. in width at "two times down." It also shows that at 3.75 kc. off resonance the interfering signal would have to be ten times as strong as the desired signal to give equal output, or that the interfering signal of the same field strength would be only one-tenth as effective as the desired signal.

Sensitivity

The sensitivity of a receiver is fundamentally limited by what is termed the "noise level." It is not simply a matter of amplification. Only signals that are readable above the noise background at the receiver output are useful. This noise background has its source in atmospheric disturbances or static, in commercial and domestic electrical equipment, and in the receiver itself. If there should be no external

World Radio History

sources of noise interference, the receiver's own noise level would be the ultimate factor determining the receiver's effective sensitivity. This noise may be composed of hum from the power supply, and of hiss resulting from electronic variations in the conductors of the radio-frequency circuit and from irregularities which are inevitable in the electron flow within the radio-frequency vacuum-tube amplifier or detector. Thus the input circuit noise (*thermal agitation*), and the first tube noise (*shot effect, flicker effect, ionization*) remain as the ultimate noise limiting sensitivity, since the noise is amplified subsequently with the signal. This noise takes the form of a "hiss" sound in the output of the receiver.

The minute overlapping impulses which go to make up this hiss noise are uniformly distributed over a given section of the radio-frequency spectrum, and combine in voltage at the receiver output as the square root of the sum of the squares of the individual pulse voltages. Hence, this type of noise is reduced when the width of the frequency pass-band of the receiver is reduced. From this it is evident that the selectivity of the receiver is highly important in determining the effective sensitivity as well as in giving it discrimination against unwanted radio signals. Actually, the noise *power* output is directly proportional to the receiver's effective band-width, or inversely proportional to its selectivity; while the r.m.s. noise *voltage* output is proportional to the square-root of the effective band-width.

For describing the effective sensitivity of a receiver in terms of its own noise level, the term *noise equivalent* is used. *The noise equivalent (N.E.) of a receiver is the c.w. signal input in microvolts required to produce an output equal to the receiver noise output.* In amateur type superheterodynes of good modern design the noise equivalent should be below 0.5 microvolt for i.f. selectivity of the order shown by the curve of Fig. 702, and should be well below 0.1 microvolt for receivers with crystal-filter selectivity.

Stability

The stability of a receiver is principally a matter of its ability to stay tuned to a steady signal once the controls have been set, and therefore essentially involves radio-frequency constancy. In regenerative receivers the stability of the detector circuit is of prime consideration, while in superheterodyne receivers oscillator stability is of first importance. The frequency stability requirements become more rigorous with high selectivity, especially in receivers using crystal filters, since variations of but a few cycles can cause a relatively large change in output. The stability is affected by variation in temperature of the circuit elements, mechanical irregularities, supply voltage variations, and other factors which require special consideration in designing the circuits.

Fidelity

The fidelity requirement in amateur receivers is essentially different from broadcast receiver requirements, although this is not generally realized, and is set by the minimum required for intelligibility. For c.w. telegraph reception of hand-keyed signals (say up to 30 words per minute) adequate fidelity for intelligible reception can be obtained with selectivity such that the receiver's effective band width (the "measuring stick" for selectivity) is but 50 cycles or less; for 'phone reception with usable intelligibility the band width must be proportionately greater, although still considerably less than for good-quality broadcast reception. It is therefore evident that the most important receiver characteristic is the effective selectivity; for the higher the selectivity, the greater can be the amplification and the higher the effective sensitivity, to the limits imposed by the requirement of intelligible output.

TUNING SYSTEMS

Since the amateur frequency-bands comprise narrow slices of territory widely separated, it is not possible to cover them all effectively with one coil and condenser in the tuning system. Many schemes have been evolved to provide interchangeable coils. The use of a special form plugging into a tube socket is almost universal in amateur-built

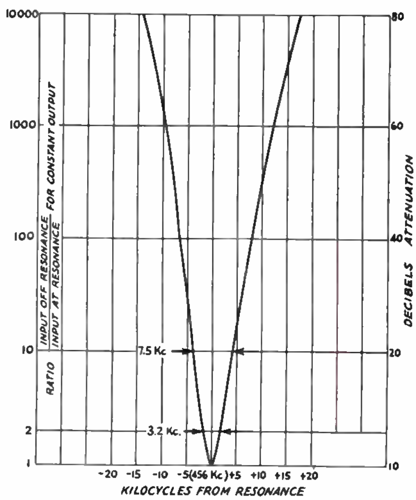


FIG. 702 — A TYPICAL RECEIVER SELECTIVITY CURVE OBTAINED BY PLOTTING MICROVOLTS INPUT, AT VARIOUS INTERMEDIATE FREQUENCIES, REQUIRED TO GIVE CONSTANT AUDIO OUTPUT; THE TEST SIGNAL IS OBTAINED FROM A STANDARD SIGNAL GENERATOR

World Radio History

receivers. Coils of this type are pictured later on with the constructional details of the receivers in which they are used.

More complicated receivers, in which a number of tuned circuits must be changed for each range, employ coil switching systems or plug-in "gangs" containing three or four coil units for each range. These units are hardly adaptable for amateur construction and are more economically purchased than they can be made up by the constructor.

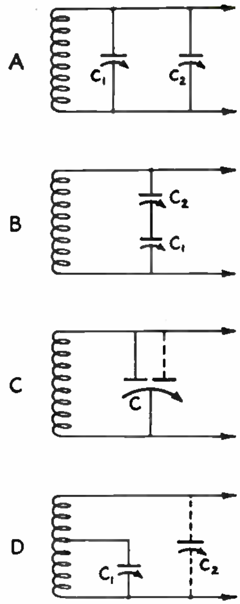


FIG. 703 — ESSENTIALS OF BAND-SPREAD TUNING SYSTEMS

Circuit Constants

The frequency range covered by a coil and condenser combination will be determined by the inductance of the coil across which the capacitance is effective, the minimum value of the effective capacitance and the maximum value of the capacitance. The inductance will, of course, be determined principally by the number of turns, length of winding and diameter of the coil, but will be affected more or less by coupling to another coil and by the presence of shielding and other conductors in its field. For practical purposes the value of inductance calculated either by the formulas given in Chapter Four or by the *Lightning Radio Calculator* can be taken, provided the shielding is spaced from the coil by a distance equal to the coil radius.

The maximum frequency limit for a given coil will be set by the minimum capacitance, which includes the minimum of the tuning condenser plus the tube and stray circuit capacitance. An allowance of 20 to 30 $\mu\mu$fd. usually can be assumed for this minimum. This is increased by "loading" with a trimmer condenser, or a "tank" condenser, in parallel with the main tuning condenser. There is an almost infinite variety of combinations possible, of course, which accounts for the wide differences in tuning combinations given for receivers of various designs.

Band-Spreading

In amateur receivers it is desirable that the tuning range be adjusted so that practically the whole scale of the tuning dial is occupied by the frequency band in use. This "band-spreading" gives the greatest ease in tuning that is possible with the particular dial or mechanical system employed, and also makes calibration easier because each dial division represents a relatively small frequency interval. The simplest method of band-spreading is to use a tuning condenser of such capacity range that the band is just covered by rotating the condenser from minimum to maximum capacity.

The amateur bands are not entirely in harmonic relation, however, and therefore a condenser which spreads one band satisfactorily may not give the same spread on others. In order to make each band cover a large number of dial divisions, the ratio of maximum to minimum capacity must be different for each band.

Several basic band-spreading schemes are shown in Fig. 703. At *A* is the parallel-condenser method. C_1 is the tuning condenser, usually with a maximum capacity of about 25 $\mu\mu$fd. C_2 is a "band-setting" condenser; its maximum capacity should be at least 100 $\mu\mu$fd. and may be larger. The setting of C_2 will determine the minimum capacity of the circuit, and the maximum capacity will be the maximum capacity of C_1 plus the setting of C_2. A different maximum-to-minimum capacity ratio can be chosen to give good band-spreading on each band.

The series-condenser method is shown at *B*. As explained in Chapter Four, the total capacity of two condensers in series is less than that of either. C_1 again is the tuning condenser. It should have 100 $\mu\mu$fd. or more maximum capacity. C_2 is the band-setting condenser and is preferably small, perhaps 25 $\mu\mu$fd. The maximum-minimum capacity ratio in the circuit will be determined by the setting of C_2. The minimum capacity changes very little for any setting of C_2, but the maximum capacity can be varied over quite a range, depending upon the ratios of the capacities of the two condensers.

At *C* is another arrangement which makes use of a "split-stator" tuning condenser — one with two separate stationary-plate sections and a single rotor. One of the stator sections is made small enough to give good band spreading on the narrower bands, and the second stator section, when connected in parallel with the small stator, will give good spread on the wider bands.

The tapped-coil system at *D* is used in several manufactured amateur-band receivers and has also been adopted by many amateurs in home-built sets. Condenser C_1 may be fairly large — 100 $\mu\mu$fd. or so — but will give good spread on any band if the right size of coil is chosen and the tap to which the stator plates of the condenser are connected is made at the right place. Trimmer condenser C_2 is the

World Radio History

"band-set" condenser. It should have a maximum capacity of 25 to 100 μμfd.

Fixed Condensers and Resistors

In both audio- and radio-frequency circuits there will be found fixed condensers connected across resistors, from plate to filament and even across portions of the circuit that appear in the diagram to be directly connected. These are *by-pass* condensers, provided to give a direct path for audio- or radio-frequency currents and to prevent these currents from flowing through other paths where they might cause undesirable degenerative or regenerative effects. In other cases fixed condensers are used to serve as paths for audio- or radio-frequency currents while preventing the flow of direct current, in which case they are known as *coupling* or *blocking* condensers. Small mica or non-inductive paper-dielectric condensers of from 100 μμfd. to 0.1 μfd. capacity are commonly used for r.f. circuits, while capacities of from 0.01 to several μfd. are used in a.f. circuits. The particular size used will be determined by the impedance across which the condenser is connected, being smaller in capacity as the parallel impedance is greater. In the case of r.f. by-passes in circuits intended to transmit audio frequencies, as in the plate circuit of a detector, the capacity must be kept small enough so that the condenser will not by-pass audio frequencies also. Typical values are 0.001 μfd. and smaller. Audio-frequency by-pass condensers, on the other hand, usually have values ranging from ¼ μfd. to 8 or 10 μfd.

Fixed resistors are also used, in a wide variety of sizes, to provide bias voltage, to drop plate voltage, to serve as coupling loads in audio circuits and to decouple in both radio- and audio-frequency grid- and plate-return circuits. Values for resistors to provide bias voltages and to drop plate voltages depend on the current flowing through them and are determined from Ohm's law, as shown previously. Plate- and grid-coupling condenser and resistor values depend primarily on the tube combination with which they are used, values shown in circuits described in this chapter being typical. Decoupling resistor and condenser combinations are not critical as to value. Usually such circuits are necessary only in high-gain amplifiers of two or more stages.

Radio Frequency Shielding

The purpose of shielding is to confine the magnetic and electrostatic fields about coils and condensers so that those fields cannot act on other apparatus, and to prevent external fields from acting upon them in turn. Chapter Three has explained the nature of these fields. They can be confined by enclosing the apparatus about which the field exists in a metal box. The effectiveness of the shield depends upon the metal of which it is made and upon the completeness of contact at the joints. At radio frequencies the best shield is one made of a low-resistance non-magnetic metal, such as copper or aluminum, because the losses in it will be low. The high frequency magnetic fields about the apparatus enclosed in the shield cause currents to flow in it, and since the flow of current is always accompanied by some loss of energy the shield in effect causes an increase in the resistance of the tuned circuit. The lower the resistance of the shielding material the lower will be the energy loss. At low frequencies, such as those in the audio range, copper and aluminum are ineffective for shielding.

The increase in resistance caused by shielding also depends upon the proximity of the apparatus inside the shield to the walls. Coils in particular should be spaced from the walls in all directions by a distance at least equal to the coil radius. For this reason small diameter coils are much to be preferred to large ones if the set is to be kept reasonably small. The losses in the shielding due to electrostatic fields are negligible in comparison to those caused by magnetic fields, so condensers can be mounted right on the walls of the shield if desired.

To be effective a shield must be grounded. Connecting the shielding to a point in the receiver at zero or "ground" r.f. potential, such as the negative side of the plate supply, is usually sufficient.

REGENERATIVE DETECTOR CIRCUITS

In the regenerative receiver a number of arrangements of the tickler coil and feed-back control in the detector circuit can be used to give similarly loud signals, but some of them are more convenient and permit adjustment of regeneration without detuning the signal. It is an advantage if the regeneration control is absolutely quiet in action; if it permits a gradual adjustment up to and past the point of oscillation; and if it permits the tube to oscillate gently all across the frequency band on which the receiver is working, without the necessity for touching anything but the tuning control.

Fig. 704 shows the circuits of regenerative detectors of various types. The circuit of *A* is for a triode tube, with an adjustable resistor in the d.c. plate feed to vary the plate voltage on the tube and thus to control regeneration. If both coils are wound in the same direction, the plate connection is to the outside of the tickler coil when the grid connection is to the outside of the tuned circuit.

The circuit of *B* is for a screen-grid tube as the detector, regeneration being controlled by

World Radio History

adjustment of the screen-grid voltage. The tickler is in the plate circuit. As in the circuit of *A*, the portion of the control resistor between the rotating contact and ground is by-passed by a large condenser (0.5 μfd. or more) to filter out scratching noise caused by variation in contact resistance when the arm is rotated. The screen-grid detector has somewhat greater gain than the triode, but requires more critical circuit adjustment. The tickler should be adjusted so that the tube just goes into oscillation at a screen voltage of approximately 30 volts. The circuit of *C* is also for a screen-grid type tube, but uses a variable by-pass condenser for regeneration control, the screen-grid voltage being fixed. This condenser usually has a maximum capacitance of 100 or 150 $\mu\mu$fd. When the capacitance is too small the tube does not regenerate, but as it increases toward maximum the reactance between the positive *B* side of the tickler and ground becomes smaller until a critical value is reached when there is sufficient feed-back to cause oscillation. This method of control is quiet and smooth in operation when the size of the tickler and coupling to the grid coil are carefully adjusted.

The circuit of *D* differs from that of *B* only in that the feed-back winding is in the cathode-to-ground circuit, being actually part of the tuned circuit coil. This places it effectively in the plate circuit (plate to ground and thence to the cathode), so that the action is much the same. However, the tickler is also in the screen-to-cathode return circuit, and the screen operates to furnish feed-back as a sort of auxiliary plate. Hence a smaller tickler winding is required to give proper regeneration and oscillation. The circuit of *E* is the same as that of *D*, except that a separate feed-back winding is used. This eliminates the necessity of tapping the cathode into the main coil.

In all methods it is best that the tickler be mounted or wound at the "ground" end and not the grid end of the tuning coil. In the interests of smooth control it will be found advisable to use just as few turns on the tickler as will allow the tube to oscillate easily all over the tuning range. If the tube starts oscillating with a sudden thump instead of a smooth rushing noise, a different value of grid leak resistance should be tried.

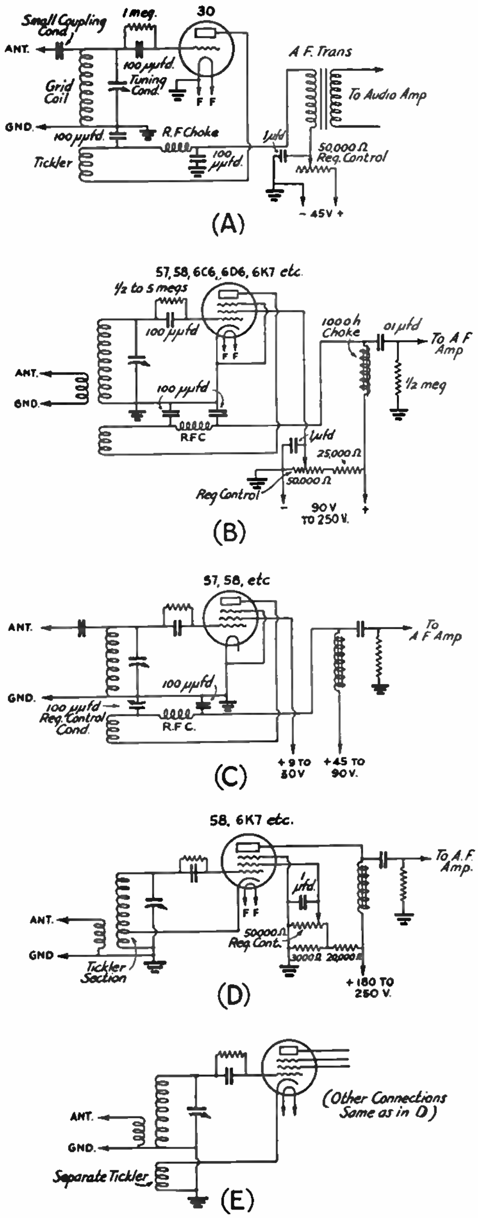


FIG. 704 — TRIODE AND PENTODE (SCREEN-GRID) REGENERATIVE DETECTOR CIRCUITS

A ONE-TUBE REGENERATIVE RECEIVER

THE regenerative receiver's appeal for the beginner lies in its simplicity and low cost. These two features are exemplified in the receiver pictured in Figs. 705 and 707, the circuit diagram for which is given in Fig. 706.[1] Its simplicity makes it almost certain to work at the first trial, even for a totally inexperienced beginner. Although only one tube is used, many of the requirements for satisfactory amateur-band operation are met. Through the use of a double-triode tube with one section as detector and the other as audio amplifier, sufficient amplification is provided for good headphone reception. Tuning is made easy because the bands are spread

World Radio History

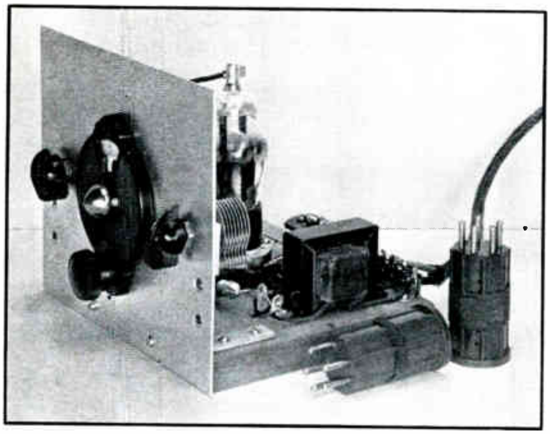


FIG. 705 — A ONE-TUBE REGENERATIVE RECEIVER

Coils for the 80- and 40-meter bands are shown at the side. The dial in center of panel is the band-spread tuning control, with regeneration control knob at right and band-setting control at left.

over most of the scale of the vernier tuning dial.

The receiver is built on a wooden base 6¾ inches long, 5½ inches deep, and 1 inch thick. The 1⁄16-inch aluminum panel for the set measures 6 inches high by 7 inches long. The panel is fastened to the base by two ¾-inch wood screws, and in addition, two angle brackets with 1½-inch legs are screwed to base and panel to increase the rigidity of the assembly.

The 3-inch vernier dial on the center of the front panel is the band-spread tuning control. The pointer knob at the left is on the band-setting condenser, C_1, while that at the right is the regeneration control condenser knob. The three are mounted in a straight line, with holes centered 2½ inches apart, three inches above the bottom edge of the panel.

After the panel has been attached to the baseboard and the condensers are in place, the tube socket is mounted on the center of the base. This socket is held to the base, on the mounting pillars supplied with it, by two 1¼-inch wood screws. The key slot is pointed directly toward the rear of the baseboard, as it is shown in the circuit diagram.

The audio transformer and the coil socket are placed somewhat nearer the rear edge of the base. The audio transformer is mounted with primary connections at the side of the receiver and secondary connections near the tube socket. The spaced pin of the coil socket is located at the side opposite the primary connections of the audio transformer, so that it is possible to make direct connections to the terminals.

The three condenser rotors are grounded to the aluminum panel. The stators of C_1 and C_2 are connected together. A short wire is used to connect the C_1 stator to the grid end of L_1. The grid leak and grid condenser, R_1 and C_5, with terminal leads connected in parallel, are soldered to the stator of C_2 at one end and to the grid cap of the tube at the other.

For convenience in following the wiring of the set, the diagram is arranged with the socket connections just as they appear from above, so it is not necessary to consult a tube data sheet for the various lug connections.

A four-conductor cable is used for heater and plate power connections, and to fasten the cable to the baseboard a four-lug terminal strip is screwed to the board at the rear edge. For the headphone tips, a two-terminal strip is provided, mounted also at the rear edge of the base.

In the diagram, the antenna post of the receiver is shown coupled to the grid end of the coil, L_1. Actually, it is not necessary to provide an antenna binding post; this purpose is served by simply twisting the antenna lead-in wire with a piece of insulated wire approximately 6 inches long, the end of which is connected to the grid lug of the coil socket. The insulated twisted wires form a

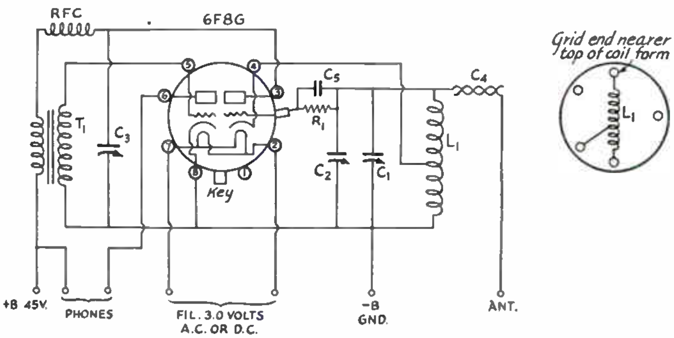


FIG. 706 — CIRCUIT DIAGRAM OF THE ONE-TUBE RECEIVER

C_1 — 75-μμfd. band-setting midget condenser (Cardwell ZU75AS).
C_2 — 10-μμfd. band-spread midget tuning condenser (Cardwell ZR10AS).
C_3 — 75-μμfd. midget regeneration control condenser (Cardwell ZU75AS).
C_4 — Insulated wire-ends, twisted (see text).
C_5 — 0.0001-μfd. fixed mica condenser (Aerovox).
R_1 — 2-megohm, ½-watt resistor (IRC).
RFC — 2.5-millihenry choke (National R-100).
T_1 — 3:1 audio transformer (Thordarson T-13A34).

World Radio History

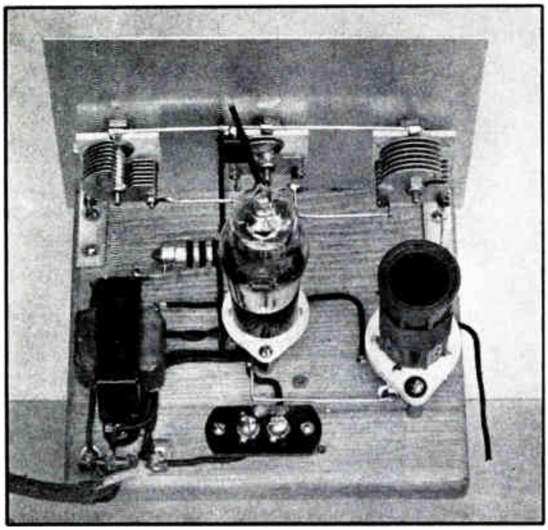


FIG. 707 — REAR VIEW OF THE ONE-TUBE RECEIVER, SHOWING WIRING AND PLACEMENT OF PARTS
This view clearly shows the simplicity of the assembly.

coupling condenser, the capacity of which may be increased by increasing the length of wire in the twisted pair. For an antenna of approximately 50 feet, two turns should be sufficient.

Although the heater rating of the 6F8G is 6.3 volts, best operation of the tube in a receiver of this type is obtained with 3 volts. A supply of two dry cells, or the portion of a 6.3-volt winding between center-tap and one end is quite suitable.

If the specifications given in the coil table are carefully followed, the receiver should operate properly at the first test. Due to differences in the characteristics of tubes of different make, however, it may be found necessary to move the cathode tap on the coil. This tap should be fixed on each coil so that the set goes into regeneration (as indicated by a light rushing noise) near the middle setting of the regeneration control condenser, C_3. If it is impossible to hear any signals, particularly during the evening hours, or if 'phone stations can be received without any regenerative "squeal," the cathode tap on the coil should be moved nearer the grid, or top end. If, on the other hand, signals are received but it is found impossible to stop the regenerative whistle by rotating C_3, the tap should be moved nearer the ground end of the coil.

The coils are designed so that each amateur band is spread over a large part of the dial range. To set C_1 to the proper position for coverage of a band, C_2 should first be set to minimum capacity and C_1 should be rotated from minimum capacity toward maximum until the high-frequency edge of the amateur band is reached. During active hours it should not be difficult to find the bands. When the position of C_1 corresponding to the high-frequency edge of the band is found, the condenser should be adjusted to a slightly lower capacity so that a small margin on each end of the band will be available on the tuning dial.

A suitable antenna length is 50 feet, although other lengths may be used. It is desirable that the antenna be non-resonant on the amateur bands so that no trouble will be experienced in holding the regeneration at a fixed level.

COIL DATA FOR THE ONE-TUBE RECEIVER

	Total No. Turns	*Total Winding Length*	*No. Turns Between Tap and Ground*
1.75-Mc. band	110	Turns close-wound	12
3.5-Mc. band	45	Turns close-wound	6
7-Mc. band	14	Turns close-wound	2
14-Mc. band	7	¾ inch	2
28-Mc. band	5	¾ inch	2

All coils are wound of No. 30 d.s.c. wire on ribbed 5-prong forms, 1¼-inch diameter by 2-inch winding length.

A TWO-TUBE REGENERATIVE RECEIVER

Figs. 708, 710 and 711 show a two-tube regenerative receiver which is thoroughly practical for everyday station operation.[2] A pentode regenerative detector is used for maximum sensitivity, followed by a triode audio amplifier for good headphone volume. It may be used with either storage-battery or a.c. filament supply, with a 90-volt "B" battery recommended for the plate supply. It is inexpensive and simple to construct. The circuit diagram is given in Fig. 709.

With the exception of the controls and the headphone jack, all the parts are mounted on a wooden baseboard with side pieces which raise it part way up the panel, forming a compartment underneath. The baseboard measures 6 by 10 inches and the side pieces 6 by 2 inches; all are made of half-inch thick soft wood, and are fastened together with finishing nails.

The top view of the set shows clearly how the parts are arranged on the baseboard. The sockets for the two tubes project partly through the base, the mounting rings being flush with the top. Each hole should be just large enough — about 1½ inches in diameter — to pass the socket, and the centers should be 2¼ inches back from the panel and 2¼ inches in from the edges of the baseboard. The detector tube socket, at the left, has a tube shield fastened to it. This shield is necessary to

World Radio History

prevent "induction" hum pickup from nearby house wiring. The sockets are held down by small wood screws.

The coil socket is midway between the two tube sockets, and is centered 3 inches behind the panel. This socket is mounted on the small porcelain pillar furnished with it, thus keeping the coil-socket wiring above the baseboard so that connections can be run directly to the various condensers and terminals. The wiring is clearly shown in the photograph, and is further explained in Fig. 712. The antenna condenser, C_3, is fastened directly to the baseboard just to the rear of the coil socket. The Fahnestock clips at the rear edge are the antenna and ground terminals.

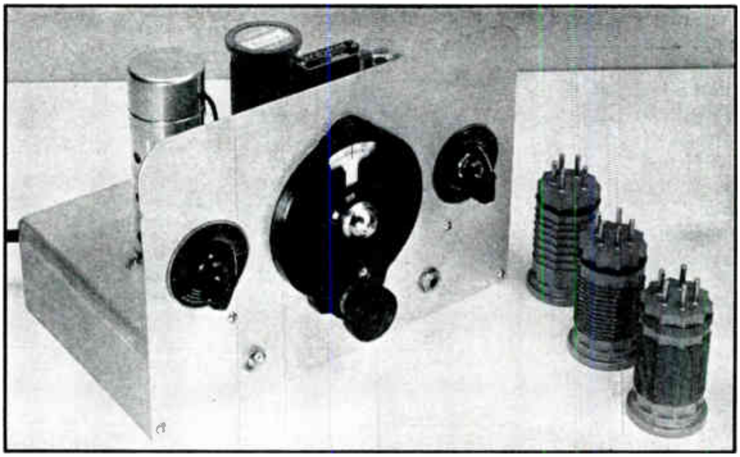


FIG. 708 — A PANEL VIEW OF THE TWO-TUBE REGENERATIVE RECEIVER AND SOME OF THE PLUG-IN COILS

The only remaining part on top of the baseboard is the audio coupling choke, L_3. It is mounted, as shown, just behind the amplifier tube. Holes must be drilled in the base so that the two connection lugs can project through.

The arrangement of parts on the panel will become clear after inspection of the front and top views. The main tuning condenser, C_1, is in the middle, the mounting hole being drilled 4 inches from the bottom edge. The band-setting condenser, C_2, and the regeneration-control resistor, R_5, are at the same height, with C_2 1½ inches from the left edge of the panel and R_5 the same distance from

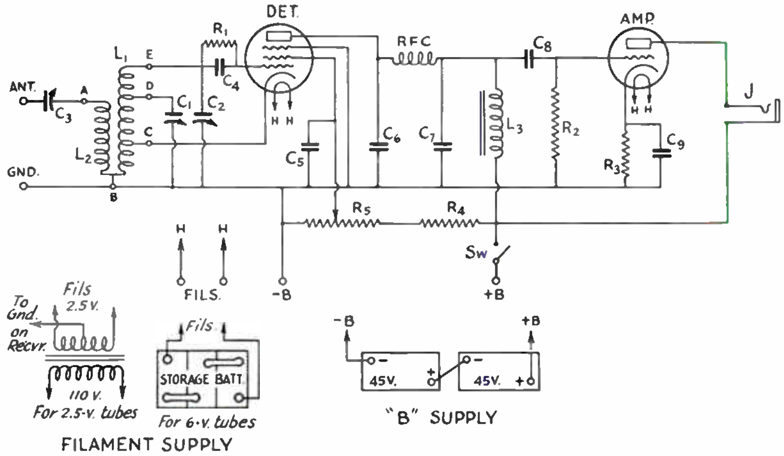


FIG. 709 — CIRCUIT DIAGRAM OF THE TWO-TUBE RECEIVER

C_1 — 35-μμfd. receiving variable condenser (Hammarlund MC-35-S)
C_2 — 140-μμfd. receiving variable condenser (National Experimenters' Type)
C_3 — 70-μμfd. mica trimmer condenser (Hammarlund BBT-70)
C_4 — 100-μμfd. midget mica condenser (Aerovox)
C_5 — 2-μfd. electrolytic, 450-volt (Aerovox PBS-2)
C_6, C_7 — 100-μμfd. midget mica (Aerovox)
C_8 — 0.01-μfd. tubular paper, 400-volt (Aerovox)
C_9 — 5-μfd., 25-volt electrolytic (Cornell-Dubilier ED-2050)

R_1 — 5 megohms, ½-watt (I.R.C.)
R_2 — 0.5 megohm, ½-watt (I.R.C.)
R_3 — 2000 ohms, 1-watt (I.R.C.)
R_4 — 25,000 ohms, 2-watt (I.R.C.)
R_5 — 50,000-ohm potentiometer (Centralab)
RFC — 2.5-millihenry r.f. choke (National R-100)
J — Open-circuit jack
Sw — S.p.s.t. toggle switch
L_3 — Audio choke, 1080 henrys at 0.5 ma. (Thordarson T-52C98)

World Radio History

TWO-TUBE RECEIVER COIL DATA

No.	Total Frequency Range, Kc.	Amateur Band, Mc.	Total Turns L_1	Cathode Tap	Band-Spread Tap	Turns, L_2
1	1200–3200	1.75	60	4	*	10
2	2650–7000	3.5	27	1¼	*	10
3	5500–15,500	7.0	13	¾	8	5
4	9100–27,750	14.0	7	½	3	4
5	15,750–47,000	28.0	3	⅓	1	1

All coils are wound with No. 24 d.s.c. wire on Hammarlund SWF 5-prong forms, diameter 1½ inches. The length of each coil is 1½ inches. The caps are counted off from the lower terminal (B) of L_1. The third column indicates the amateur band for which the coil will give band-spread over most of the tuning dial. Antenna coils are close-wound, separated from L_1 by about ¼ inch. The direction of winding is unimportant.

* No tap; C_1 is connected to the top of L_1 through a jumper connecting pins D and E in the coil form.

the right-hand edge. The "B" on-off switch and the 'phone jack, at the left and right respectively, are 1 inch from the bottom of the panel and 2½ inches in from the edges. The panel is of 1/16-inch aluminum and is 7 by 10 inches.

All the parts on the panel can be mounted directly except the 'phone jack, which must be insulated by washers which are obtainable for that purpose. Although other materials than aluminum could be used, the panel should be of metal in order to act as a shield between the operator's hand and the receiver circuits, thus preventing "body-capacity" effects which cause a shift in the receiver tuning when the hand is brought near the radio-frequency circuit.

The receiver parts mounted underneath the baseboard can be identified readily in Fig. 711. Although the exact placement of parts is not critical, the general arrangement shown should be followed. A four-wire cable, fastened to the left-hand side-piece in the bottom view, provides connections to the filament and "B" supplies. Fig. 712 gives the socket connections for the detector and amplifier tubes; the detector socket should be mounted with the heater prongs toward the bottom (rear edge) of the base, while the heater prongs on the amplifier socket should be toward the upper right corner.

The panel serves as the connection between the rotor plates of C_1 and C_2. The other connections in the r.f. circuit are made by bus wire as shown in Fig. 710. The ground connection (B) on the coil socket is made to the rear end-plate of C_1. A connection also is brought from the detector shield to this point so that the shield will be grounded. The left-hand terminal of R_5 (viewed from the front) goes to a soldering lug on the baseboard as shown in the top view. This lug is held in place by a machine screw which passes through the baseboard and similarly connects to R_4 underneath. The center terminal of R_5, the moving contact, goes through a hole in the base and thence to the screen-grid terminal of the detector socket. The right-hand terminal of R_5 connects to the panel through a soldering lug which is under one of the wood-screws holding the panel to the base. The wood-screw on the other side holds another soldering lug to which connections can be made from underneath the base.

The grid condenser, C_4, and grid leak, R_1, are mounted on the upper stator terminal of C_2, being soldered directly to the lug. It is desirable to keep the lead to the grid cap of the tube as short as possible, and close to the tube shield, to minimize the induction hum already mentioned.

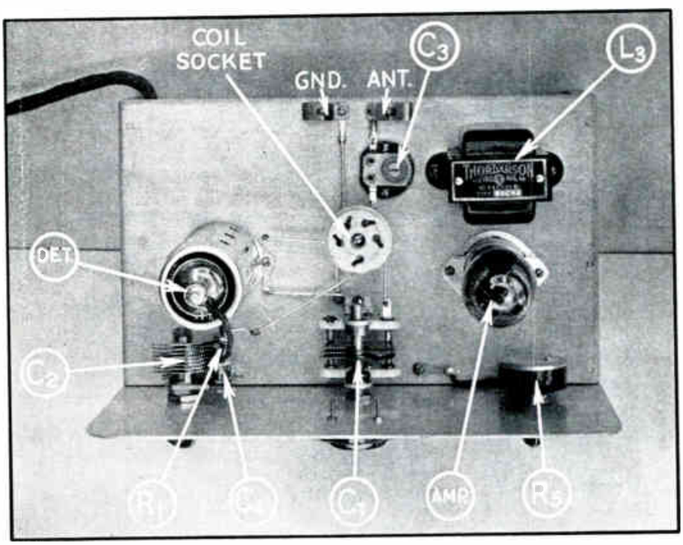


FIG. 710 — PLAN VIEW OF THE TWO-TUBE RECEIVER

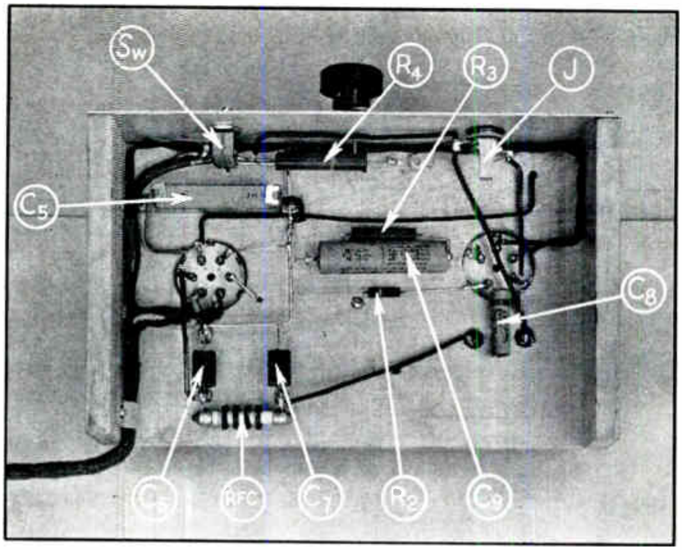


FIG. 711 — BOTTOM VIEW OF THE TWO-TUBE RECEIVER

Underneath the baseboard, the "L"-shaped piece of bus wire is the common negative-"B" or "ground" connection. It starts at a lug just below the detector socket, to which one side of C_6 also is connected, and runs up toward the panel to the soldering lug under the screw holding the panel in place.

In connecting condensers C_5 and C_9, be sure that the "plus" terminal on C_5 goes to the screen-grid prong on the detector socket and on C_9 to the cathode terminal on the amplifier socket. The "minus" terminals should connect to the common ground wire.

The winding data on the coils are given in the table, while Fig. 712 illustrates the method of construction. All L_1 windings are made exactly the same length, 1½ inches. On all except Coil No. 1 the turns must be spaced evenly to fit the length; No. 1 is close-wound. The taps are made by drilling a hole at the appropriate place, feeding the wire through to the proper pin and cutting it off; then a new piece with its end fastened in the same pin (and going back out through the same hole) continues the winding. When the coils are finished, the windings should be coated with Duco cement or similar adhesive along the coil-form ridges.

The main tuning dial is one with a variable "vernier" ratio so that the tuning can be rapid or slow as the operator wishes. The slow movement is desirable for fine tuning.

Pointer knobs and dial plates are used for the band-setting and regeneration controls. The band-setting dial plate has a semi-circular scale with divisions running from 100 at the left-hand side to 0 at the right. The knob should be set so that with the condenser plates all out the pointer is at 100 on the scale. The settings specified later for the amateur bands are given in terms of this type of dial plate and condenser setting.

If a.c. heater supply is to be used tubes with 2.5-volt heaters are recommended in preference to the 6-volt types, since the latter usually give some hum in a regenerative receiver. Either the 57 or 58 may be used as the detector, and the amplifier should be a 56. If a 6-volt storage battery is to be used for heater supply, the detector tube should be a 6C6 or 6D6, and the amplifier a 76.

Fig. 709 shows how to connect two 45-volt "B"-battery units to the receiver. The "B" voltage is not critical; the receiver will, in fact, operate well with only one 45-volt unit, although the volume will be somewhat reduced as compared with two. A regular "B" eliminator or power pack also can be used but is not particularly recommended, since such a supply frequently introduces "tunable hum" with simple receivers of this type. Tunable hum is caused by the power circuit's tending to act as part of the r.f. circuit at some frequencies and thereby introducing hum on the detector grid.

When a transformer is used for heater supply, the center-tap of the secondary winding should be connected to ground, as shown in Fig. 709. This connection balances out hum from the filaments. The actual connection may be made to the negative terminal of the "B" battery for convenience.

After the set is completed and the wiring checked, insert the coil which covers the band between 1200 and 3200 kc. (No. 1) in the coil socket, set C_2 at about half scale, and connect the heater supply, headphones, antenna and ground. After the tubes have lighted, the "B" battery may be connected. Make sure *Sw* is closed.

Now turn the regeneration control knob until the set goes into oscillation. This phenomenon is easily recognizable by a distinct click, thud or hissing sound. The point where oscillation just begins is the most sensitive operating point at that particular tuning-dial setting. If the set refuses to oscillate, the sensitivity will be poor and no code signals will be heard. It should oscillate easily, however, if the coils are made exactly as shown. At frequencies to which the antenna system is

World Radio History

resonant, however, the antenna may "load" the detector so heavily that it cannot oscillate; this effect may be overcome by reducing the capacity of C_3. For any given band of frequencies, adjust C_3 so that the detector oscillates over the whole range, using as much capacity at C_3 as is possible. This will give the best compromise between "dead spots" and signal strength.

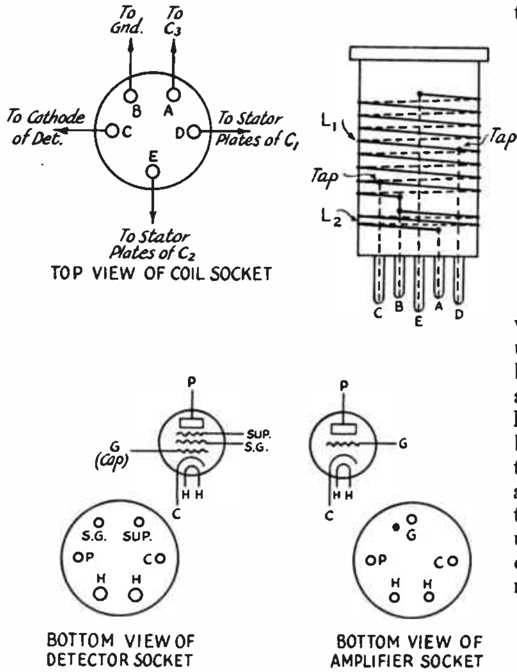


FIG. 712 — TUBE AND SOCKET CONNECTIONS FOR THE TWO-TUBE RECEIVER

The method of winding the coils also is indicated.

To cover the 1750- to 2050-kc. amateur band, C_2 should be set at about 70 on the scale, the exact setting being determined experimentally. Further tuning then should be done with the band-spread dial. The 3500- to 4000-kc. band will be found on Coil No. 2 with C_2 at about 50 on the scale. On Coil No. 3 the band will be found when C_2 is set at about 45; on Coil No. 4 about 60; and on Coil No. 5 about 75.

A suitable antenna for the receiver would be 50 to 75 feet long, as high and clear of surrounding objects as possible. A ground connection to a heating radiator or water piping will be satisfactory.

Speaker Output Stage for Two-Tube Receivers

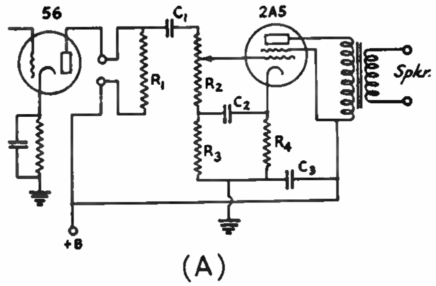
If increased audio output for loud-speaker operation is desired with either of the foregoing receivers, a pentode power stage can be added. This is feasible only with a.c. power supply, since the power stage requires more plate current than can be furnished economically by "B" batteries. The diagram of Fig. 713 shows two different circuits which may be used. That of *A* employs resistance coupling between the first audio stage in the receiver and the power tube, while *B* has transformer coupling. In either arrangement, the volume control R_2 can be replaced by a 500,000-ohm ½-watt fixed resistor if the receiver's audio stage already has a volume control. Instability in the form of "howling" or "motorboating" is less likely with the circuit of *B*. This form of instability is not unusual in high-gain audio circuits following a regenerative detector, especially with a loud speaker operating at fairly high volume. The trouble is partly electrical and partly acoustical in origin. Sound waves from the speaker aggravate instability by vibrating the tube of the sensitive regenerative detector circuit with the result that microphonic "howl" builds up. To prevent this trouble, the speaker should be placed and faced so that the sound is least able to affect the detector, and the volume level should be kept as low as possible. The best speaker location should be determined by trial. The audio power unit can be built up on a small base about 3 inches wide to match the particular receiver with which it is to be used. Usually the output transformer is incorporated in the speaker unit, and therefore need not be mounted in the amplifier stage.

TUNED RADIO-FREQUENCY AMPLIFIERS

A RADIO-FREQUENCY amplifiera head of the detector is very desirable. The increase in sensitivity provided by it can be put to good use. A further advantage of such an amplifier is that it isolates the detector from the antenna, reducing the radiation from the detector in an oscillating condition. A radio-frequency amplifier is also of considerable service in the elimination of "dead-spots" — points on the tuning dial at which the antenna, coming into resonance, might otherwise stop the detector from oscillating.

The circuit of a typical tuned r.f. stage is shown in Fig. 714. When the r.f. amplifier uses a screen-grid tube of the variable-mu type (such as the 58, 6K7, 6D6, etc.) its gain can be made adjustable by means of a variable cathode resistor, additional to the usual fixed cathode resistor, as is also shown in Fig. 714. As the value of the resistance in series with the cathode is increased the voltage drop across it rises, making the bias applied to the grid increasingly negative with respect to the cathode and thereby reducing the amplification

World Radio History



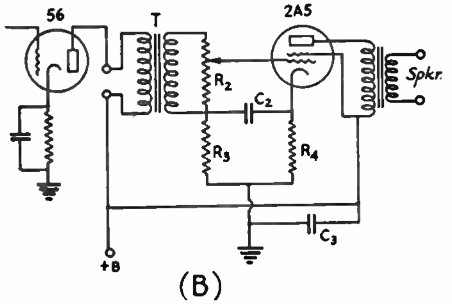


FIG. 713 — CIRCUITS OF POWER AMPLIFIERS FOR TWO-TUBE RECEIVERS, THAT OF B BEING PREFERRED

If six-volt filament supply is used, a 42 or 6F6 may be substituted for the 2A5 shown.

R_1 — 20,000 ohms, 1-watt.
R_2 — 500,000-ohm potentiometer.
R_3 — 250,000 ohms, ½-watt.
R_4 — 400 ohms, 1-watt.
C_1 — .02 μfd.
C_2 — 1 μfd.
C_3 — 8 μfd., 400 volts.
T — Interstage audio transformer.

of the stage. Since the space current of the tube falls as the grid becomes more negative, thereby tending to lessen the rate of increase in negative bias with increasing resistance, it is advisable to provide a bleeder resistor from the cathode side of the gain control to a more positive point of the high-voltage supply such as the screen-grid voltage tap. Suitable resistance values for a single r.f. amplifier tube would be 300 to 500 ohms for the fixed cathode resistor, 10,000 ohms for the variable gain control resistor and 50,000 ohms for the bleeder. If the gain of several stages is to be controlled by the one variable resistor, its value can be proportionately less and the bleeder may be omitted.

Rather complete shielding is always required when the input circuit to the r.f. amplifier tube is tuned. For this reason the tuned r.f. type receiver is somewhat more costly and more difficult to build. In one form such a receiver has two separate tuning dials — one for the input circuit to the r.f. tube and one for the input circuit to the detector. The obvious inconvenience of tuning these two controls has led to the development of receivers in which the two tuning condensers are "ganged." The construction of a receiver of this type is a work requiring a little more skill, and had best be attempted after experience has been gained with the simpler types.

T.R.F. Autodyne with Band-Spread and General Coverage Tuning

A tuned radio frequency regenerative type receiver using shielded plug-in coils, with switching to give a choice of amateur-band spreading or general coverage tuning, is illustrated with its power supply in Fig. 715 and the two succeding photographs. As shown in Fig. 716, the tube line-up consists of a t.r.f. pentode stage, regenerative detector and two audio stages, the output amplifier being a power pentode for loud-speaker operation. The two-section coil switch, SW_1, operates to connect the ganged main tuning condensers in the r.f. and detector circuits across the whole of each coil for general coverage or across part of each coil for amateur band spreading. Each coil unit is equipped with a small compression-type trimmer condenser (C_3 and C_4) for individual alignment of the circuits, and the r.f. circuit also has a panel-control trimmer, C_5, to peak the r.f. tuning and compensate for antenna variations.

As shown in the general view of Fig. 715, at the left of the base are the 6C5 first audio amplifier in front and the 6F6 output pentode at the rear, placing the audio circuits well away from the r.f. The double-gang tuning condenser, C_1, C_2, is in the center, behind the National Type A tuning dial. At the right of this condenser are the sub-base mounted National 6-prong coil sockets, into which the National Type PB10 shielded coil units plug,

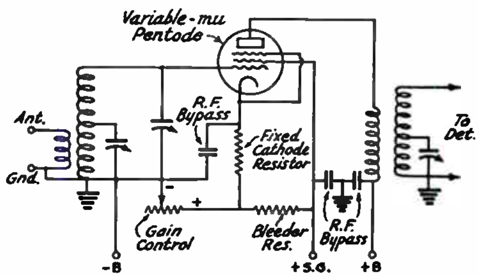


FIG. 714 — A TYPICAL RADIO-FREQUENCY AMPLIFIER CIRCUIT WITH BIAS GAIN CONTROL

It is suited to any of the variable-μ r.f. amplifier tubes such as the 58, 78, 6D6, 6K7, etc. With non-pentode types the suppressor-grid connection shown would be omitted. The value of the fixed cathode resistor will depend upon the tube type; values of the gain-control and bleeder resistors are discussed in the text.

World Radio History

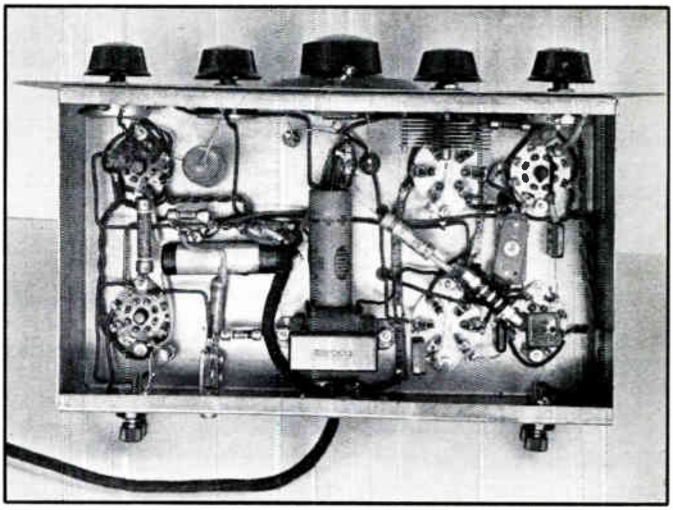


FIG. 717 — BOTTOM VIEW OF THE T.R.F. AUTODYNE

the r.f. coil unit in front and the detector coil unit to the rear. Alongside these are the 6K7 r.f. tube in front and the 6K7 detector tube at the back with a baffle shield bent from a piece of 1/16-inch aluminum.

The steel chassis measures 12 by 7 by 3 inches and the electralloy panel 14 by 7 inches. The bottom view of Fig. 717 shows the sub-base arrangement, with the audio volume, regeneration, send-receive switch, r.f. trimmer and r.f. gain controls along the front of the base, from left to right. The coil-tap switch, SW_1, is between and slightly to the left of the r.f. and detector tube sockets at the extreme right. The control-grid lead of the r.f. stage runs directly from terminal (1) of the r.f. coil to one contact on this switch and then through a rubber grommet in the base to the tube's grid cap. The grid leak and condenser of the detector, R_5C_7, connect on one side to terminal (3) of the detector coil socket and on the other side to the grid lead, running to the detector tube's grid cap through a rubber grommet in the base. The remaining connections in the r.f. and detector circuits are short and direct. Note that the antenna input leads and the lead from the r.f. plate to the detector coil primary are run through copper braid which is grounded to the chassis, as indicated on the diagram.

The coils, which depart from the conventional, should be copied closely. The forms are made from a 36″ dowel, 1″ in diameter, cut into 3″ lengths. The twelve forms are boiled in beeswax until the wood is thoroughly impregnated. Then each piece should be drilled ¼″ deep with a No. 45 drill in the center of each end and at intervals of ¼″ along one side. The holes at the ends are for the screws which hold the forms to the PB10 bases. Inserted in the holes along the sides are ½″ lengths of No. 12 wire, used as a combination anchorage and terminal connection for the windings.

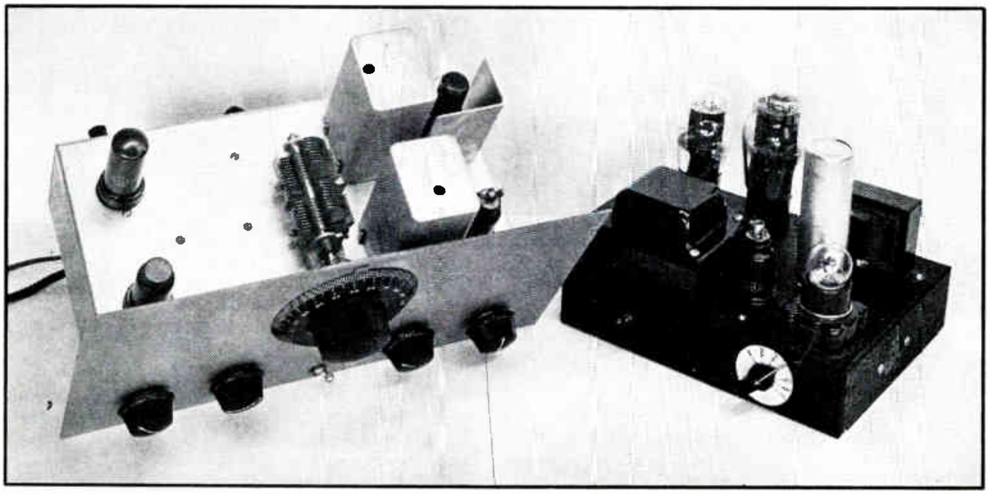


FIG. 715 — A TUNED RADIO FREQUENCY TYPE RECEIVER USING SHIELDED PLUG-IN COILS WITH SWITCHING FOR AMATEUR BAND-SPREADING OR GENERAL COVERAGE ON EACH RANGE

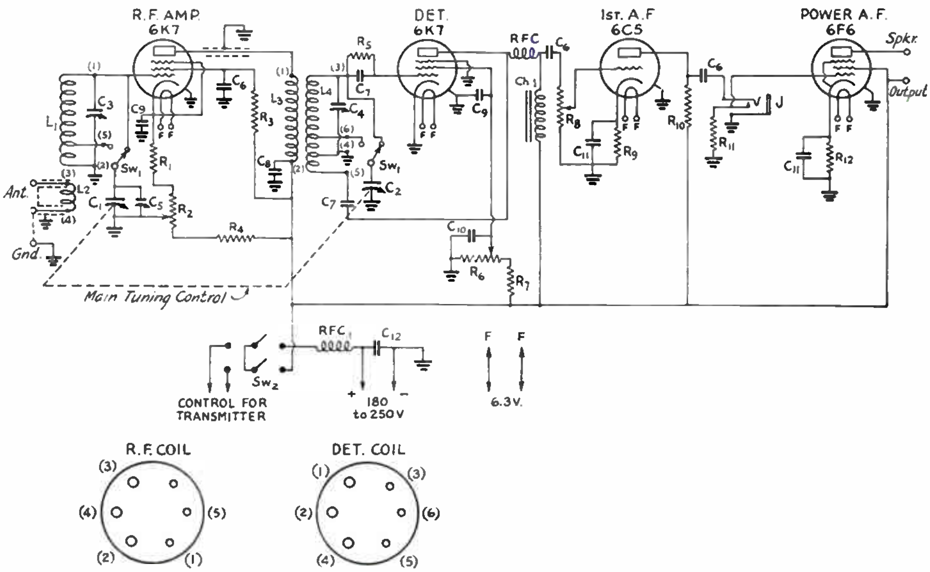
The voltage-regulated power supply (at the right) is described in Chapter Fourteen

World Radio History

The mica trimmers, adjustments for which may be made through the hole in the top of the can, are mounted at the opposite end. It is important that the rotor ends of these trimmers connect to ground and that the stator ends be held in firmly to the forms by wood screws.

All coils are wound in the same direction. The primary of the detector coil is inter-wound with the grid coil (between turns) on all except the 160-meter coil, where it is wound over the grid end.

When the wiring has been completed and the first pair of coils has been wound, the receiver is ready for test and preliminary tuning alignment. A calibrated test oscillator or signal generator may be used if available. Otherwise, connect an antenna and tune for signals, starting with the coil switch in the band-spread position. The regeneration control should be advanced to the point where a slight "plop" and hissing sound indicate that the detector is oscillating. Then the r.f. trimmer, C_5, should be adjusted for maximum "hiss," the regeneration control being kept at the point where oscillation just starts. The r.f. gain control should be kept slightly below the full-on position and the audio volume control set to give a suitable output level. After this preliminary lineup, the coil trimmer C_4 of the detector should be set for detector resonance on a signal having a frequency near the middle of the band, with the main tuning control at mid-scale. Then the r.f. coil trimmer should be set for peak response, with the r.f. trimmer C_5 near minimum capacitance. The other coils are similarly lined up. It will be noted that the r.f. trimmer adjustment will affect the regeneration setting and shift the detector tuning slightly. For best sensitivity, this trimmer should be set to allow oscillation



(Bottom views of Coil Sockets)

FIG. 716 — CIRCUIT OF THE T.R.F. AUTODYNE

L_1, L_2, L_3, L_4 — R.f. and detector coil windings. (See table.)
C_1, C_2 — Dual midget variable. 100-$\mu\mu$fd. per section (Hammarlund MCD 100S).
C_3, C_4 — 30-$\mu\mu$fd. trimmer condensers, one in each coil unit (National M30).
C_5 — 100-$\mu\mu$fd. midget condenser (Hammarlund MC 100S).
C_6 — 0.01-μfd. paper tubular condenser.
C_7 — 100-$\mu\mu$fd. mica fixed condenser.
C_8 — 0.002-μfd. mica fixed condenser.
C_9 — 0.001-μfd. mica fixed condenser.
C_{10} — 0.5-μfd. paper condenser.
C_{11} — 5-μfd. 35-volt dual electrolytic condenser (Tobe T325).
C_{12} — 8-μfd. 500-volt electrolytic condenser (Tobe ET58).
R_1 — 300-ohm ½-watt resistor.
R_2 — 10,000-ohm potentiometer (r.f. gain control).
R_3 — 0.25-megohm ½-watt.
R_4 — 50,000-ohm 2-watt.
R_5 — 5-megohm ½-watt grid leak.
R_6 — 10,000-ohm potentiometer (regeneration control).
R_7 — 50,000-ohm 1-watt.
R_8 — 500,000-ohm volume control.
R_9 — 3000-ohm 1-watt.
R_{10} — 50,000-ohm ½-watt.
R_{11} — 500,000-ohm ½-watt.
R_{12} — 500-ohm 2-watt.
RFC — 2.5-mh. r.f. chokes (National R-100).
CH_1 — Screen-grid detector audio coupling choke (Thordarson T2927).
SW_1 — D.p.d.t. rotary switch (Eby Type 35).
SW_2 — D.p.d.t. toggle switch.
J — Closed circuit jack for 'phones.

World Radio History

at the lowest possible voltage setting of the regeneration control.

A regenerative receiver of this type is susceptible to hum modulation from an inadequately-filtered power supply, and good voltage regulation is essential for stability. A regulated power supply such as is illustrated with the receiver in Fig. 715 is recommended.

T.R.F. AUTODYNE RECEIVER COIL TABLE

1.75-Mc. Bandspread (1150 to 1800 kc. General Coverage

L_1 — 78 turns No. 28 d.s.c. close wound, tap(5) 42 t. from ground.
L_2 — 21 t. No. 28 d.s.c. closewound.
L_3 — 25 t. No. 28 d.s.c. closewound over grid end of L_4.
L_4 — 103 t. No. 28 d.s.c. closewound tap (6) at 67 t. and (4) at 25 t. from lower end.

3.5-Mc. Bandspread (2.0 to 3.4 Mc. General Coverage)

L_1 — 51 t. No. 24 d.s.c. closewound, tap (5) 20 t. from ground.
L_2 — 13 t. No. 28 d.s.c. closewound
L_3 — 19 t. No. 28 d.s.c. wound over middle of L_4.
L_4 — 51 t. No. 24 d.s.c. closewound from (3) to (4), tap (6) 20 t. from ground; 18 t. No 28 d.s.c. closewound from (4) to (5).

7-Mc. Bandspread (3.8 to 6.2 Mc. General Coverage)

L_1 — 21 t. No. 24 d.s.c. spaced 1¼ in. long, tap (5) 5 t. from ground.
L_2 — 10 t. No. 28 d.s.c. closewound.
L_3 — 13 t. No. 28 d.s.c. wound over grid end of L_4.
L_4 — 21 t. No. 24 d.s.c. spaced 1¼ in. long from (3) to (4), tap (6) 5 t. from ground; 13 t. No. 28 d.s.c. closewound (4) to (5).

14-Mc. Bandspread (6.4 to 12.7 Mc. General Coverage)

L_1 — 14 t. No. 24 d.s.c. spaced 1¼ in. long, tap (5) 3 t. from ground.
L_2 — 6 t. No. 28 d.s.c. closewound.
L_3 — 8 t. No. 28 d.s.c. wound over grid end of L_4.
L_4 — 14 t. No. 24 d.s.c. spaced 1¼ in. long from (3) to (4), tap (6) 3 t. from ground; 7 t. No. 28 d.s.c. closewound from (4) to (5).

28-Mc. Bandspread (24 to 45-Mc. General Coverage)

L_1 — 7 t. No. 24 d.s.c. spaced 1¼ in. long, tap (5) ¾ t. from ground.
L_2 — 4 t. No. 24 d.s.c. closewound.
L_3 — 4 t. No. 24 d.s.c. interwound at grid end of L_4.
L_4 — 7 t. No. 24 d.s.c. spaced 1¼ in. long from (3) to (4), tap (6) ¾ t. from ground; 4 t. No. 24 d.s.c. closewound from (4) to (5).

SUPERHETERODYNE RECEIVERS

At the beginning of this chapter it was explained that the superhet-type receiver differs from the simpler regenerative autodyne types in that the incoming signal frequency is first converted to a fixed intermediate radio frequency and is then amplified at that frequency prior to audio-frequency detection. This process results in several benefits which make the superhet the preferred type of receiver for communications work. It is possible to secure a great deal more amplification, with stability, at the lower radio frequencies; furthermore, because the amplification is done at a fixed frequency the sensitivity tends to be more uniform over a wide range of input-signal frequencies. Also, at the intermediate frequencies ordinarily used, much greater selectivity is possible than at signal frequencies; again, the selectivity is practically unaffected by the frequency to which the input circuit may be tuned. Further advantages are greater receiver stability than is possible with the autodyne, accompanied by the ability to handle stronger signals without loss of effective selectivity. Because of the greater selectivity that can be attained, the sensitivity of the superhet receiver can be made higher than that of autodyne types.

In home-constructed superhet receivers, the regenerative principle which contributes so much to the effectiveness of the autodyne receiver can be incorporated to secure a high order of overall performance from a small number of tubes. The superhet receivers in this chapter all employ regeneration in one form or another for this purpose. To a considerable extent, therefore, the success of the receiver will depend upon skill in operation as well as construction, a skill which can be obtained readily by intelligent and observant practice.

In commercial receivers, regeneration usually is avoided in order to make

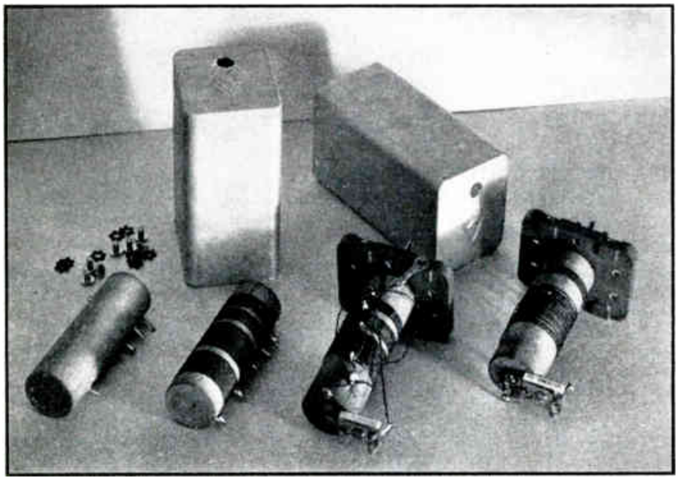


FIG. 718 — ILLUSTRATING THE CONSTRUCTION OF THE COILS, AS DESCRIBED IN DETAIL IN THE TEXT

World Radio History

operation simple and convenient. Whether or not regeneration is used, the principles outlined in the following discussion of superhet circuit features are equally valid.

Input Circuits for Best Image and Noise Ratio

A peculiarity of heterodyne action is that one of the two frequencies which are combined may be either higher or lower than the other

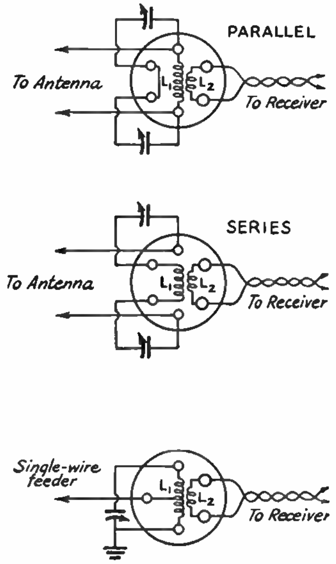


FIG. 719 — TUNED ANTENNA COUPLING CIRCUITS TO REDUCE IMAGE RESPONSE AND IMPROVE SIGNAL-NOISE RATIO

Connections to standard 5- and 6-prong coil forms are indicated. In general, inductances must be adjusted by experiment for optimum results. In the parallel-tuned circuits, L_1 should be of sufficient inductance to resonate on the desired hand in conjunction with C_1 (100 $\mu\mu$fd.). With series tuning, the number of turns required on L_1 probably will be small. L_2, the link coupling coil, should have from two to five turns, depending upon the band and the input circuit of the particular receiver used.

(by the proper frequency difference) and still give the same beat-frequency output. The oscillator frequency in the superhet receiver usually is made higher than the desired signal frequency by the amount of the intermediate frequency; however, there is possibility of first detector i.f. output from a second signal higher (by the i.f.) than the *oscillator* frequency. This will occur if there is insufficient selectivity ahead of the first detector to prevent such signals from reaching the mixing circuit. Such undesired signals are referred to as *images*, and the relative ability of a receiver to discriminate against them is termed its *image ratio;* that is, the ratio of image-frequency signal voltage to desired-frequency signal voltage required to give the same receiver output.

Using the conventional 450–465 kc. intermediates, image ratios of several hundred are obtainable at the lower amateur frequencies with but one non-regenerative input circuit, but to maintain such ratios above 7000 kc. and especially above 14 Mc., requires considerably greater input selectivity. Two tuned circuits (one r.f. stage preceding the detector input circuit) will give image ratios ranging from over 10,000 at 1.75 Mc., through approximately 1500 at 3.5 Mc. and 150 at 7 Mc., to only 50 at 14 Mc. Higher ratios can be obtained by using an i.f. of the order of 1600 kc., but the i.f. selectivity and gain are lower for the same number of stages.

One simple method of improving the image ratio is to tune the antenna circuit, as shown in Fig. 719. The ratios can be made higher by introducing regeneration in the pre-selecting circuits, which has the effect of increasing the strength of the desired signal without affecting the response to the image. One way to introduce this "negative resistance" effect is to connect a separate regenerative circuit in parallel with the superhet's input circuit as shown in Fig. 720, connecting the antenna terminal of a simple regenerative detector to the antenna terminal of the superhet. The regenerative circuit is tuned to the same frequency and operated just below the point of oscillation. Alternatively, the r.f. or first-detector circuit of the superhet can be of the regenerative type, using one of the feed-back arrangements shown for simple regenerative detectors. Regeneration tends to make the gain non-uniform over wide frequency ranges, however, and hence is best applied to amateur-band ranges only, where frequent readjustment with tuning probably will not be required. Commercial practice is to avoid regeneration and depend on additional tuned circuits for image suppression.

A simple and inexpensive method of suppressing images that is fairly effective and entirely practical is a wavetrap placed in the antenna circuit and tuned to the image, introducing high impedance right at the unwanted (image) frequency. It is easy to install, as

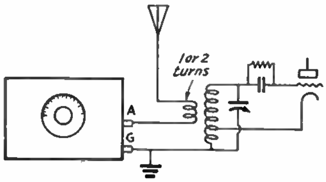


FIG. 720 — A SEPARATE REGENERATIVE CIRCUIT IMPROVES THE INPUT SELECTIVITY

No constructional changes in either superhet or regenerative detector are required.

World Radio History

shown in Fig. 721-A and -B. For the usual i.f. of approximately 450 kc. the images are about 900 kc. higher than the desired-signal frequency. Thus a trap circuit resonating 900 kc. above the signal frequency can be used, introducing only low values of impedance at the amateur-band frequency. Such a trap is broad enough so that it seldom requires adjustment if once set at the center of the frequency range it is desired to eliminate. It can be tuned easily for maximum suppression of any particular frequency, however. It produces an improvement of at least several times in the signal-to-image ratio.

Capacitive coupling resulting from the stray capacitance of antenna and tuned-circuit coils also aggravates image response. This can be reduced by the use of an electrostatic screen between the two coils, as shown in Fig. 722. The screening can be made up by space-winding No. 24 d.c.c. wire on a cylinder of celluloid temporarily supported on a 3-inch diameter form, and then treating the winding with liquid Victron, Q-Max or other dielectric "dope." When the winding is thoroughly dry the form is removed and the cylinder cut lengthwise to form a rectangle. The wire ends along one edge are soldered together to a wire for the ground connection, the ends at the other edge being left separated. Such screening is also effective in preventing some noise pick-up at the receiver's input circuit.

A tuned antenna circuit or radio-frequency amplifier not only improves the image ratio, but is also effective in improving the signal-to-noise ratio of the receiver. Some compromise is

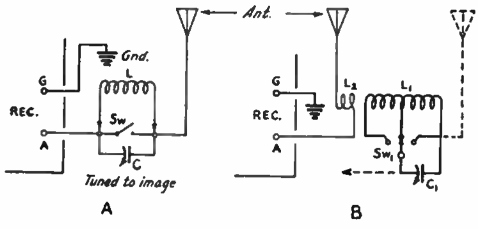


FIG. 721 — CIRCUITS FOR TWO TYPES OF WAVE-TRAP IMAGE REJECTORS

Type A is fitted with plug-in coils and is intended for use external to the receiver. The coils, L, are wound on 1½-inch diameter plug-in forms, 30 turns for the 3.5-Mc. range, 14 turns for 7-Mc., 7 turns for 14-Mc. The tuning condenser C is a 140- or 150-μμfd. midget, Sw is a single-pole single-throw shorting switch.

Type B is more adaptable to mounting within the receiver, coupled inductively to the antenna lead as shown or directly in series with the lead. It should be shielded from the receiver input. For rejection of images in the 7- and 14-Mc. ranges, where image trouble is likely to be most pronounced, the coil L_1 should have 14 turns on a 1½-inch diameter form, with a tap at the sixth turn from the "set" end. A single-section three-position tap-switch SW_1 selects all or part of the coil, or shorts the trap. C_1 is a 150-μμfd. midget condenser.

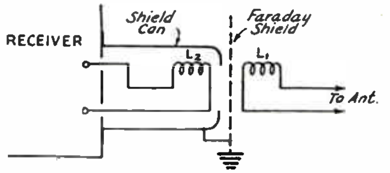


FIG. 722 — A SUGGESTED ARRANGEMENT FOR BALANCED INPUT COUPLING WITH A FARADAY SHIELD TO MINIMIZE CAPACITY EFFECTS

L_1 and L_2 each may be 4 turns or so on a tube-base form. The coil sizes and degree of coupling are not especially critical, one combination being satisfactory for all bands.

necessary in reconciling the two considerations of image suppression and sensitivity, however. Image suppression will generally be better as the coupling between antenna and input circuit is looser, while signal-to-noise ratio will be better with closer coupling. The ultimate limit on sensitivity is the noise originating in the first circuit of the receiver, as was pointed out earlier in this chapter. It is therefore important to make the signal voltage in the first tuned circuit as large as possible, to compete with the thermal agitation voltage; and to obtain the best amplification possible in the first stage, to make the signal voltage as large as possible in comparison with the tube-noise voltages in the plate circuit of the first stage. Tube noise is dependent upon the type of tube used, so that proper selection of tubes also is desirable. The 6K7 is generally used in r.f. stages, but newer types such as the 1851 and 1852 are somewhat less noisy, so that their installation often will effect an improvement in this respect. However, the input resistance of these tubes is lower than that of the 6K7 at the rated grid voltage, so that it is necessary to use greater-than-normal bias to preserve the image ratio. The effective amplification is therefore about the same. A radio-frequency amplifier has more gain than a first detector, which makes the r.f. pre-selector stage advantageous in overcoming tube noise.

Frequency Conversion

The frequency converter (first detector or mixer) is an important part of the superhet receiver. In all practical communications superhets the mixer and oscillator circuits, essential to frequency conversion, are separate. Although sometimes the two functions are performed by a single tube of a special type, in general more satisfactory performance results, especially at the higher frequencies, when separate tubes are used.

Several varieties of both mixer and oscillator circuits may be used, and almost any combination of the two is possible. Fig. 723 shows a number of representative mixer circuits, with

World Radio History

the point at which the oscillator voltage is introduced indicated in each case. In *A*, the screen-grid tube functions as a plate detector; the oscillator voltage is applied to the grid of the tube in parallel with the tuned input circuit. The conversion gain (ratio of i.f.-voltage output to signal-voltage input) and input selectivity are generally good so long as the sum of the two voltages (r.f. and oscillator) impressed on the grid does not exceed the grid bias. It is desirable to make the oscillator voltage as high as possible without exceeding this limitation. The oscillator voltage required is small and the power negligible. As an alternative to the oscillator coupling condenser shown, the oscillator may be coupled to the screen-grid so that the screen-to-control-grid capacity performs the same function as the condenser.

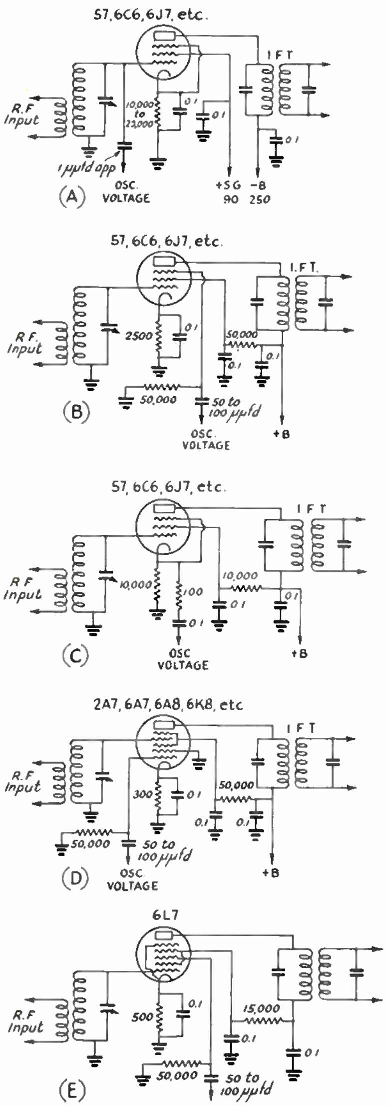


FIG. 723 — REPRESENTATIVE MIXER OR FIRST DETECTOR CIRCUITS

These may be used in conjunction with the oscillator circuits of Fig. 725. *A*, grid injection; *B*, suppressor injection; *C*, cathode injection, all with pentode detectors; *D*, electron coupling with pentagrid or hexode mixers; *E*, electron-coupling with 6L7 mixer.

In *B* the suppressor grid of a pentode-type detector is used as the means for introducing the oscillator voltage into the mixer circuit. The oscillator voltage required, while greater than in the case of control-grid injection, is not critical. The suppressor must be maintained at an average voltage considerably negative with respect to the cathode for good conversion. This, however, lowers the plate impedance of the first detector and tends to lower the gain.

In *C* the r.f. oscillator voltage is injected into the cathode circuit of the mixer across the bias resistor, giving effective grid modulation. The 100-ohm resistor in the cathode lead, in series with the 0.01-μfd. blocking condenser, minimizes undesirable detector reaction. This arrangement gives good conversion gain at the higher frequencies but may tend to cause excessive regeneration unless the circuit is carefully proportioned. The shortest possible connection between the oscillator and detector cathode should be made and the two circuits should be otherwise isolated by thorough shielding.

A pentagrid-converter tube is used in the circuit at *D*. Although intended for combination oscillator-mixer use, this type of tube usually will give more satisfactory performance when used in conjunction with a separate oscillator, the output of which is coupled to its No. 2 grid as shown. The circuit gives good conversion efficiency, and because of the electron coupling gives desirable isolation between the mixer and oscillator circuits. This helps prevent "pulling," or change in oscillator frequency with tuning of the mixer input circuit. Pulling of the oscillator frequency is especially undesirable in sets in which the mixer is coupled to the antenna, since a slight change in the antenna constants will affect the oscillator frequency and thereby introduce instability.

Circuit *E*, using the 6L7 mixer tube, has features which correct to some extent the several deficiencies encountered in conversion circuits of the other types. The space-charge coupling between detector input and oscillator circuits which characterizes the -A7 and -A8 pentagrids is largely eliminated, while the lowering of plate impedance which is characteristic of suppressor injection in a pentode is absent, since the oscillator grid (No. 3) is completely screened and is backed up by a separate suppressor grid. A smaller oscillator voltage is

World Radio History

required for good conversion than with suppressor injection. The value of oscillator voltage can vary over a considerable range without affecting the conversion gain. The lack of critical adjustments and the effective oscillator-mixer isolation afforded by this circuit have led to its use in the several complete receivers described in this chapter.

Typical combination mixer-oscillator circuits are shown in Fig. 724. That at *A* is for pentagrid converters, while *B* uses the recently-developed triode-hexode converter tube, the 6K8. The pentagrid arrangement is not particularly desirable for high-frequency work because the output of the oscillator drops off as the frequency is raised and because the two sections of the tube are not well-enough isolated to prevent space-charge coupling and pulling. The 6K8, really two tubes in one, has a better triode section and overcomes some of the defects of the pentagrids, especially at the higher frequencies. The oscillator circuits in both cases are similar to those discussed in the next section.

Oscillator Circuits — Stability and Tracking

In addition to the "pulling" effects previously emphasized, inherent stability in the high-frequency oscillator is highly important in amateur-band receivers. Variations in oscillator frequency with changes in supply voltage and with heating (drift) are of particular importance. A screen-grid type oscillator has an inherent tendency to maintain constant frequency with changes in supply voltage because of the compensating action when both plate and screen voltages are changed in the same direction. Special arrangements with triode oscillators can be made to give similar results; for instance, the oscillator plate voltage can be taken from a power supply in which tubes are used to maintain a nearly constant output voltage. (See Chapter Fourteen.)

In all these circuits it is essential that the oscillator be shielded from the mixer. Coupling other than by the means intended, especially between the tuned circuits, will result in "pulling" and will render accurate tuning difficult. Several types of oscillator circuits are shown in Fig. 725; in many cases one can be substituted for another without affecting the functioning of the detector or mixing circuit. In triode circuits, the 6J5 tube is to be preferred. The circuit at *D* with grounded cathode, is helpful in preventing hum modulation of the signal at the highest frequencies.

Where ganged tuning control of oscillator and signal-input circuits is used, it is necessary to maintain a constant frequency difference throughout the tuning range, this difference being equal to the intermediate frequency. For the narrow ranges of the amateur bands, particularly above 7 Mc., this can be accomplished to a fair extent with equal-capacitance condensers in the several tuning circuits, simply by making the oscillator inductance

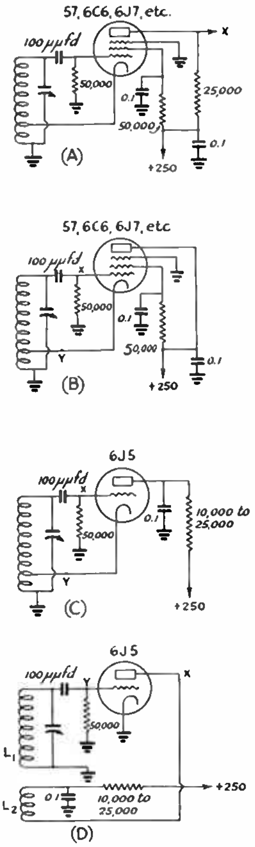


FIG. 725 — HIGH-FREQUENCY OSCILLATOR CIRCUITS

A, electron-coupled oscillator, with output taken from plate circuit; *B*, screen-grid grounded-plate oscillator; *C*, triode grounded-plate oscillator; *D*, triode, tickler circuit. Coupling to mixer may be taken from points X and Y. In *B* and *C*, coupling from Y will reduce pulling effects, but gives less voltage than from X; it is therefore best adapted to those mixer circuits with small oscillator-voltage requirements. Circuit *A* is practically free from pulling, but the oscillator output power is low; hence the circuit is best suited to grid injection in the mixer.

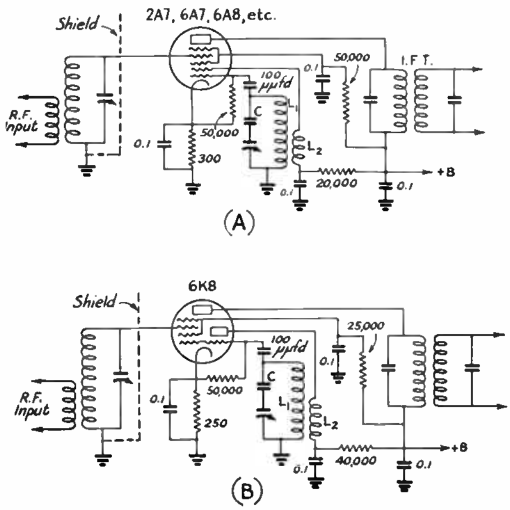


FIG. 724 — COMBINATION OSCILLATOR-MIXER CIRCUITS USING DUAL-PURPOSE TUBES

A, circuit for pentagrid converters; *B*, circuit for the 6K8 triode-hexode mixer.

World Radio History

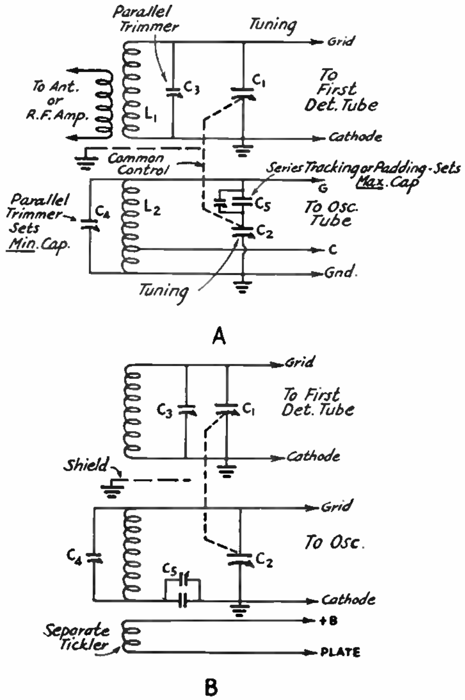


FIG. 726 — CONVERTER CIRCUIT TRACKING METHODS

Approximate circuit values for 450- to 465-kc. intermediates with tuning ranges of approximately 2.15-to-1, C_1 and C_2 having a maximum of 140 $\mu\mu$fd. and the total minimum capacitance, including C_3 or C_4, being 30 to 35 $\mu\mu$fd.

Tuning Range	L_1	L_2	C_5
1.7–4 Mc.	50 μh.	40 μh.	0.0013 μfd.
3.7–7.5 Mc.	14 μh.	12.2 μh.	0.0022 μfd.
7–15 Mc.	3.5 μh.	3 μh.	0.0045 μfd.
14–30 Mc.	0.8 μh.	0.78 μh.	None used

Approximate values for 450- to 465-kc. i.f. with a 2.5-to-1 tuning range, C_1 and C_2 being 350 $\mu\mu$fd. maximum, minimum capacitance including C_3 and C_4 being 40 to 50 $\mu\mu$fd.

Tuning Range	L_1	L_3	C_5
0.5–1.5 Mc.	240 μh.	130 μh.	425 $\mu\mu$fd.
1.5–4 Mc.	32 μh.	25 μh.	0.00115 μfd.
4–10 Mc.	4.5 μh.	4 μh.	0.0028 μfd.
10–25 Mc.	0.8 μh.	0.75 μh.	None used

sufficiently smaller than the signal-frequency circuit inductance. For more precise tracking over the tuning ranges, especially at the lower frequencies, a tracking capacitance in series with the oscillator tuning condenser is used. Two typical arrangements are shown in Fig. 726. As indicated on the diagrams, the tracking capacitance C_5 commonly consists of two condensers in parallel, a fixed one of somewhat less capacitance than the value needed and a smaller variable in parallel to allow for adjustment to the exact proper value. In practice, the trimmer capacitance C_4 is first set for the high-frequency end of the tuning range and then the tracking capacitance is set for the low-frequency end. The tracking capacitance becomes larger as the ratio of the oscillator to signal frequency becomes nearer to unity (that is, as the tuning frequency becomes higher). Typical circuit values are given in the accompanying table.

Intermediate-Frequency Amplifiers

The intermediate-frequency amplifier (i.f. amplifier) of a superhet is, as mentioned, simply a tuned radio-frequency amplifier designed to work at a fixed frequency, generally in the region of 450 to 500 kc., occasionally around 1600 kc. The tuned circuits of i.f. amplifiers usually are built up as transformers, consisting of a shielding container in which the coils and condensers are mounted. The coils are of the universal-wound or honey-comb type and are very small in size so that the magnetic field will be restricted. Both air-core and powdered-iron-core coils are used, the latter having somewhat higher *Q*'s and, hence, greater selectivity and gain per unit.

Variable tuning condensers are of the midget type and may have either mica or air dielectric, air-dielectric condensers being preferable for short-wave superhets because their capacity is practically unaffected by changes in temperature. Iron-core transformers may be tuned by varying the inductance (permeability tuning) in which case stability comparable to that of variable air-condenser tuning can be obtained by use of high-stability fixed mica condensers. Such stability is of great importance in highly selective i.f. amplifiers or single-signal superhets equipped with quartz crystal filters because a slight change in tuning capacity can greatly impair the performance of the receiver.

Intermediate-frequency amplifiers usually consist of one or two stages. With modern tubes and transformers, two stages at 455–465 kc. will give all the gain usable, considering the noise level. If regeneration is introduced into the i.f. amplifier — as is described later — a single stage will give enough gain for all practical purposes.

Typical circuit arrangements for three types of transformers are shown in Fig. 727. Alternative methods of gain-control biasing, by-passing and decoupling are indicated. The method of returning all by-passes to the cath-

World Radio History

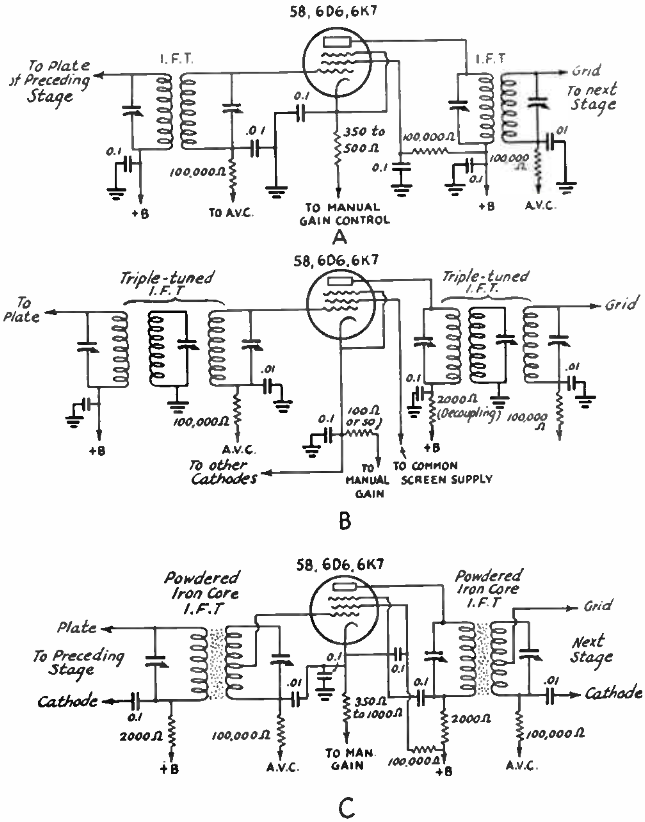


FIG. 727 — I.F. AMPLIFIER CIRCUITS FOR THREE TYPES OF TRANSFORMERS. A, DOUBLE-TUNED; B, TRIPLE-TUNED; C, HIGH-GAIN IRON CORE

ode shown in *C* is recommended in high-gain circuits using iron-core transformer units. Where two such stages are used there will be a tendency to instability and oscillation because of the high gain, and careful circuit arrangement is necessary. It is also advisable to use tapped transformers in such cases, thereby reducing the gain per stage but obtaining the increased selectivity which is possible.

Variable Selectivity

Transformers giving variable selectivity are being used to considerable extent in current receivers. One method of accomplishing this is by variable coupling between the coils of the transformers, employing mechanical adjustment, over a range from slight over-coupling to relatively loose coupling, giving a selectivity curve that varies from double-humped to very sharp. The band-width variation obtainable is approximately 7-to-1.

Another method is illustrated in Fig. 728. The special transformer has a winding L_3 in addition to the usual tuned primary and secondary L_1 and L_2. L_3 is coupled to the primary. With the switch in No. 1 position, the extra winding is cut out. In No. 2 position a part of the auxiliary winding is connected in series with the secondary, and in No. 3 position the whole of it is in series. Thus the mutual coupling and secondary inductance are simultaneously altered so that the band-width is progressively increased (the selectivity is reduced) while the mid-frequency remains the same. The band-width at 10 times down, for a single transformer, is approximately 15 kc. for position No. 1, 30 kc. for No. 2 and 45 kc. for position No. 3. Such variable-selectivity transformers permit increasing the i.f. band width for high-fidelity reception or for reception of relatively unstable signals on the ultra-high frequencies.

Second Detectors

The second detector of a superhet receiver performs the same function as the detector in the simple receiver, but usually operates with a higher input level because of the relatively great r.f. amplification which is obtained in the preceding i.f. stages. Therefore, in the second detector of the superhet the aim is to have ability to handle large signals without distortion rather than to have high sensitivity. Grid-leak and plate detection are used to some extent, but the diode detector is the most popular. It is especially adapted to furnishing automatic gain or automatic volume control (a.v.c.) as a by-product of its detector opera-

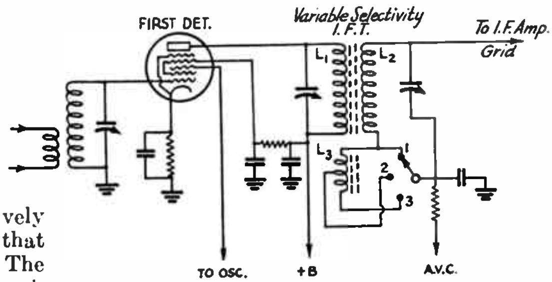


FIG. 728 — CIRCUIT OF I.F. TRANSFORMER WITH VARIABLE SELECTIVITY OBTAINED BY ELECTRICAL VARIATION OF MUTUAL COUPLING AND SECONDARY INDUCTANCE

tion, which gives it an additional advantage. A wide variety of combinations will be found, including circuits using multi-element tubes which include diode elements, but all are basically the same.

Beat Oscillators for Code Reception

A beat oscillator is always the companion to the second detector in amateur-band superhets, being used for heterodyne action in the detector circuit for c.w. telegraph reception. The oscillator circuits themselves are of the same types as those used for the frequency conversion in the high-frequency end of the receiver, but tuned near the i.f. frequency. The oscillator may be coupled to the second detector through a small coupling condenser. One consideration in the beat oscillator which is especially important is that every precaution should be taken to prevent its output, particularly harmonics of its fundamental frequency, from reaching the earlier circuits of the receiver. This is taken care of by proper shielding and filtering of its supply circuits, and by operating it at as low a plate voltage as permissible.

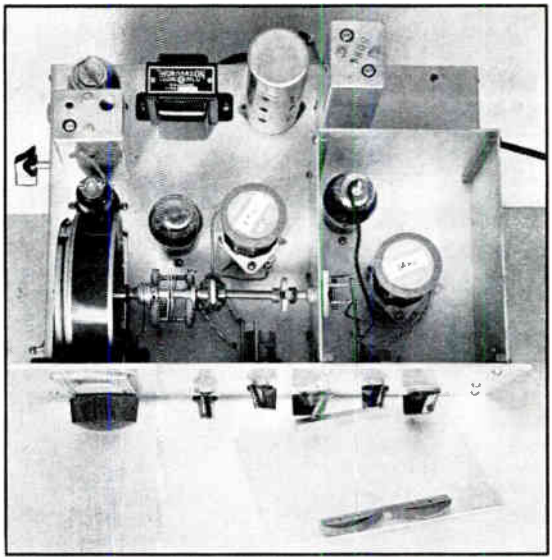


FIG. 729 — TOP VIEW OF THE FIVE-TUBE SUPERHET

The high-frequency oscillator tuning condenser, in the center foreground, is ganged to the mixer circuit in the shield compartment. The i.f. transformer is directly in back of the mixer tube, and the grid leak and condenser are mounted directly on the grid lead to the second detector. The audio coupling choke and audio amplifier tube are to the left of the second detector. The b.f.o. unit and tube are directly in back of the drum dial. The oscillator tuning condenser is supported above the chassis by two brass posts.

A FIVE-TUBE DOUBLE-REGENERATIVE SUPERHET

The foregoing discussion has made it plain that for best all-around performance the h.f. oscillator and mixer circuits should use separate tubes, and the same also is true of the second detector and beat oscillator. To keep down the number of tubes in the receiver, therefore, it is necessary to employ regeneration to provide gain and selectivity. The receiver of Fig. 729 is designed on this principle.[3]

Instead of the customary i.f. amplifier a regenerative second detector is used, with a separate beat-frequency oscillator which avoids "blocking" on strong signals, a disadvantage of autodyne detectors. An audio stage provides coupling to the headphones or speaker. The receiver uses an intermediate frequency of 1600 kc. to reduce image response and a regenerative mixer to increase the gain at signal frequency. A high-*C* high-frequency oscillator circuit is used for stability, and a low-*C* signal circuit for maximum gain. The oscillator and mixer tuning controls are ganged together.

The mixer is a 6L7G, chosen because of its excellent characteristics and lack of necessity for critical adjustment of oscillator voltage. The high-frequency oscillator is a 6J5G. A 6K7G is used for the second detector because it goes in and out of oscillation smoothly, besides providing sensitivity. The beat-frequency oscillator is a 6K7 and the audio amplifier a 6C5.

Fig. 730, the circuit diagram, shows that most of the details are straightforward and conform to usual practice. The No. 3 grid of the mixer tube is coupled directly to the grid of the high-frequency oscillator, and the mixer and oscillator tuning circuits are band-spread by the tapped-coil method. The completeness of tracking will depend on the patience of the builder in getting just the right spread by means of the taps. However, since the mixer padding circuit is adjustable from the panel, it is not necessary to make the two circuits track exactly. If the coil dimensions given are followed closely, the tracking will be quite good.

The mixer regeneration control is a variable resistor placed between two fixed resistors, giving a variation in screen voltage from 50 to 200 volts. The second detector employs a tuned cathode circuit for regeneration. The detector is coupled to the audio tube by means of a 0.1-μfd. condenser and a 500-henry choke. Suitable r.f. filtering is used before the high-inductance choke to prevent "motorboating" or "howling."

There is no connection between the b.f.o. and the second detector. This results in slightly-below-optimum coupling between oscillator and detector for strong signals, with consequent "limiter" action. However, the coupling

World Radio History

is just about right for weak signals, which is favorable to the signal-to-noise ratio. If it is found that too much oscillator voltage reaches the second detector, the voltage to the plate of the b.f.o. can be reduced, and if too little oscillator voltage is being fed to the detector the coupling can be increased by bringing a piece of insulated wire near the two circuits. The b.f.o. is made to turn off, for 'phone reception, by bending over one corner of the rotor plate of C_5, which shorts with the stator plate in the extreme position.

To facilitate home construction, shielding is reduced to a minimum. The first detector portion of the set is housed in a separate box, 4¾″ × 6¼″ × 4⅜″ high, with are movable lid for changing coils. The chassis is made by bending a 9½″ × 16¼″ piece of 3/32″ aluminum into a shallow "U" with 2⅛″ sides and fastening on a rear strip and the ⅛″ × 6½″ × 13″ panel with ¼″ square brass rod. The photographs show the construction. Care should be taken to make the chassis rigid, to insure stability. After all the holes have been drilled, the chassis and panel may be given a dull finish by soaking them in a lye solution for about fifteen minutes.

To avoid variable ground paths as the dial is turned, an insulated flexible coupling is used between the dial and the oscillator tuning condenser. This obviates a tendency of the frequency to "jump" as the dial is turned.

Lining up the receiver is relatively easy. If a modulated oscillator is available, set it at around 1600 kc. (the exact frequency is unimportant) and connect its output to the grid of the 6L7 mixer. Then tune the i.f. transformer until the signal is the loudest. The b.f.o. condenser (on the side of the chassis) is set at half scale and the trimming condenser in the shield can is adjusted until a beat is obtained between the b.f.o. and the 1600-kc. signal from the signal generator. If no signal generator is available, set the second-detector regeneration control to the point where the detector oscillates and then adjust the b.f.o. until a beat is

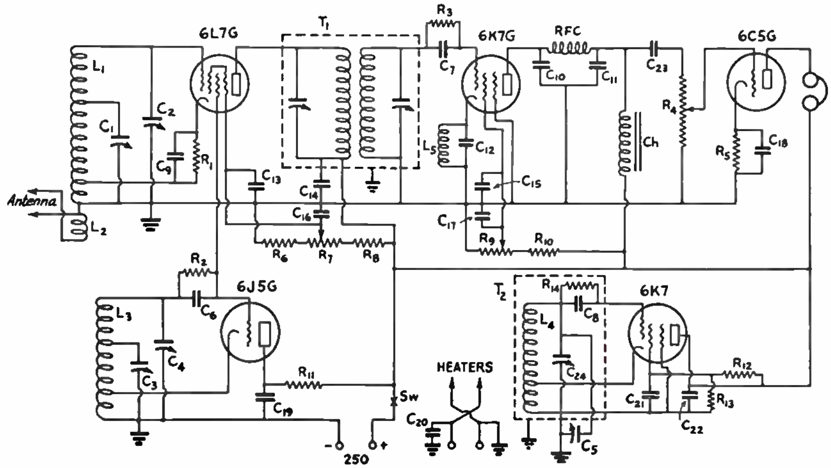


FIG. 730 — CIRCUIT DIAGRAM OF THE FIVE-TUBE RECEIVER

C_1 — 15-μμfd. tuning condenser (Hammarlund HF15).
C_2 — 35-μμfd. handset condenser (Hammarlund HF35).
C_3 — 35-μμfd. tuning condenser (Hammarlund MC-35-S).
C_4 — 100-μμfd. handset condenser (Hammarlund HF100).
C_5 — 2-plate midget variable for heat-note adjustment (Sickles ATR-21).
C_6, C_7 — 100-μμd. mica.
C_9, C_{10}, C_{11}, C_{12} — 250-μμfd. mica.
C_{13} — 0.005-μfd. mica.
C_{14}, C_{15} — 0.01-μfd., 400-volt paper.
C_{16} — 0.1-μfd., 400-volt paper.
C_{17} — 0.5-μfd. 400-volt paper.
C_{18} — 5-μfd., 50-volt electrolytic.
C_{19} — 0.005-μfd. mica.
C_{20}, C_{21}, C_{22} — 0.01-μfd., 400-volt paper.
C_{23} — 0.1-μfd., 400-volt paper.
R_1 — 500 ohms, ½-watt.
R_2 — 40,000 ohms, ½-watt.
R_3 — 0.25 megohm, ½-watt.
R_4 — 0.5-megohm potentiometer.
R_5 — 1000 ohms, 1-watt.
R_6 — 25,000 ohms, ½-watt.
R_7, R_9 — 15,000-ohm wire-wound potentiometer. (Yaxley C15MP. Rotor must be insulated from panel.)
R_8 — 500 ohms, 1-watt.
R_{10} — 30,000 ohms, 10-watt wire-wound.
R_{11} — 10,000 ohms, 1-watt.
R_{12}, R_{13} — 15,000 ohms, 2-watt.
RFC — 2.5-mh. choke.
L_1, L_2, L_3 — See coil tahle.
L_5 — 2.5-mh. choke.
T_1 — 1600-kc. air-tuned i.f. transformer. (Sickles 8084. The grid lead, which is tapped down on the coil in the transformer as it comes from the manufacturer, must be moved to the stator plates of the grid tuning condenser before the transformer is used.)
T_2, (L_4, C_{24}, R_{14}, C_8) — 1600-kc. h.f.o. unit (Sickles 6631).
Ch — 500-henry audio impedance (Thordarson T-3736).

World Radio History

heard. The primary tuning of the i.f. transformer is next adjusted to the point where the regeneration control must be advanced the farthest to maintain oscillation. The primary will then be in tune with the secondary. If later it is found that the i.f. frequency selected falls on some broadcast harmonic or other unwanted signal, a slight readjustment will be necessary.

Adjustment and trimming of the r.f. coils follows the i.f. alignment. With a mixer and oscillator coil wound according to the table and placed in the receiver, set the tuning dial at the low-frequency end of its scale and tune with the oscillator band-set condenser C_4 until a familiar marker or amateur signal at the low-frequency end of the particular band is heard. This adjustment should be with C_4 set at about ⅔ full capacity. Tune to the other end of the band to check for the bandspread of the oscillator. If the band does not occupy enough space on the dial, move the tap that goes to the tuning condenser C_3 *down* on the coil. If there is too much bandspread, move the tap *up* on the coil.

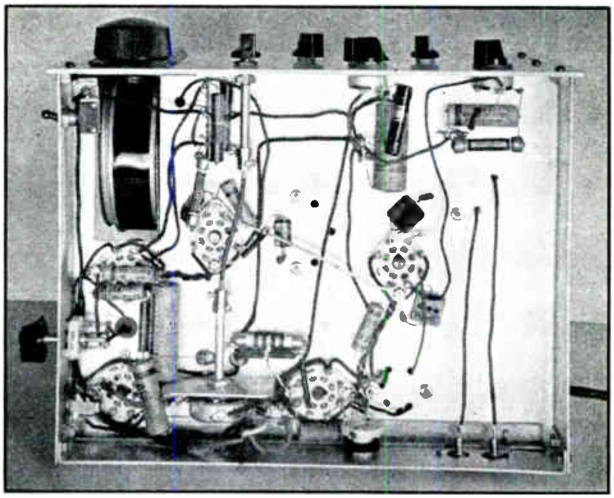


FIG. 731 — BOTTOM VIEW OF THE FIVE-TUBE RECEIVER

A flexible shaft is used to turn the audio volume control at the rear of the set. Any stray coupling is avoided by thus mounting the audio volume control near the audio tube. The r.f. choke fastened to the back of the chassis is used to make the second detector regenerative. The switch near the drum dial turns off the plate voltage.

To make the mixer circuit track with the oscillator, first tune in a signal at the high-frequency end of the band and peak the signal with the mixer band-set condenser C_2. Then tune in a signal at the low-frequency end of the band and see whether C_2 has to be increased or decreased to peak the signal. If the capacity has to be increased at the low-frequency end of the band the tuning tap should be moved *up* on the coil. If the capacity has to be decreased to peak the signal, the tap should be moved *down*. The adjustments should be not more than a quarter-turn at a time on the 14- and 28-Mc. ranges, but can be half-turns at the other frequencies. The tracking can be made as complete as one cares to go — it is simply a matter of patience. The total number of turns is right if C_2 resonates at about half-scale.

Adjustment to the cathode tap on the mixer coil comes next. It is desirable to have the cathode tap and the antenna coil so proportioned that the mixer goes into oscillation with the regeneration control set at about ⅔ scale. If the mixer goes into oscillation too soon, i.e., with the regeneration control set at something much less than ⅔ scale, the cathode tap should be made lower on the coil. The point at which oscillation takes place can also be varied by loosening the antenna coupling, either by reducing the number of turns in L_2 or by moving it farther away from L_1. All antenna-coil adjustments should be made with the antenna connected to the receiver.

When the "front end" of the receiver is working smoothly it may be worthwhile to experiment a little with the second-detector cathode condenser C_{12}. If oscillation of the second detector takes place at something less than ⅔ setting of the regeneration control, C_{12}

FIVE-TUBE SUPERHET COIL TABLE

Band	L_1 Total Turns and Wire Size	L_1 Length of Winding	Cathode Tap*	Band Spread Tap*	L_2 Total Turns and Wire Size	L_3 Total Turns and Wire Size	L_3 Length of Winding	Cathode Tap*	B.S. Tap*
3.5 Mc.	39 No. 24 d.s.c.	1 1/16"	⅛	36	4 No. 24 d.s.c. closewound	15½ No. 20 enam.	1⅛"	5	14
7	26½ No. 20 enam.	1⅝"	⅛	8	4 No. 32 d.s.c. "	14½ No. 20 "	1¼"	5	12
14	12½ No. 18 "	1 1/16"	⅔	3½	2 No. 24 d.s.c. "	6⅛ No. 18 "	1¼"	2	3⅔
28	5½ No. 18 "	¾"	⅛	2	3 No. 32 d.s.c. "	2 No. 18 "	1"	⅞	1⅔

All coils wound on 1½" diam. Hammarlund forms. L_1 and L_2 wound next to each other except on 7 Mc. where spacing between L_1 and L_2 is ¼". All coils except 3.5-Mc. L_1 are space wound to occupy winding length given.

* Tap turns counted from grounded end of coil.

should be made slightly smaller. It will be found that the two regeneration controls interlock slightly when both detectors are being run too close to the oscillating point, but this can be avoided by running the mixer in a slightly less regenerative condition.

In operation, the second detector is run in a regenerative condition but *not* oscillating. The b.f.o. is not tuned exactly to the same frequency as the regenerative second detector, but about 1000 cycles to either side. When this is done the signal on one side of zero beat will be louder than on the other side. This condition is only achieved when the second detector is almost oscillating, and proves very useful in separating two signals quite close together. Although the "single-signal" effect (see later section) obtained in this receiver does not approach that which results from the use of a crystal filter or regenerative 450-kc. amplifier, it does result in an S7 signal on one side of zero beat being reduced to an S4 signal on the other side. A little experimenting with the adjustment will make the operator familiar with the process of adjusting for maximum single-signal effect.

No trouble should be experienced with image response. The presence of images indicates that the antenna coupling is too tight, and loosening it should cure the trouble.

SINGLE-SIGNAL SELECTIVITY

In ordinary beat-note reception, the same beat note can be obtained from a signal above as from another below the local oscillator frequency. For instance, if the beat note on a desired signal is 1000 cycles (with the oscillator 1 kc. lower than the signal frequency), another signal 2 kc. lower than the desired signal will also give a 1000-cycle beat note and interfere as if it were on the same frequency as the desired signal. As shown by Fig. 732, this audio-image interference is eliminated in the single-signal superhet. This type of receiver resembles the conventional superheterodyne of ordinary selectivity, but has in addition an intermediate circuit in which extremely high selectivity is obtained either by means of a piezo-electric filter (quartz crystal) or by regeneration.

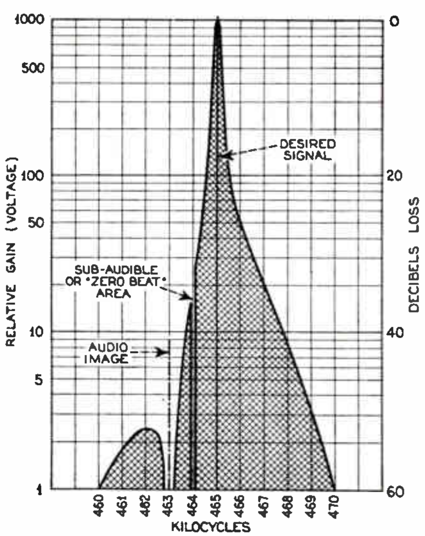


FIG. 732 — A GRAPHICAL ILLUSTRATION OF SINGLE-SIGNAL SELECTIVITY. THE SHADED AREA INDICATES THE REGION IN WHICH RESPONSE IS OBTAINABLE

Because of the high selectivity, the signal voltage reaching the second detector drops to a negligible value a few hundred cycles off resonance, especially when the filter circuit is of the quartz crystal type which can be adjusted to reject particularly at one frequency. Hence, with the beat oscillator coupled to the second detector practically only one beat-note response will occur, and this will be for the signal tuned in on the resonance peak of the i.f. circuit. When a receiver of this type is tuned across a signal, it will be heard on only one side of zero beat, instead of on both sides as with receivers of ordinary selectivity. The extreme selectivity also reduces noise and other types of interference. The single-signal superhet should be provided with a means for varying the selectivity so that the receiver will be suitable for the reception of voice as well as c.w. telegraph signals, since a wider band must be passed for faithful reproduction of voice modulation.

Regenerative I.F. Amplifiers

A regenerative i.f. amplifier stage can be used to provide high selectivity combined with high gain in the amateur superhet. Such an amplifier operates in much the same fashion as a regenerative input amplifier or first detector in giving high selectivity. The regenerative amplifier increases the signal at resonance frequency of the i.f. circuit and leaves signals of other frequencies at practically the same amplitude they would have if the amplifier were not regenerative. A representative circuit of an i.f. amplifier of this type is shown in Fig. 733. In addition to the usual input and output transformer windings L_1 and L_2, the input transformer has a feed-back coil L_3 connected in the plate return circuit between cathode and ground, through the usual by-passed cathode bias resistance R_1. This coil is connected so that r.f. current flowing back to the cathode induces voltage in L_2 in phase with the r.f. voltage on the grid. Regeneration is controlled by R_2, which shunts the tickler coil for r.f., through C_4. The latter is necessary to prevent variation of R_2 from varying the d.c. grid bias. Regeneration is maximum when the resistance of R_2 is all in circuit, and is minimum when R_2 is zero, shorting the tickler coil.

Selectivity comparable with that obtained with a crystal filter can be obtained with a regenerative i.f. stage. However, the regenerative amplifier is not as stable and does not provide adjustable rejection. The maximum gain is very high and not more than one i.f. stage is advisable in a receiver using such an amplifier. Greatest effective selectivity will result when the tube gain is made relatively low

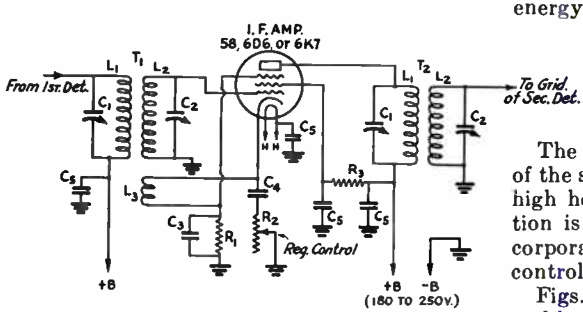


FIG. 733 — HIGH-SELECTIVITY REGENERATIVE I.F. AMPLIFIER CIRCUIT

L_1 and L_2 — 1.2-mh. coils of 450- to 465-kc. i.f. transformer, optimum coupling.
L_3 — Tickler winding, approximately 20 turns coupled to L_2.
C_1 and C_2 — 50- to 100-$\mu\mu$fd. i.f. tuning condensers (air type).
C_3 — 0.1-μfd. tubular by-pass condenser.
C_4 — 0.01-μfd. blocking condenser.
C_5 — 0.01 to 0.1 by-pass condensers.
R_1 — 350-ohm cathode resistor.
R_2 — 2000-ohm variable resistor (selectivity control).
R_3 — 100,000-ohm screen voltage dropping resistor.

(as by using a larger value of cathode resistor, R_1), thus preventing strong signals from overloading the stage.

Any method of introducing feedback may be used; the chief requirement is smooth control of regeneration so that the amplifier can be operated near the critical regeneration point where maximum selectivity is secured.

A SIX-TUBE REGENERATIVE SINGLE-SIGNAL RECEIVER

AN INEXPENSIVE receiver of simple construction, using i.f. regeneration for single-signal reception, is shown in Fig. 734.[4] Fig. 735 gives the circuit diagram.

The regenerative mixer, a 6L7, is coupled to the antenna; the oscillator is 6J5 triode. There is a single i.f. stage, using a 6K7 and iron-core transformers. The second detector is a 6C5, and the audio output tube, for loud-speaker work, is a 6F6. A 6C5 beat oscillator completes the tube complement.

To avoid constructional complications, the mixer tuning is not ganged with the oscillator, so that the two circuits must be tuned separately. The mixer tuning condenser, C_1, can be used as a volume control. The regeneration control is a variable resistor, R_2, in series with the 6L7 cathode resistor.

The i.f. gain is controlled by R_4, which varies the control-grid bias on the 6K7. The stage is made regenerative by running a short length of wire from the control grid of the 6K7 through a hole in the shield can of i.f. transformer T_2 so that a small amount of energy is coupled back to the grid from the plate. When this is done R_4 serves as a regeneration control. If the high selectivity afforded by regeneration is not wanted, the regenerative coupling may be omitted.

The headphones plug into the plate circuit of the second detector; the signal level is quite high here and no additional audio amplification is needed. No audio gain control is incorporated in the set, since the various r.f. controls afford quite a range in volume.

Figs. 736 and 737 show the layout, both top and bottom, quite plainly. The chassis is steel and measures 11 by 7 by 2 inches. The bandspread tuning condenser, C_3, is at the front center, operated by the vernier dial. At the left is C_1, the mixer tuning condenser, and at the right, C_2, the oscillator band-setting condenser. The oscillator tube is directly behind C_3, with the mixer tube to the left on the other side of a baffle shield which separates the two r.f. sections. This shield, measuring 3¾ by 4¾ inches, is used to prevent coupling between oscillator and mixer. The mixer coil socket is at the left edge of the chassis behind C_1; the oscillator coil socket is between C_2 and C_3.

The i.f. and audio sections are along the rear edge of the chassis. The transformer in the rear left corner is T_1; next to it is the i.f. tube, then T_2. The transformers are mounted so that the adjusting screws project to the rear where they are easily accessible. With the particular type of transformer used this requires drilling a new hole in the shield of T_1 so that the grid lead to the 6K7 can be brought out the proper side. In T_2, the grid lead should be pulled through the side of the can and brought out the bottom with the other leads, since the grid of the 6C5 second detector comes through the base.

The transformer at the rear right is for the beat oscillator. The 6C5 second detector is directly in front of it and the beat oscillator tube is about midway along the right chassis edge. The 6F6 output tube is in the rear right-hand corner.

Power cord, headphone jack (insulated

World Radio History

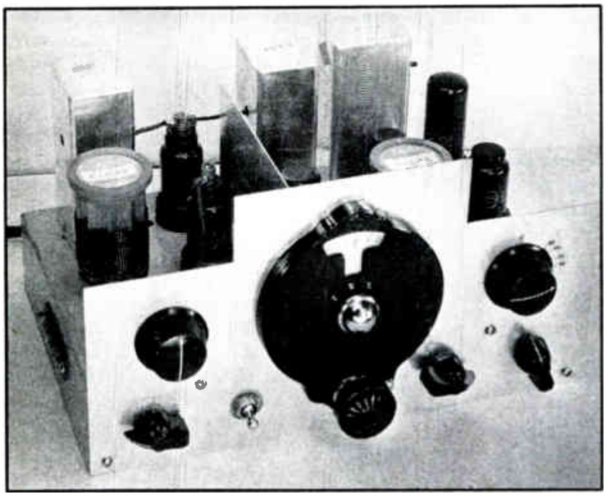


FIG. 734 — A SIX-TUBE REGENERATIVE SINGLE-SIGNAL RECEIVER OF INEXPENSIVE DESIGN

A variable-ratio vernier dial (National Type B) is used for the fine tuning required with single-signal selectivity. Power supply requirements are 2.2 amperes at 6.3 volts, and 60 milliamperes d.c. at 200–250 volts, for loud-speaker operation. A voltage-regulated supply such as is described in Chapter Fourteen is recommended.

from the chassis) and a tip jack for the speaker are on the rear edge of the chassis. The antenna input terminals are on the left edge, near the mixer coil socket.

The controls along the bottom edge of the panel are, from left to right, the mixer regeneration control, R_2, the on-off switch, *Sw*, the i.f. gain or regeneration control, R_4, and the beat-oscillator vernier condenser, C_{20}. The latter has the corner of one rotary plate bent over so that when the condenser plates are fully interleaved the condenser is short-circuited, thus stopping oscillation.

One side of the heater circuit is grounded, so that only one filament wire need be run from tube to tube. The more conventional method of running heater current through a twisted pair can be used if preferred.

The oscillator-mixer coupling condenser, C_5, is mounted from one of its connection tabs on a small ceramic pillar (furnished with one of

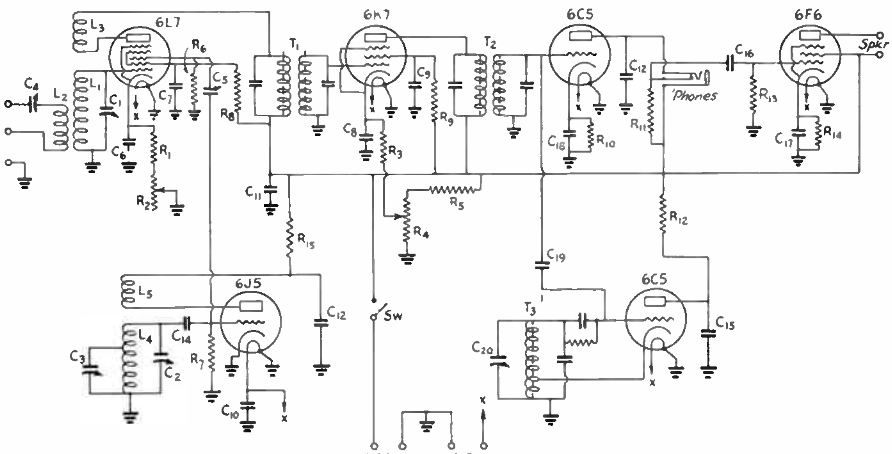


FIG. 735. — CIRCUIT DIAGRAM OF THE REGENERATIVE S.S. RECEIVER

C_1, C_2 — 50-μμfd. variable (Hammarlund MC-50-S).
C_3 — 35-μμfd. variable (National SS-35).
C_4 — 70-μμfd. mica trimmer (Hammarlund BBT-70).
C_5 — 30-μμfd. isolantite-insulated mica trimmer (National M-30).
C_6-C_{10}, inc. — 0.1-μfd. paper, 400-volt.
C_{11} — 0.2-μfd. paper, 400-volt (or larger).
C_{12}, C_{13} — 0.005-μfd. mica.
C_{14} — 100-μμfd. mica.
C_{15}, C_{16} — 0.01-μfd. paper, 400-volt.
C_{17} — 10-μfd. 25-volt electrolytic.
C_{18} — 5-μfd. 25-volt electrolytic.
C_{19} — See text.
C_{20} — 25-μμfd. variable (Hammarlund SM-25).
R_1 — 300 ohms, ½-watt (see text).
R_2 — 100#-ohm variable, wire-wound.
R_3 — 300 ohms, ½-watt.
R_4 — 25,000-ohm volume control.
R_5 — 50,000 ohms, 2-watt.
R_6 — 50,000 ohms, ½-watt (I.R.C. Type F).
R_7 — 150,000 ohms, ½-watt (I.R.C. Type F).
R_8 — 12,000 ohms, 1-watt.
R_9, R_{10}, R_{11}, R_{12} — 50,000 ohms, ½-watt.
R_{13} — 0.5 megohm, ½-watt.
R_{14} — 450 ohms, 1-watt.
R_{15} — 15,000 ohms, 1-watt.
T_1, T_2 — 455-kc. interstage-type i.f. transformers (Sickles 6504).
T_3 — 455-kc. beat oscillator transformer, with grid condenser and leak (Sickles 6577).
L_1-L_5, inc. — See coil table.
Jack — Double-circuit type.
Sw — S.p.s.t. toggle.

World Radio History

the tube sockets) between the oscillator and mixer tube sockets. The antenna series condenser, C_4, is mounted between one terminal on the antenna strip and one of the mixer coil-socket prongs. These condensers do not require readjustment in normal operation, hence are screw-driver adjusted from the bottom.

The b.o. coupling condenser, C_{19}, is simply the capacity existing between the grid prong on the 6C5 socket and the adjacent prong on the side away from the plate. This prong, ordinarily unused, is connected to the b.o. as shown in Fig. 735.

The method of winding coils is shown in Fig. 738, and complete specifications are given in the table. All windings are in the same direction. In Fig. 735, the ticklers, L_3 and L_5, have been shown coupled to the grid ends of L_1 and L_4, respectively. This was done purely to make the diagram less awkward; the actual method of construction is given in Fig. 738, with the ticklers coupled to the grounded ends of the grid coils.

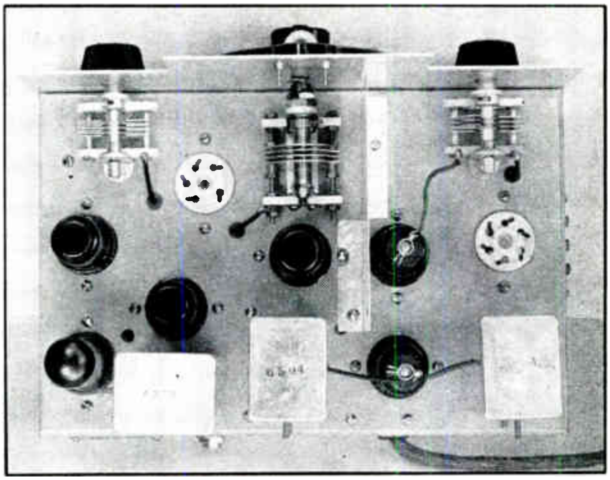


FIG. 736 — PLAN VIEW OF THE SIX-TUBE SUPERHET
Location of the various parts is discussed in the text.

Any convenient pin-connection arrangement may be used. Make the connections so that the shortest leads between coil socket and circuit points result.

A test oscillator and 0–1 milliammeter make a suitable combination for i.f. alignment. The i.f. should be aligned without the regenerative connection and with the h.f. oscillator coil out of its socket. A mixer coil should be in place to complete the 6L7 plate connection. If no speaker is used either the speaker terminals must be short-circuited to prevent damage to the 6F6, or else the tube must be out of its socket.

Connect the test oscillator output between the 6L7 grid and chassis, with the normal grid connection to C_1 removed. Connect the milliammeter to a 'phone plug and insert the plug in the headphone jack. Set the oscillator to 455 kc. and adjust the trimmers on T_1 and T_2 to give maximum meter reading, with R_4 set for maximum gain or slightly below. The beat oscillator should be off. Without signal the second detector plate current should be between 0.1 and 0.2 ma.; adjust the test oscillator output so that the reading with signal is about 0.4 or 0.5 ma. As the circuits come into line, reduce the signal input to keep the reading about the same.

After the i.f. is aligned, plug in a set of coils for some band on which there is a good deal of activity. Set the oscillator padding condenser, C_2, at approximately the right capacity; with the coil specifications given, the proportion of total C_2 capacity on each band will be about as follows: 1.75 Mc., 80 per cent; 3.5 Mc., 75 per cent; 7 Mc., 95 per cent; 14 Mc., 90 per cent; 28 Mc., 45 per cent. Set the mixer regeneration control, R_2, for minimum regeneration — all the resistance in circuit. Connect an antenna and set C_4 at maximum capacity. Switch the beat oscillator on by turning C_{20} out of the maximum position, and adjust the screw on T_3 until the characteristic beat-oscillator hiss is heard.

REGENERATIVE S.S. RECEIVER COIL DATA

Band	*Coil*	*Wire Size*	*Turns*	*Length*	*Tap*
1.75 Mc. . . .	L_1	24	70	Close-wound	—
	L_2	24	10	"	—
	L_3	24	3.5	"	—
	L_4	22	42	"	Top
	L_5	22	8	"	—
3.5 Mc. . . .	L_1	22	35	"	—
	L_2	22	7	"	—
	L_3	22	2.5	"	—
	L_4	22	25	1 inch	17
	L_5	22	5	Close-wound	—
7 Mc. . . .	L_1	18	20	1 inch	—
	L_2	22	4	Close-wound	—
	L_3	22	2	"	—
	L_4	18	13	1 inch	6
	L_5	22	3	Close-wound	—
14 Mc. . . .	L_1	18	11	1 inch	—
	L_2	22	4	Close-wound	—
	L_3	22	2.5	"	—
	L_4	18	7	1 inch	2.4
	L_5	22	2	Close-wound	—
28 Mc. . . .	L_1	18	5	1 inch	—
	L_2	22	3	Close-wound	—
	L_3	22	2.5	"	—
	L_4	18	3.6	1 inch	1.3
	L_5	22	1.4	Close-wound	—

All coils 1½ inches in diameter, on Hammarlund SWF forms. Spacing between coils on same form approximately ⅛ inch. Band-spread taps are measured from bottom (ground) end of L_4. All coils wound with enamelled wire.

World Radio History

Now tune C_1 slowly over its scale, starting from maximum capacity. Using the 7-Mc. coils as an example, when C_1 is at about half scale there should be a definite increase in noise and in the strength of the signals which may be heard. Continue on past this point until a second peak is reached on C_1; at this peak the input circuit is tuned to the frequency which represents an image in normal reception. The oscillator in the receiver is designed to work on the high-frequency side of the incoming signal, so that C_1 always should be tuned to the peak which occurs with most capacity.

After the signal peak on C_1 has been identified, tune C_3 over its whole range, following with C_1 to keep the mixer circuit in tune, to see how the band fits the dial. With C_2 properly set, the band edges should fall the same number of main dial divisions from 0 and 100; if the band runs off the low-frequency edge, less capacity is needed at C_2, while the converse is true if the band runs off the high edge. Once the band is properly centered on the dial, the panel may be marked at the appropriate point so that C_2 may be reset readily when changing bands.

Now tune in a signal and adjust C_1 for maximum response. Advance R_2 slowly, simultaneously swinging C_1 back and forth through resonance. As regeneration is increased signals and noise both will become louder and C_1 will tune more sharply, until finally the mixer circuit will break into oscillation when, with C_1 right at resonance, a loud carrier will be heard, since the oscillations generated will go through the receiver in exactly the same way as a signal. Always work the mixer somewhat below the critical regeneration point and never permit it to oscillate in practical operation.

If the antenna happens to be nearly resonant in the band, it may not be possible to make the mixer oscillate; on the other hand if the antenna loading is negligible the circuit may oscillate continuously regardless of the setting of the regeneration control. The former condition can be cured by reducing the capacity of C_4 or by increasing the number of turns on L_3. If the mixer oscillates continuously, the opposite remedies are required.

The oscillator-mixer coupling condenser, C_5, should be adjusted so that pulling of the oscillator frequency at 14 Mc. is negligible as C_1 is tuned through resonance with the incoming signal. The setting generally will be with the plates rather far apart. On 7 Mc. and lower there should be no detectable change in beat note as C_1 goes through the signal peak. A few hundred cycles change is typical of 14 Mc.

After the preceding adjustments have been completed, the i.f. regeneration may be added. The amount of feed-back will be determined by the length of wire inserted in the can containing T_2. Optimum selectivity usually will be secured when the regenerative coupling is adjusted so that the 6K7 goes into oscillation with the gain control, R_1, fairly well "down" — far enough so that it is well below maximum gain and in the region where, without regeneration, its effect on gain is not great. Balance gain and regeneration so that the average signal level, at resonance with peak regeneration, is about the same as with normal i.f. gain without regeneration.

For single-signal c.w. reception, set the beat oscillator so that when R_4 is advanced to make the i.f. just go into oscillation the resulting tone is the desired beat-note frequency. Then back off on R_4 to give the desired selectivity. Maximum selectivity will be secured with the i.f. just below the oscillating point. The "other side of zero beat" will be very much weaker than the desired side.

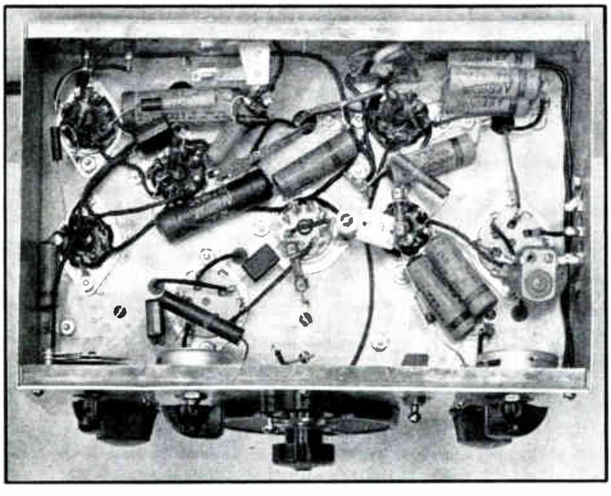


FIG. 737 — BELOW-CHASSIS VIEW OF THE REGENERATIVE S.S. SUPER

AUTOMATIC VOLUME CONTROL

With the wide range of signal levels encountered in high-frequency reception and the severe fading which is practically always prevalent, automatic regulation of the gain of the receiver in inverse proportion to the signal strength is a great advantage, especially in 'phone reception. This is readily accomplished in the superheterodyne by using the average rectified voltage developed by the received signal across a resistance in a detector circuit to vary the bias

World Radio History

on the r.f. and i.f. amplifier tubes. Since this voltage is practically proportional to the average amplitude of the detector signal, the gain is reduced as the signal strength is greater. The control will be more complete as the number of stages to which the a.v.c. bias is applied is greater. Control of at least two stages is advisable.

A typical circuit of a diode-triode type tube used as a combined a.v.c. rectifier, detector and first audio amplifier is shown in Fig. 739. One plate of the diode section of the tube is used for signal detection and the other for a.v.c. rectification. The detector diode plate is connected directly to the "high" side of the i.f. transformer secondary, while the a.v.c. diode plate is fed through the small coupling condenser C_3. The audio diode load consists of R_2 and R_1 in series. The load condenser is split into two sections, C_1 and C_2, to aid in filtering r.f. from the lead which goes through the audio coupling condenser, C_8, to R_8, the audio volume control, thence to the grid of the triode section of the tube. C_{10} is the usual high-capacity by-pass across the cathode resistor.

The triode section of the tube is used as an audio amplifier, resistance coupling being used on both input and output circuits. R_9 is the plate load resistor. C_4 is a mica by-pass which short-circuits any r.f. which may have escaped by the filter in the diode circuit.

The a.v.c. diode load resistor is R_4, across which is developed the negative bias resulting from the flow of rectified carrier current. This negative bias is applied to the grids of the controlled stages through the filtering resistors R_5, R_6 and R_7.

It does not matter which of the two diode plates is selected for audio and which for a.v.c. The reason for separating the two is to permit the audio diode return to be made directly to the cathode and the a.v.c. diode return to ground. This places negative bias on the a.v.c. diode equal to the d.c. drop through the cathode resistor (a matter of a volt or two) and thus delays the application of a.v.c. voltage to the amplifier grids, since no rectification takes place in the a.v.c. diode circuit until the carrier amplitude is large enough to overcome the bias. Without this delay, the a.v.c. would start working even with a very small signal, which is undesirable because the full amplification of the receiver then cannot be realized on weak signals. In the audio diode circuit this fixed bias must be avoided; hence the return is made directly to the cathode.

Time constant is important in the a.v.c. circuit, and is determined by the RC values in the diode and bias-feed circuits to the controlled stages. In high-frequency reception a large time constant is not desirable because it prevents the a.v.c. from keeping up with rapid fading. A too-small time constant would tend to "wash out" modulation. The values shown have been found to be satisfactory in operation.

HIGH-PERFORMANCE SUPERHET WITH REGENERATIVE FIRST DETECTOR

The receiver illustrated in Fig. 740 is intended to give maximum performance for the number of tubes and circuits used, while combining good mechanical stability and adaptability to amateur construction.[5] It is also designed to accommodate a noise-silencer and crystal filter unit, as described farther on, in case the builder wishes to include all the features available in the modern single-signal type receiver. The circuit line-up, as shown in the diagram of Fig. 741, consists of a regenerative mixer using a 6L7 tube, a separate high-frequency oscillator using either a 6D6 glass or 6K7 metal tube, an iron-core transformer coupled i.f. stage using a 6L7 with dual automatic gain control, a 6H6 duo-diode second detector and a.v.c. rectifier, a 6D6 or 6K7 i.f. beat oscillator, a 76 or 6C5 triode first audio stage and a 42 or 6F6 pentode output amplifier. There is also a 6E5 tuning indicator tube which, while not essential to operation of the receiver circuit proper, is an extremely useful adjunct. The receiver operates from a separate power supply, such as the heavy-duty type described in Chapter Fourteen, which must be capable of at least 2.8 amperes at 6.3 volts and 90 ma. at 250 volts d.c.

The injector (No. 3) grid of the 6L7 is capacitively coupled to the cathode of the oscillator. This circuit shows negligible "pulling" effect as the result of mixer input tuning up through the 14-Mc. band, and only slight effect at 28 Mc., provided the coils are properly ad-

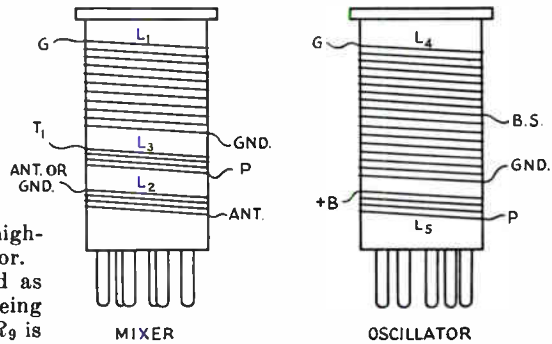


FIG. 738 — METHOD OF WINDING THE MIXER AND OSCILLATOR COILS

All windings are in the same direction.

justed. The single-control tuning system employs the tapped-coil method of band-spreading and tracking with adjustable air condensers for setting the range. Regeneration in the mixer input circuit is obtained by a cathode circuit feedback coil coupled to the grid coil, regeneration being controlled by a variable resistor acting as an r.f. shunt across this tickler winding. It maintains the electrode voltages constant and has but slight effect on the mixer tuning, even at the higher frequencies.

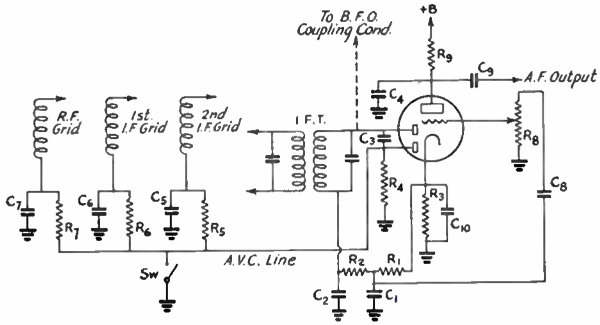


FIG. 739 — SECOND-DETECTOR AND FIRST AUDIO CIRCUIT WITH A.V.C., USING DUO-DIODE-TRIODE TUBE

R_1 — 250,000 ohms, ½-watt.
R_2 — 50,000 to 250,000 ohms, ½-watt.
R_3 — 2000 ohms, ½-watt.
R_4 — 2 to 5 megohms, ½-watt.
R_5, R_6, R_7 — 1 megohm, ½-watt.
R_8 — 500,000 ohms, ½-watt.
R_9 — 250,000 ohms, ½-watt.
C_1, C_2, C_3 — 100 μμfd.
C_4 — 250 μμfd.
C_5, C_6, C_7 — 0.01 μfd.
C_8, C_9 — 0.01 to 0.1 μfd.
C_{10} — 5 to 10-μfd. electrolytic.

Only two points need be mentioned in connection with the i.f. amplifier circuit. The No. 3 grid of the 6L7 is connected in parallel with No. 1 for d.c., but not for r.f., and a voltage divider instead of a simple series resistor is used for obtaining screen voltage. The No. 3 grid is returned to the ground side of the i.f. transformer secondary, where it picks up the a.v.c. voltage along with the No. 1 grid. The rather heavy screen voltage divider maintains the screen at practically constant potential despite the bias applied to the grids, thus increasing the effectiveness of both the manual and automatic gain controls. The manual gain control is bled off the plate supply by the usual method.

One section of the 6H6 is used for detection and the other for obtaining a.v.c. voltage. Since the a.v.c. action is limited, it is not necessary to bias the a.v.c. diode to give delay.

The i.f. beat oscillator operates at low plate voltage and is very loosely coupled to the detector. A weak b.o. signal is favorable for the reception of weak signals and tends to limit the beat response on strong ones.

The diode load circuit consists of the resistors R_{18} and R_{19} in series. R_{18} serves as an r.f. attenuator, backed up by R_{20} for further attenuation. C_{26}, across the 76 grid, is a further aid to keeping r.f. out of the audio circuits and gives some tone-control action to reduce noises of high audio frequency.

The grid of the 6E5 tuning indicator is connected to the audio-diode load rather than to the a.v.c. line. This method of connection permits using the tube as a strength indicator on c.w. signals, since the shadow movement is instantaneous.

The audio circuits require no particular comment. The gain is such that a 'phone signal whose carrier barely moves the tuning indicator will give good loud-speaker strength. Headphone signals are rather more than comfortable level with the audio gain wide open.

The cadmium-plated steel chassis of the receiver is 12 inches by 10 inches by 3 inches deep. As shown in the bottom view of the set, half-inch L-girder strips of aluminum run front to back and across the center under the r.f. circuits to stiffen the chassis. A heavier type of chassis than the kind ordinarily available could be used to good advantage, since mechanical rigidity is of utmost importance in obtaining good electrical stability. Mechanical stability is also aided by the National PW tuning unit, and by the four-corner mounting coil sockets. The tuned circuit wiring is stiff No. 14 tinned solid copper, except for the grid connectors. Even these should be given attention, especially that of the oscillator. If a glass oscillator tube (6D6) is used, a rubber grommet should be provided to support the grid lead where it passes through the tube shield. Otherwise, slight jarring will cause appreciable jumping of the oscillator frequency as the result of this lead shifting position.

The arrangement of the receiver can be followed quite readily from Figs. 740 and 742. Referring to the top view, the tuning-condenser assembly is centrally mounted, the oscillator condenser being that at the left and the mixer at the right. The air trimmers, C_3 and C_4, are directly behind the tuning condensers, followed in each case by the coil sockets and finally by the tubes. The coil and socket pin arrangement is shown in Fig. 743. This arrangement becomes of some importance at the higher frequencies if the receiver and coils are to be duplicated, since the lead lengths have their influence on the coil design. A baffle shield measuring 4½ inches high by 6 inches long runs down the center of the chassis from the dial gear box to the rear edge, shielding the oscillator and mixer

World Radio History

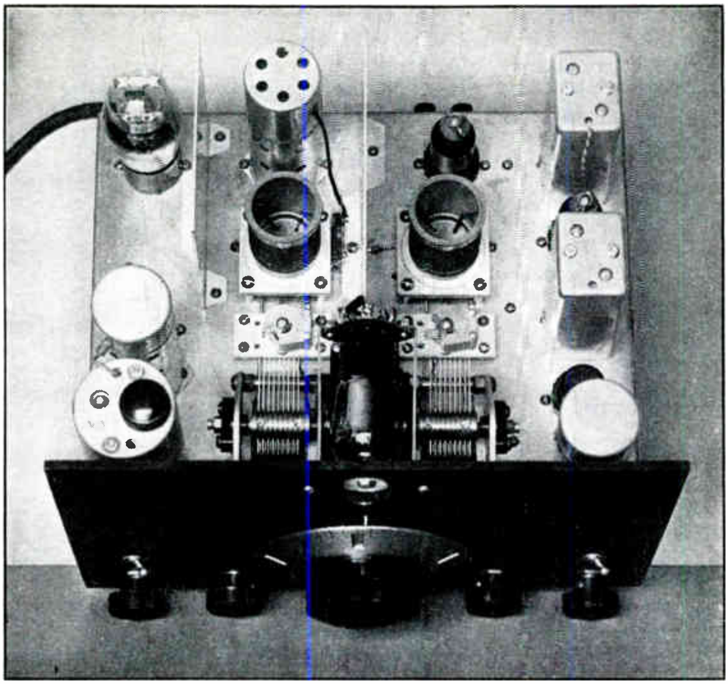


FIG. 740 — TOP VIEW OF THE HIGH-PERFORMANCE SUPERHET, SHOWING THE LAYOUT OF THE COMPONENTS

circuits from each other. A similar baffle, 4½ by 4½ inches, encloses the oscillator on the other side. This shielding is sufficient to prevent coupling between the two tuned circuits.

Connections from the condenser rotors and from the ground ends of the coils should be made to the chassis with the shortest possible leads. In this case we also have ground leads through the tuned circuit paralleling the chassis grounds to insure good conductivity. *But the short, direct grounds to the chassis itself are of prime importance if the set is to be stable in operation,* especially with regeneration on the mixer.

Wiring for the oscillator and mixer circuits occupies the rear center section of the chassis, as shown in the bottom view. The parts are wired in so that short connections can be made, using insulating soldering-lug strips wherever necessary. The antenna-ground post assembly is mounted on the back near the mixer socket, with a shielded lead running through a hole in the chassis to the antenna post on the coil socket.

The regeneration control resistor, R_4, is mounted on a home-made bracket near the back of the chassis. A flexible coupling and a piece of ¼-inch round brass rod bring the control out to the front panel. The bracket should be made so that the resistor shaft will line up with the panel hole when ready for mounting. A bearing keeps the extension shaft in place on the panel and helps make the control smooth-turning. It is necessary to mount the regeneration control in the position shown so that the r.f. trimmer, C_5, can be mounted close to C_1, and thus make possible a short stator connection between the two.

The first i.f. transformer is in the rear right corner of the chassis. Progressing toward the front, next in line is the 6L7 i.f. amplifier tube, second i.f. transformer, 6H6 duo-diode rectifier, and 76 audio tube, the latter being in a shield. Sub-chassis wiring, shown to the left in the bottom view, is again simply a matter of fitting in a considerable number of small parts so that short leads are possible. Ground leads once more should be short and directly to the chassis.

In the bottom view, the audio volume control is at the extreme left. It is the right-hand control in the right-side-up views, and is mounted on the front of the chassis directly below the audio tube socket. A shielded lead runs from the plate of the 76 along the left-hand bracing girder to the back of the chassis, thence to the right along the rear edge to the 'phone jack. The shield is grounded at several points to prevent r.f. pickup.

The left-hand section of the chassis (top view) contains, in order from front to back, the beat-oscillator transformer, b.o. tube and power output tube. These parts are at the right in the bottom view. The control in the corner is the r.f. gain control.

The beat-oscillator transformer used in the receiver is furnished complete with tuning condenser, grid condenser and grid leak, so that it is only necessary to connect the tube and supply the plate circuit resistors and condensers. If the oscillator circuit is made up from different parts, the values given in Fig. 741 will be satisfactory. The lead from the plate of the b.o. tube runs in shielded wire — grounded at several points — to the diode detector plate, coupled through a small condenser mounted right on the appropriate tube-socket prong. This condenser is a home-made affair consisting of two thin brass plates, separated about a sixteenth inch, the facing areas being

World Radio History

about a half-inch square. It is made by removing the center lug from an insulating strip having three lugs, then soldering one brass plate to each of the remaining lugs, on opposite sides of the strip. The size is not critical, but the capacity should be small both to keep down the beat-oscillator signal and to avoid

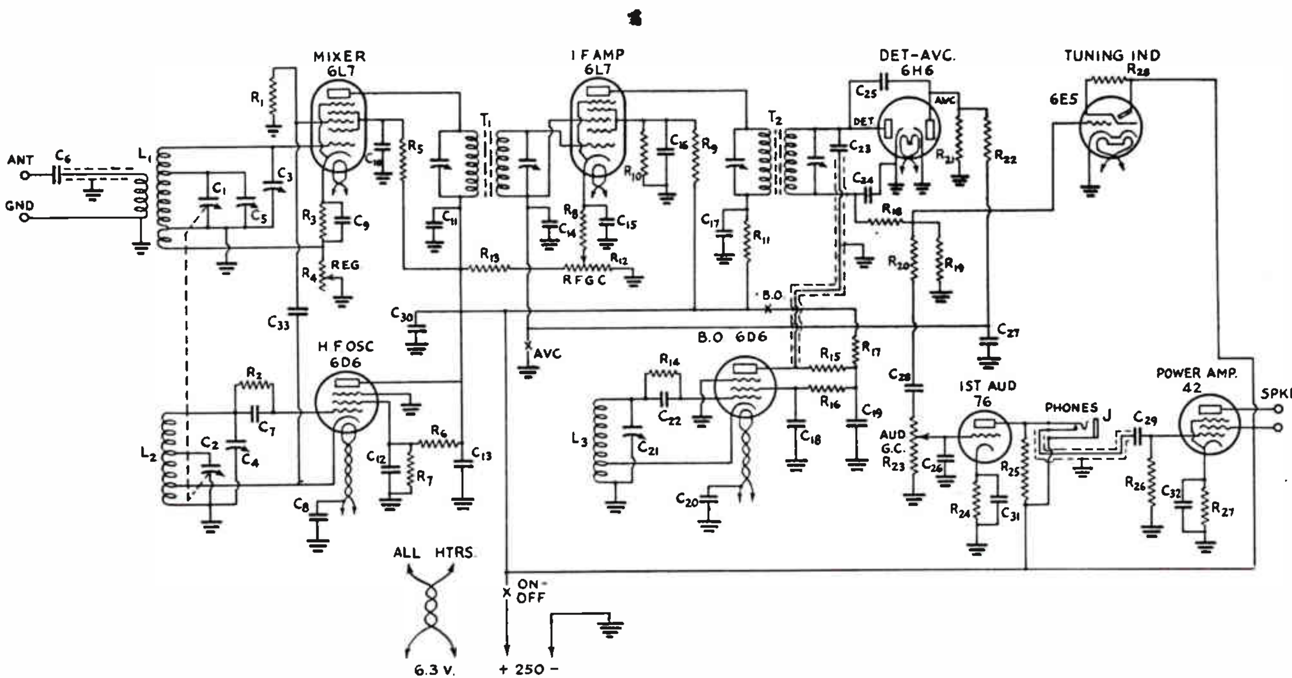


FIG. 741 — THE HIGH-PERFORMANCE SUPERHET CIRCUIT DIAGRAM. SHELL PIN TERMINALS OF METAL TUBES ARE ALL GROUNDED TO THE CHASSIS

C_1, C_2 — Ganged Condensers, 160-$\mu\mu$fd. each (National type PW tuning unit).
C_3, C_4 — 50-$\mu\mu$fd. air trimmers (National type UM-50).
C_5 — 25-$\mu\mu$fd. midget variable (Hammarlund MC-25-S).
C_6 — 50-$\mu\mu$fd. midget mica condenser.
C_7 — 100-$\mu\mu$fd. midget mica condenser.
C_8 — 0.002-μfd. mica condenser.
C_9–C_{20}, inc. — 0.01-μfd. paper condensers, non-inductive.
C_{21} — 140-$\mu\mu$fd. variable (in B.O. unit).
C_{22} — 250-$\mu\mu$fd. mica condenser (in B.O. unit).
C_{23} — B.O. coupling condenser, about 5 $\mu\mu$fd. (see text).
C_{24}, C_{25}, C_{26} — 100-$\mu\mu$fd. mica condensers.
C_{27}, C_{28}, C_{29} — 0.1-μfd. paper condensers.
C_{30} — 0.5-μfd. paper condenser.
C_{31} — 5-μfd., 25-volt electrolytic.
C_{32} — 25-μfd., 25-volt electrolytic.
C_{33} — 50-$\mu\mu$fd. fixed mica condenser.
R_1, R_2 — 50,000 ohms, ½ watt.
R_3 — 500 ohms, ½ watt.
R_4 — 2000-ohm variable (Centralab 72-101).
R_5 — 15,000 ohms, 1 watt.
R_6 — 50,000 ohms, 1 watt.
R_7 — 50,000 ohms, ½ watt.
R_8 — 300 ohms, ½ watt.
R_9 — 10,000 ohms, 10 watts.
R_{10} — 15,000 ohms, 1 watt.
R_{11} — 2000 ohms, ½ watt.
R_{12} — 5000-ohm variable (Centralab 72-110).
R_{13} — 50,000 ohms, 1 watt.
R_{14} — 50,000, ½ watt (in B.O. unit).
R_{15} — 10,000 ohms, 1 watt.
R_{16} — 100,000 ohms, ½ watt.
R_{17} — 50,000 ohms, 1 watt.
R_{18} — 50,000 ohms, ½ watt.
R_{19} — 500,000 ohms, ½ watt.
R_{20} — 100,000 ohms, ½ watt.
R_{21}, R_{22} — 1 megohm, ½ watt.
R_{23} — 1-megohm variable (Centralab 72-116).
R_{24} — 2000 ohms, ½ watt.
R_{25} — 50,000 ohms, ½ watt.
R_{26} — 1 megohm, ½ watt.
R_{27} — 450 ohms, 2 watts.
R_{28} — 1 megohm, ½ watt.
T_1 — Air-tuned iron-core i.f. transformer for coupling 6L7 converter to 6L7 amplifier (Aladdin S-2242-A).
T_2 — Air-tuned iron-core i.f. transformer for coupling 6L7 amplifier to diode rectifier (Aladdin S-2242-B).
L_1, L_2 — See coil table.
L_3 — Beat-oscillator coil, 465 kc. (in B.O. unit).
J — Double-circuit jack.
All switches single-pole single-throw.

World Radio History

adding any appreciable shunt capacity to the diode circuit.

The cathode-ray tuning indicator is mounted on home-made brackets of brass strip so that the top of the tube projects slightly through the panel. The 1-meg. resistor is mounted on the socket, and the necessary leads are twisted into a cable and carried down through the chassis on the detector side of the central baffle shield. The length of these leads does not matter particularly. Mount the tube with the target side downward (heater pins to the right when viewed from the top) so that the shadow will be at the bottom where it is most easily seen.

The three switches are mounted as follows: At left in panel view, beat oscillator on-off switch; below the tuning dial, B cutoff switch; at right, a.v.c. on-off switch.

Keep the filament wires in the corners of the chassis; this is helpful in preventing hum.

When the wiring has been completed and checked, the i.f. circuits should be aligned before the mixer and oscillator coils are given final adjustment. The intermediate circuits should be tuned exactly to the right frequency, 465 kc., since the tracking of the oscillator and first detector circuits depends on the intermediate frequency. This is best done with a test oscillator of the type described in Chapter Sixteen. To line up the i.f., clip the oscillator leads on ground and the 6L7 mixer grid — with the coils out of their sockets — set the oscillator to 465 kc., and adjust the trimmers to give maximum deflection of the 6E5. If the "eye" closes entirely, decrease the test oscillator output or reduce the r.f. gain control so that a definite maximum point can be passed through on each trimmer.

If no test oscillator is available, the c.w. beat oscillator can be used for the purpose. To set the b.o. on the proper frequency, connect a wire to its plate and bring it near the lead-in to a broadcast receiver. Tune the latter to 930 kc. and adjust the beat oscillator until its second harmonic is at zero beat with the station heard. Then couple the b.o. output to the grid of the mixer — simply taking a turn around the grid cap should be enough — connect the grid to ground through a resistor of a megohm or so, and line up as already described.

The i.f. should show no tendency to oscillate with all circuits at resonance, provided the shells of the metal tubes are grounded.

In winding the coils, make the 14-Mc. set first. This is usually the hardest set to get lined up properly, and it is also the easiest set to duplicate from specifications. Follow the mechanical layout of the oscillator and detector circuits, particularly spacing between condensers and coil sockets so the lead lengths will be about the same as in the original receiver. Wind the 20-meter coils *exactly* as given in the table. Plug in the coils, set the regeneration control at the zero position (resistance all out), and set C_5 at half capacity. Set the tuning dial at about 250, couple on the antenna and tune C_4 carefully until amateur signals are heard. Make a final adjustment to C_4 to bring the low frequency end of the band at about 100 on the tuning dial. With the low-frequency end at 100, the high-frequency end should fall between 350 and 400.

When the trimmers are properly adjusted, they should be marked so that they can be returned to the same settings at any time. The correct settings will be found to be somewhere in the vicinity of half capacity.

With the 14-Mc. range in working order, the other coils must be wound to fit the trimmer settings just found. Some slight modification of the specifications given may be necessary,

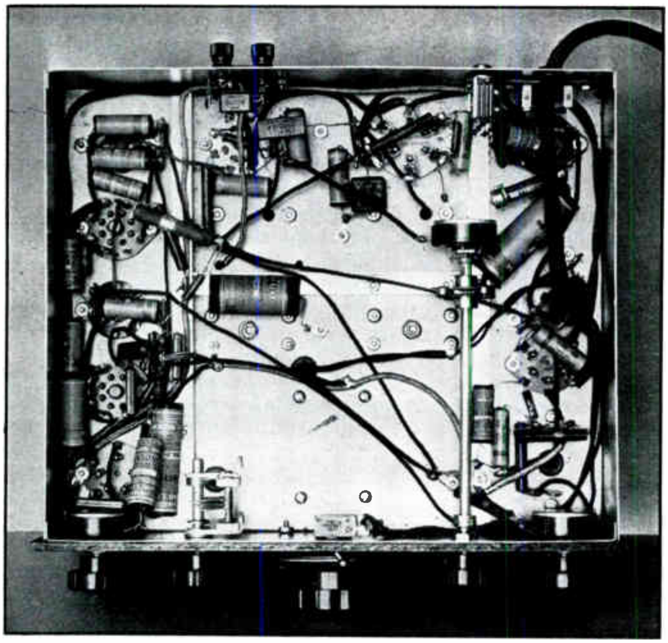


FIG. 742 — UNDERNEATH THE HIGH-PERFORMANCE SUPER'S CHASSIS

Resistors and by-pass condensers are placed to give short, direct connections. Other components are located as described in the text.

World Radio History

HIGH-PERFORMANCE SUPERHET COIL TABLE

	Oscillator, L_2			*Mixer, L_1*			
Band	*Total Turns*	*Cath. Tap*	*Band Spread Tap*	*Total Turns*	*B.S. Tap*	*Cath. Coil Turns*	*Ant. Coil Turns*
28 Mc.	3.0	1.0	0.25	3.3	0.25	0.8	2
14 Mc.	8.3	2.8	1.5	8.3	1.5	0.8	3
7 Mc.	16.8	4.8	4.0	16.8	4.0	0.4	4
3.5 Mc.	29.3	8.8	11.5	29.3	12.5	0.5	9
1.75 Mc.	50.3	17.8	23.5	55.3	30.5	0.5	12

Oscillator coils are space-wound to occupy a length of 1½ inches, on 1½-inch diameter forms. Mixer coils are space-wound to occupy a length of 1¼ inches, on similar forms, except 1.75-Mc. coil which is close-wound. Wire is No. 24 d.s.c. The cathode coil on L_1 is wound in the opposite direction to the grid coil, starting from the ground end of the grid coil. It is very closely coupled to the grid coil. Antenna coils are close-wound, spaced about ¼ inch from grid coil at ground end. Cathode tap on L_2, and band-spread taps on L_1 and L_2, are measured from the ground end of each grid coil.

Specifications are given to the nearest tenth of a turn. The tenths can be measured off quite accurately by making a paper scale equal in length to the circumference of the coil form and dividing it into ten equal parts. Spacing between turns should be adjusted to be as uniform as possible, and the turns doped in place after the coil is finished. Coil forms are National 6-prong, with corresponding coil sockets.

but they should work out quite closely with reasonable care in duplication.

QUARTZ CRYSTAL FILTERS

The quartz crystal filters used in the i.f. amplifiers of single-signal type receivers are of two distinct types. One type permits adjustment of the sharpness of crystal resonance (selectivity) from the maximum usable for c.w. telegraph reception to a minimum which permits reception of telephone signals with fair intelligibility, while the other type has a practically fixed sharpness of resonance. Typical circuits of both types of filters are shown in Fig. 744, *A* and *B* being variable band-width circuits while *C* is a fixed selectivity circuit. In each of the three arrangements shown, the crystal, which is connected in one arm of a bridge circuit, is especially ground to have a series-resonant frequency corresponding to the receiver's intermediate frequency and to have negligible response as a resonator at other frequencies in this vicinity. To insure active response, the crystal is usually mounted in a holder having an air gap of approximately 0.001 inch between the crystal and one plate.

The crystal serves as the selective series coupling element between the input transformer T_1 and the output transformer T_2. Since the crystal has a series-resonant impedance of the order of 2500 to 3000 ohms, a step-up is provided in the output transformer to give an efficient match between the crystal network and the high-impedance tuned grid circuit of the following amplifier. This is obtained either by the auto transformer connection of T_2 in *A*, or by the separate primary L_4 in *B* and *C*. For 450 to 465 kc. intermediates, L_3 is of approximately 1.2-millihenry inductance, as is also the secondary of the input transformer, L_2, in *A* and *B*. In *C*, input primary L_1 is approximately 1.2 mh. and C_1 is a 100-$\mu\mu$fd. variable, while the center-tapped input secondary L_2 is of approximately ⅓ the primary inductance, to give an impedance step-down from the tuned primary L_1, and is coupled closely to the latter. In *A* and *B*, the untuned primary L_1 has approximately 5.5-millihenry inductance and is closely coupled to L_2. In each case the output coupling condenser C_3, which allows adjustment to compensate for crystal variations, is of approximately 50-$\mu\mu$fd. maximum capacitance. Since none of the coupling values in the filter circuit is especially critical, a fixed condenser of this capacitance is sometimes used at C_3. In all three circuits, the "rejection control" condenser C_2 has a maximum capacitance of 10 $\mu\mu$fd. or so and a very low minimum. The switch, *Sw*, is used to short out the crystal for "straight" superhet reception with ordinary selectivity. In the construction of such filters, the input and output circuits are shielded from each other.

Variable Selectivity Action

In circuits of the type of *A* and *B*, variable selectivity is obtained by adjustment of the variable input impedance, which is effectively in series with the crystal resonator, by means of the "Band Width" control. This control varies C_1 (50$\mu\mu$fd. in *A* and 100$\mu\mu$fd. in *B*), which tunes the balanced secondary circuit of T_1. When the secondary is tuned to i.f. resonance, which is also the series-resonant frequency of the crystal, the parallel impedance of the L_2-C_1 combination is maximum and is purely resistive. Since the secondary circuit is center-tapped, one-fourth of this resistive impedance (approximately 25,000 ohms) is in

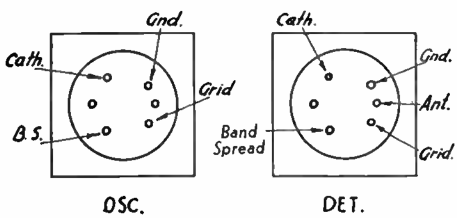


FIG. 743 — THE HIGH-PERFORMANCE SUPERHET'S COIL SOCKET CONNECTIONS AS VIEWED FROM THE TOP

World Radio History

series with the crystal, through C_3 and L_4. This effective resistance lowers the Q of the crystal circuit and makes its selectivity minimum. At the same time, the voltage applied to the crystal circuit is maximum.

When the input circuit is detuned from the crystal resonant frequency, the resistance component of the input impedance decreases, and so does the total parallel impedance. Accordingly, the selectivity of the crystal circuit becomes higher and the applied voltage falls off. At first the resistance decreases faster than the applied voltage, with the result that at first the c.w. output from the filter *increases* as the selectivity is increased. The output then falls off gradually as the input circuit is detuned farther from resonance and the selectivity becomes still higher. The net result of this behavior is that the filter output for a pure c.w. signal is least when the band width is the greatest (input tuned to resonance), then increases to maximum at medium selectivity, and finally falls off slightly at maximum selectivity. The total variation is only a few decibels, however.

The selectivity can be varied over a range of more than 12 to 1, at 10 times down, with the crystal filter. The maximum selectivity is more than 35 times that obtained with the crystal filter switched out in typical receivers having two i.f. stages.

Adjustable Rejection

The crystal is connected in the bridge circuit so that counter voltage of controllable phase can be applied to the output side of the filter so as to modify the shape of the crystal's normal resonance curve, both to prevent unselective transmission through the capacitance of the holder and to make the crystal anti-resonant for a particular interfering signal in a range from a few kilocycles above to a few kilocycles below the series-resonant frequency.

The capacitive reactance of the crystal electrodes normally resonates with the inductive reactance of the crystal to make this part of the circuit *anti-resonant* at a frequency approximately 0.5 percent above crystal resonance. By means of the phasing condenser C_2 the effect of the capacitive reactance of the holder can be modified to shift the anti-resonant frequency, or to make the crystal resonance curve practically symmetrical. Rejection of at least 60 db for interference up to within a few hundred cycles of resonance on either side can be obtained. Fig. 732 illustrates the type of resonance curve obtained with C_2 set to reject the audio image of a heterodyned c.w. signal.

Rejection is practically independent of bandwidth control. The phasing condenser is sometimes used as a "selectivity" control to broaden the response in filters of the fixed band-width type (Fig. 744-C) by adjusting its capacitance above or below the rejection region. However, this only serves to by-pass the crystal circuit, in effect, and the phasing condenser is then ineffectual for rejection of interfering signals.

NOISE INTERFERENCE REDUCTION

Much of the interference experienced in reception of amateur signals is caused by domestic electrical equipment and automobile ignition systems. The interference is of two types in its effects. The first is of the "hiss" type consisting of overlapping pulses, similar in nature to the receiver noise previously discussed. It is largely reduced by high selectivity in the receiver, especially for code reception. The second is the "pistol shot" or "machine gun" type, consisting of separated impulses of high amplitude. The "hiss" type of interference is usually caused by commutator sparking in d.c. and series a.c. motors, while the "shot" type results from separated spark discharges (a.c. power leaks, switch and key clicks, ignition sparks, and the like).

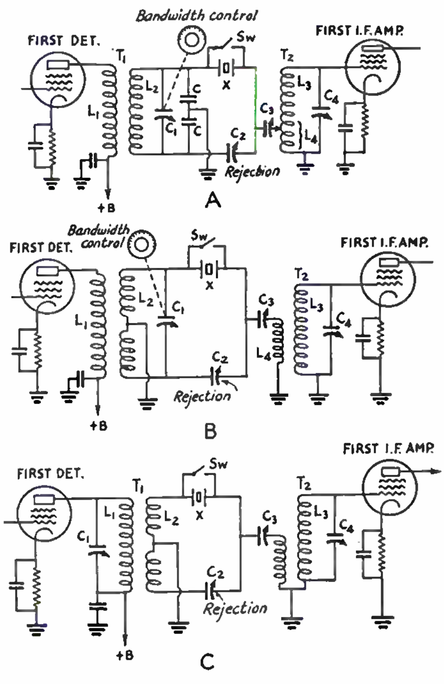


FIG. 744—THREE TYPES OF CRYSTAL FILTER CIRCUITS

Circuits A and B give variable band width, while C is a fixed sharpness of resonance circuit. All three have adjustable rejection. Circuit values for 450 to 500 kc. operation are given in the text.

World Radio History

With the "hiss" type, both the effective (r.m.s.) and peak voltage values are reduced as the *square-root* of the ratio of reduction in receiver effective band-width; but with the "shot" type of interference, while the r.m.s. voltage value varies as the square-root of the effective band-width, the peak value is reduced in direct proportion to the reduction in band-width. This occurs because the damped wave trains resulting from the impulses are prolonged as the selectivity is increased and will overlap if the selectivity is made high enough. This accounts for the continuous "ringing" effect noticed with crystal-filter receivers when there is severe spark interference.

Both "hiss" and "shot" interference may be reduced by use of a receiving antenna system of the "noise reduction" type, where the antenna proper is located remotely from the noise sources and connected to the receiver by a balanced or shielded transmission line which has small pick-up. Other methods may be applied in the receiver itself.

Noise-Silencing I.F. System

One method which is particularly effective against "shot" type interference is applied to the i.f. circuit of a superhet. This system operates to make the noise pulses "commit suicide" before they have a chance to reach the second detector. Fig. 745 gives the circuit of such a silencer applied to the second i.f. stage. Noise voltage in excess of the desired signal's maximum i.f. voltage is taken off at the grid of the i.f. amplifier, amplified by the noise amplifier stage and rectified by the full-wave diode noise rectifier. The noise circuits are tuned to the i.f. The rectified noise voltage is applied as a pulse of negative bias to the No. 3 grid of the 6L7 used as an i.f. amplifier, wholly or partially disabling this stage for the duration of the individual noise pulse, depending on the amplitude of the noise voltage. The noise amplifier-rectifier circuit is biased, so that rectification will not start until noise voltage exceeds the desired-signal amplitude, by means of the "Threshold Control." For reception with automatic volume control, the a.v.c. voltage is also applied to the grid of the noise amplifier to augment this threshold bias. This system of noise silencing gives signal-noise ratio improvement of the order of 30 db (power ratio of 1000) with heavy ignition

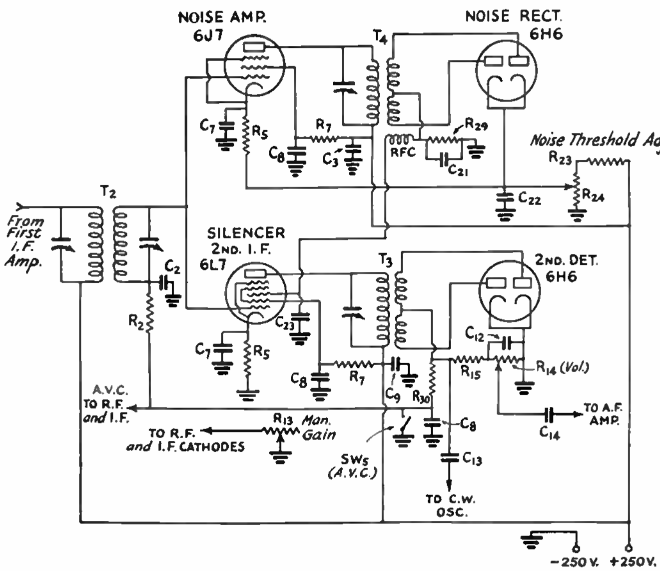


FIG. 745 — SILENCER CIRCUIT APPLIED TO THE SECOND I.F. STAGE OF A TYPICAL SUPERHET. THIS CIRCUIT IS NOT ADAPTABLE TO RECEIVERS IN WHICH A COMMON BIAS CIRCUIT IS USED FOR I.F. AND AUDIO CONTROL GRIDS. THE NEGATIVE-B OF THE HIGH-VOLTAGE SUPPLY MUST BE GROUNDED AT THE FILTER OUTPUT

C_2 — 0.01-μfd. grid by-pass condensers, 200-volt tubular.
C_3 — 0.01- to 0.1-μfd. plate by-pass condensers, 400-volt tubular.
C_7 — 0.1-μfd. cathode by-pass condensers, 200-volt tubular.
C_8 — 0.01- to 0.1-μfd. screen by-pass condensers, 400-volt tubular.
C_9 — 0.25-μfd. main by-pass condenser, 600-volt tubular.
C_{12} — 50-μμfd. detector load by-pass, mica midget.
C_{13} — 50-μμfd. beat osc. coupling condenser, mica midget.
C_{14} — 0.1-μfd. detector output coupling condenser, 200-volt tubular.
C_{21} — 0- to 250-μμfd. noise rectifier load by-pass, mica midget.
C_{22} — 0.1-μfd. threshold resistor by-pass, 200-volt tubular.
C_{23} — 50-μμfd. silencer r.f. by-pass, mica midget.
R_2 — 100,000-ohm grid filtering resistor, ½-watt.
R_5 — 350- to 1000-ohm cathode resistors, ½-watt.
R_7 — 100,000-ohm screen-voltage dropping resistors, ½-watt.
R_{13} — 500-ohm manual r.f. gain control.
R_{14} — 1-megohm volume control.
R_{15} — 50,000-ohm detector load resistor, ½-watt.
R_{23} — 20,000-ohm threshold bleeder resistor, 1-watt.
R_{24} — 5000-ohm threshold control potentiometer, volume-control type.
R_{29} — 100,000-ohm noise rectifier load resistor, ½-watt.
R_{30} — 1-megohm a.v.c. filter resistor, ½-watt.
RFC — 20-millihenry r.f. choke.
T_2 — Double air-tuned i.f. transformer (Hammarlund ATT-465).
T_3 and T_4 — Single air-tuned full-wave diode coupling transformers (Sickles 456-kc.).

World Radio History

interference, raising the signal-noise ratio from −10 db without the silencer to +20 db with the silencer in a typical instance.

A Noise-Silencer and Crystal Filter Unit

In a receiver using a crystal filter, application of the noise silencer to a subsequent stage is ineffectual with noise interference of the pulse type, because of the reduction in peak-to-effective-voltage ratio and elongation of the noise wave trains in the high-selectivity circuit. The silencer must be able to get at the noise before this occurs; that is, it must precede the crystal filter. A practical circuit for accomplishing this is shown in Fig. 747. It operates in the same manner as the second i.f. stage arrangement, except that the signal gain of the 6L7 stage is reduced and its noise-control sensitivity increased to obtain action at the lower amplification level. This is accomplished by reduced screen voltage obtained from the screen-cathode voltage divider, which also maintains relatively high cathode-drop bias on the signal and silencer grids.

The noise-silencer and crystal filter unit diagrammed in Fig. 747 and shown in Figs. 746 and 748 is especially designed for the "High-Performance" receiver, but is also adaptable to other receivers using one or two i.f. stages.[6]

FIG. 746 — THE CRYSTAL FILTER AND NOISE-SILENCER UNIT ATTACHED TO THE HIGH-PERFORMANCE SUPER

The unit bolts to the right-hand side of the receiver chassis. No receiver wiring changes are necessary. The various components are identified in the text.

The 6L7 is an extra i.f. amplifier tube, preceding the crystal filter; the paralleled control grids of the 6L7 and 6J7 pick up their i.f. exciting voltages from the grid cap which normally goes to the i.f. tube in the receiver. After passing through the unit, the i.f. signal goes to the grid of the receiver i.f. tube.

The primary of the crystal input transformer, T_1, connected in the plate circuit of the 6L7, is untuned. The particular transformer used has its secondary tuned by an air trimmer of the usual type; to get the balanced circuit needed for the crystal filter, and also to provide a selectivity control, a split-stator condenser, C_1, is connected across the secondary circuit. C_2 is the phasing condenser or rejection control. The crystal output transformer, T_2, is a single-winding affair, also air-tuned, tapped to give a suitable match for the crystal impedance. The tap is coupled to the crystal through a 50-$\mu\mu$fd. fixed condenser. The ground terminal of T_2 is indicated in the diagram as going to the a.v.c. line in the receiver. In case the unit is applied to another type of receiver which does not have a.v.c., this lead can be connected directly to the chassis, in which case C_{11} may be omitted.

In the silencer circuit, the 6J7 noise amplifier is biased for normal operation, but its cathode is connected to the rotor arm of a variable resistor, R_8, so that the bias applied to its grid can be varied between a minimum of three volts (resulting from the use of the cathode resistor R_5) and a maximum of about 20 volts. R_8, by setting the point at which the noise circuit starts to operate, acts as a threshold control. The cathode of the 6H6 noise rectifier also is connected to the movable arm of R_8 to bias the diode plates so that rectification will not take place until the incoming signal or noise reaches the desired level. The switch Sw_2 opens the cathode circuits of both tubes to disable the noise-silencing circuit when desired.

Only the primary of the diode input transformer is tuned. Its secondary is center-tapped so that the diode can be used as a full-wave rectifier. This helps prevent r.f. from getting into the line to the No. 3 grid of the 6L7, where it might upset the action of the silencer. Additional filtering is provided by C_3, C_4, and *RFC*.

The chassis is made up of aluminum, 4 inches wide, 10 inches deep and 3 inches high, to line up with the receiver chassis. The layout permits getting quite short leads from the first i.f. transformer in the receiver and back again into the grid of the i.f. amplifier tube.

Looking at Fig. 746, the crystal filter occupies the left-hand section and the noise silencer the right, with the exception of C_1, the selectivity control. The 6L7 is in the left rear corner. In front of it is the output transformer, T_2,

World Radio History

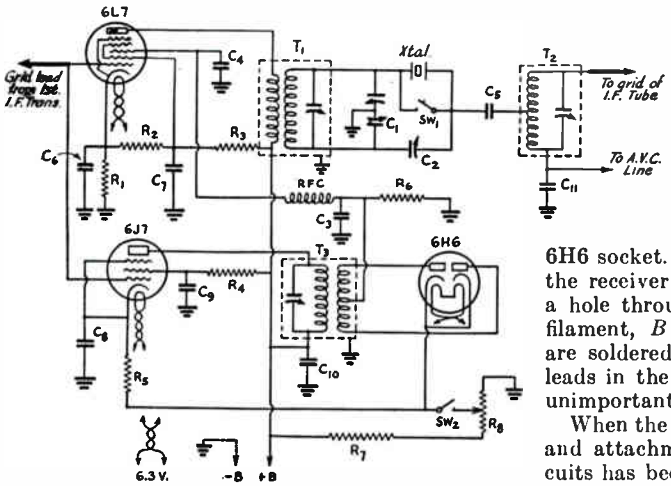


FIG. 747 — CIRCUIT DIAGRAM OF THE CRYSTAL FILTER AND NOISE-SILENCER UNIT

The only r.f. connection disturbed in the receiver is the grid-cap connection to the i.f. tube.

C_1 — Split-stator condenser (selectivity control), 50 $\mu\mu$fd. per section (National STD-50).
C_2 — 15-$\mu\mu$fd. variable (phasing condenser) (National UM-15).
C_3 — 100-$\mu\mu$fd. mica.
C_4, C_5 — 50-$\mu\mu$fd. mica.
C_6 to C_{10}, inc. — 0.1 paper.
C_{11} — 0.01 paper.
R_1 — 2000 ohms, ½-watt.
R_2 — 50,000 ohms, 1-watt.
R_3, R_4 — 100,000 ohms, 1-watt.
R_5 — 300 ohms, ½-watt.
R_6 — 100,000 ohms, ½-watt.
R_7 — 30,000 ohms, 2-watt.
R_8 — 3000-ohm wire-wound volume control (noise-silencer threshold control) (Yaxley).
RFC — 20 millihenry r.f. choke (Sickles).
T_1 — Crystal filter input transformer, 465 kc. (Sickles).
T_2 — Crystal filter output autotransformer, 465 kc. (Sickles).
T_3 — Diode transformer for noise circuit, 465 kc. (Aladdin).
SW_1 — S.p.s.t. switch; see text for description.
SW_2 — S.p.s.t. toggle switch mounted on R_8.
XTAL — Bliley BC-3, 465 kc.

then the crystal socket, and finally, right at the front, the input transformer, T_1. The 6L7 plate lead is run through shield braid to prevent coupling to the other wiring. On the right-hand side, the 6J7 is at the rear right, next is the diode transformer T_3, next the 6H6, and finally C_1, the crystal selectivity control.

By-pass condensers underneath the chassis are placed so that short connections to the chassis can be made. The phasing condenser, C_2, is mounted below deck by one of the brackets furnished for that purpose. An insulating coupling between the condenser rotor and an extension shaft brings the control out to the front. A condenser with an insulating mounting is essential, since neither side of C_2 can be grounded. The crystal on-off switch, S_1, is simply a piece of thin brass cut so that when C_2 is set at minimum its rotary plates touch the brass and short-circuit the crystal. The "switch" is mounted on a spare hole in the isolantite mounting plate of the condenser.

The r.f. choke in the silencing circuit is mounted on the side of the chassis near the 6H6 socket. The whole unit is fastened to the receiver chassis with machine screws; a hole through both furnishes an inlet for filament, B plus, and a.v.c. leads. These are soldered to convenient corresponding leads in the receiver itself; their length is unimportant.

When the wiring of the silencer-filter unit and attachment to the other receiver circuits has been completed, the next step is to align the i.f. circuits to the crystal frequency (465 kc.). The i.f. circuit can be first aligned using the crystal in a separate test oscillator circuit as shown in Chapter Sixteen. During this process the silencer threshold adjustment should be in the "off" position. If the i.f. circuit has been aligned previously, using a 465-kc. test oscillator, it is not entirely necessary to use the crystal in a separate oscillator circuit and an alternative procedure can be followed. The first step is to find the main peak of the crystal.

Remove the grid cap from the first detector in the receiver and connect the appropriate leads from the test oscillator. Using headphones, with the beat oscillator off, Sw_2 open and Sw_1 open, vary the oscillator frequency slowly while listening closely for the characteristic "plop" or chirp as the oscillator frequency goes through a crystal peak. If more than one peak shows up (usually there is more than one, but not closer than seven or eight, kilocycles to the main peak), it will be necessary to go through the tuning procedure on each in order to determine which is the main peak. The principal one will give the greatest response.

With the test oscillator peaked on the crystal frequency, tune all circuits for maximum deflection of the 6E5. It may be necessary to back off the r.f. gain as the circuits come into line, to keep the deflection within the right operating range. Readjust the test oscillator occasionally to keep the frequency on the crystal peak. To adjust T_1, set C_1 near maximum capacity and line up with the trimmer in T_1. When the selectivity control, C_1, is set to give maximum response with the crystal "in," the 6E5 deflection should be the same with Sw_1 either closed or open.

To adjust the noise silencer, close Sw_2 and advance R_8 to about four-fifths maximum.

World Radio History

Again using the test oscillator, adjust the condenser in T_3 to block off the signal. The point at which blocking occurs will depend upon the signal strength and the setting of R_8; use a signal which will deflect the 6E5 to about half scale and keep retarding R_8 until the signal just blocks off when T_3 is tuned to resonance. The blocking is very easily seen on the "eye." With a local noise source the adjustment of T_3 can be made equally well without a signal — possibly better — by adjusting for greatest noise suppression.

If no test oscillator is available, a strong incoming signal may be used for lining-up purposes. It should, however, be perfectly steady. A local broadcast harmonic or signal from the freq-meter-monitor is best.

In operation, with the crystal switch, Sw_1, closed (this occurs with the phasing condenser, C_2, set at minimum, as already described), the crystal is cut out of the circuit and the receiver is simply a "straight" superhet. C_1 should in that case be set for maximum signal strength. With the switch open, and C_1 set at the same point, the selectivity is greatly increased and the signal strength unchanged. Tune in a signal to maximum strength, using the 6E5 as an indicator, and set the beat oscillator to the desired pitch. Tune the main dial to the same pitch on the other side of zero beat, without touching anything else. This "other side" will be quite weak compared to the right setting. Now vary C_2 slowly until the beat note disappears, or reaches a very low minimum. This process eliminates the audio-frequency image and is an important setting in obtaining maximum c.w. selectivity. The selectivity can be further increased by tuning C_1 down in capacity from the resonance setting; maximum selectivity will be found with C_1 considerably on the high-frequency side of i.f. resonance. At maximum selectivity (C_1 all out) some decrease in signal strength results, although the decrease is unimportant compared with the increase in selectivity. Should a strong interfering signal still cause trouble, it can often be eliminated by careful adjustment of C_2, which moves the point of maximum rejection over a small frequency range. For tuning across the band, and for most communication, the selectivity will be sufficient with C_1 set for optimum selectivity — at or slightly higher than resonance — and with C_2 set for rejection of the a.f. image.

The action of the silencer in taking out strong noise peaks of the auto-ignition type, plus the selectivity of the crystal in reducing

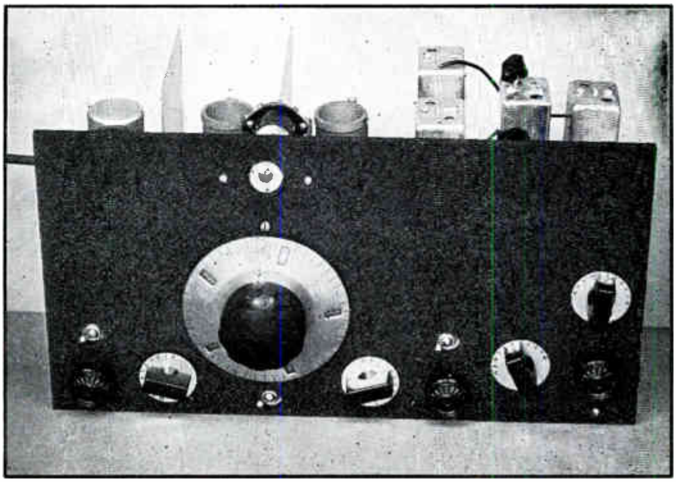


FIG. 749 — THE HIGH-PERFORMANCE AMATEUR SUPERHET INCORPORATING VARIABLE-SELECTIVITY CRYSTAL FILTER AND NOISE-SILENCER CIRCUITS

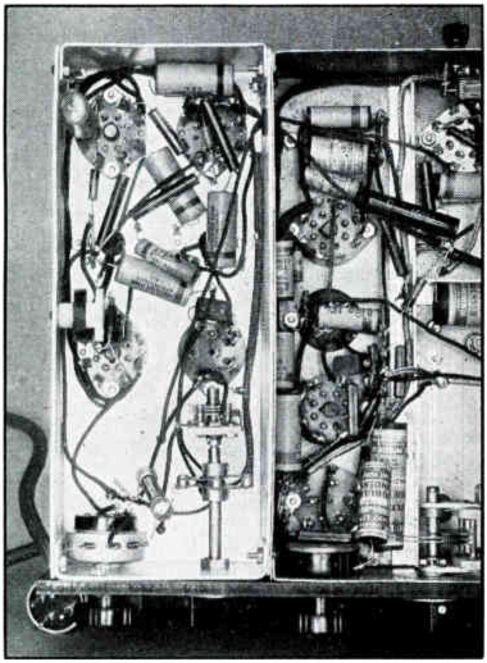


FIG. 748 — SUB-BASE WIRING OF THE FILTER-SILENCER

In most cases, parts are simply placed in convenient locations, using short r.f. leads. The d.c. and filament supply connections to the receiver go through the grommet in the side of the unit.

World Radio History

noise of the hiss type, makes it possible to copy weak signals through a noise background which completely masks them with the ordinary superhet arrangement.

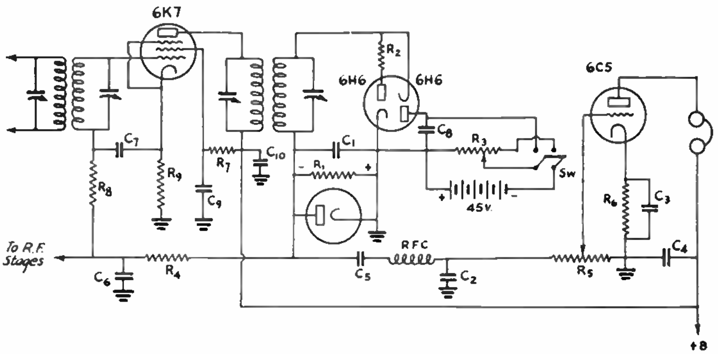


FIG. 750 — CIRCUIT DIAGRAM OF THE "SEE-SAW" SILENCER

R_1 — 0.5 megohm.	RFC — 20-mh. choke
R_2 — 1000 ohms.	C_1, C_2 — 100 μμfd.
R_3 — 25,000 ohms.	C_3, C_4 — 0.5 μfd.
R_4 — 0.5 megohm.	C_5 — 0.01 μfd.
R_5 — 0.25 megohm.	C_6 — 0.05 μfd.
R_6 — 1000 ohms.	C_7 — 0.01 μfd.
R_7, R_8 — 0.1 megohm.	C_8 — 0.5 μfd.
R_9 — 350 ohms.	C_9, C_{10} — 0.1 μfd.

"See-Saw" Second Detector Noise Silencer

Fig. 750 shows the "see-saw" circuit of B. S. McCutchen applied to a conventional superheterodyne receiver.[7] The left-hand diode elements of the 6H6 are connected in the usual manner and form the signal detector, R_1 being the load resistance. The right-hand diode elements, together with the anode bias battery and potentiometer R_3, form the noise "gate." The double-pole switch throws the silencer in and out of operation and at the same time prevents the discharge of the anode bias battery through the potentiometer when not in use.

The rectifying action of the normal signal diode builds up a negative voltage across resistance R_1. The amplitude of this voltage varies with the modulation of the received signal. If the moving arm of potentiometer R_3 is moved all the way to the ground end, the right-hand diode elements, which are reverse-connected, will build up a positive potential across R_1. In this condition the see-saw is in balance; one half cycle of i.f. builds up a negative potential and the next half cycle of i.f. drains it off again, the net result being that no audio signal is produced. If the arm of the potentiometer is moved away from ground, thus applying negative bias to the gate diode, this diode will not function until the amplitude of the received signal exceeds the bias potential. The correct setting is easily determined in practice by simply reducing the bias until the quality of the received signal begins to be hurt, and then increasing the bias very slightly. When a noise pulse of amplitude in excess of the signal comes in, the gate diode goes into operation and cuts out that portion of the noise pulse which is above the signal level, thus preventing it from being demodulated into an audio pulse.

The purpose of R_2 is to handicap the signal diode slightly, so that when noise pulses bring the gate diode into operation, it will have a little leverage on its end of the see-saw. This resistance is important, as it not only improves the degree of elimination, but also makes the setting of the potentiometer less critical. In most cases a value of 1000 ohms will be satisfactory, but this depends to some extent on the particular receiver, and it is suggested that a range of values from several hundred to several thousand ohms be tried.

As resistance R_2 handicaps the signal diode, in the presence of very strong noise interference the gate diode will win out, and a positive resultant audio voltage will tend to be built up across the load resistor R_1. To overcome this condition, a leakage diode is connected as shown across R_1, to drain off any positive potential. (For further details see *QST*, July, 1937.)

Noise- and Signal-Limiting Detector Circuit

A circuit which provides amplitude limiting for noise pulses and which also is useful for

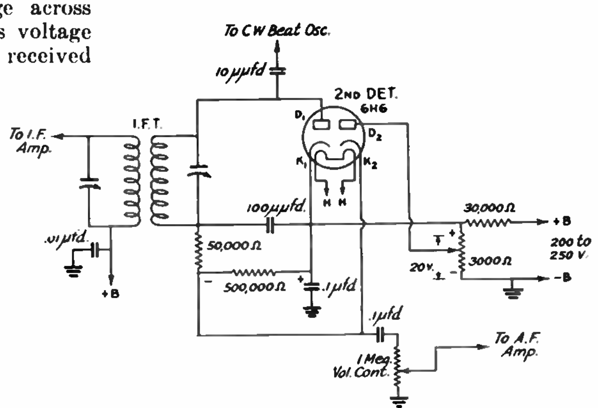


FIG. 751 — NOISE- AND SIGNAL-LIMITING DIODE DETECTOR CIRCUIT

maintaining approximately constant c.w. signal output with fading is shown in Fig. 751. The signal from the last i.f. transformer is detected by the No. 1 diode section, the useful a.f. signal voltage being taken off across the 500,000-ohm load resistor. The No. 2 diode section of this same tube is effectively in shunt with this resistor, with its anode biased negative with respect to its cathode by the voltage obtained across the 3000-ohm potentiometer. Excessive signals or pulses of noise great enough to cause the voltage across the 500,000-ohm load resistor to exceed the negative bias on D_2 will cause the No. 2 diode to draw current and present a low impedance across the signal diode load circuit, thus limiting the signal and noise output. In operation, the potentiometer should be adjusted so that the signal output is not distorted in the case of 'phone reception, or is at the desired average level in the case of c.w. telegraph. With this circuit the a.v.c. voltage should be obtained from a separate rectifier. (Adapted from the limiter circuit used in RCA communication-type receivers.)

Automatic Noise Suppressor Circuit

A second-detector noise limiting circuit which automatically adjusts itself to the received carrier level (J. E. Dickert)[8] is shown in Fig. 752. The diode load circuit consists of R_6, R_7, R_8 (shunted by the high-resistance audio volume control, R_4) and R_5 in series. The cathode of the 6N7 noise-limiter is tapped on the load resistor at a point such that the average rectified carrier voltage (negative) at its grid is approximately twice the negative voltage at the cathode, both measured with reference to ground. A filter network, R_1C_1, is inserted in the grid circuit so that the audio modulation on the carrier does not reach the grid, hence the grid potential is maintained at substantially the rectified carrier voltage alone. The cathode, however, is free to follow the modulation, and when the modulation is 100% the peak cathode voltage will just equal the steady grid voltage.

At all modulation percentages below 100% the grid is negative with respect to cathode and current cannot flow in the 6N7 plate-cathode circuit. A noise pulse exceeding the peak voltage which represents 100% modulation will, however, make the grid positive with respect to cathode and the relatively-low plate-cathode resistance of the 6N7 shunts the high-resistance audio output circuit, effectively short-circuiting it so that there is practically no response for the duration of the noise peak over the 100% modulation limit. The system automatically adjusts itself to the carrier level, and squelches noise when no carrier is present.

R_5 is used to make the noise-limiting tube more sensitive, by applying to the plate an audio voltage out of phase with the cathode voltage so that at the instant the grid goes positive with respect to cathode, the highest positive potential also is applied to the plate, thus further lowering the effective plate-cathode resistance.

By proportioning the resistors properly, the system can be adjusted to give silencing at any pre-determined modulation percentage. With the constants given, silencing starts at about 80% modulation, which has been found to give effective noise limiting without introducing objectionable audio distortion. The circuit also is effective in c.w. reception, the time constant of R_1C_1 being sufficiently rapid to follow normal keying speeds. R_6 may be reduced or even eliminated for more effective silencing in c.w. reception.

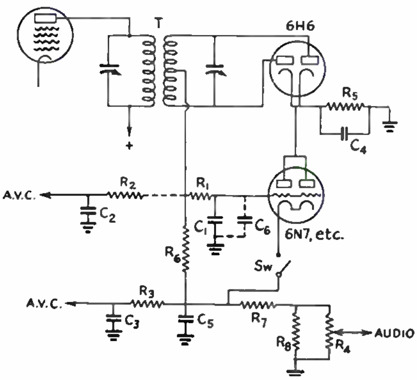


FIG. 752 — AUTOMATIC NOISE LIMITING CIRCUIT FOR SUPERHET RECEIVERS

T — I.F. transformer with balanced secondary for working into diode rectifier.
R_1, R_2, R_3 — 1 megohm, ½-watt.
R_4 — 1-megohm volume control.
R_5 — 250,000 ohms, ½-watt.
R_6, R_8 — 100,000 ohms, ½-watt.
R_7 — 25,000 ohms, ½-watt.
C_1 — 0.1-μfd. paper.
C_2, C_3 — 0.05-μfd. paper.
C_4, C_5 — 50-μμfd. mica.
C_6 — 0.001-μfd. mica (for r.f. filtering, if needed).
Sw — S.p.s.t. toggle (on-off switch).

The switch should be mounted close to the circuit elements and controlled by an extension shaft if necessary.

Audio Limiter Circuits

A considerable degree of noise reduction in code reception also can be accomplished by limiter arrangements applied to the output circuits of both superhet and regenerative receivers.[9] Such limiters also maintain the signal output nearly constant with fading, the effect for both noise and signal limiting being shown in Fig. 753. Diagrams of several output limiter circuits are shown in Fig. 754. In the

World Radio History

circuit of *A*, a neon tube is connected effectively in parallel with the headset, through the audio transformer T_1, and sufficient d.c. volt-

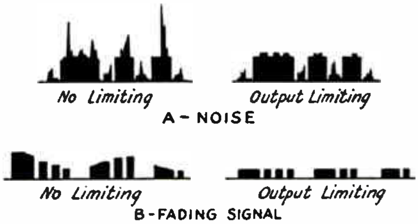


FIG. 753 — ILLUSTRATING LIMITER ACTION WITH NOISE-PEAK INTERFERENCE AND WITH A FADING SIGNAL

age is applied to the tube so that it will ionize and short-circuit the audio output on peaks exceeding the desired signal level. The tube should have the usual limiting resistor in the base removed. This arrangement is less effective than the others shown. Circuit *B* employs a triode tube which is operated at practically saturation signal excitation at normal plate voltage, with the output to the 'phones tapped to give a comfortable audio level. Increase in signal strength or noise peaks will then be ineffectual. This is not as satisfactory as the triode circuit of *C*, in which the tube is operated at reduced plate voltage (approximately 10 volts) so that it saturates at a lower signal level. The arrangement of *D* has the best limiting characteristics, and is preferred. A pentode audio tube is operated at reduced screen voltage (35 volts or so), so that output power remains practically constant over a grid excitation voltage range of more than 100-to-1. The output limiter systems are simple and adaptable to most all receivers. However, they cannot prevent noise peaks from overloading previous circuits and do not bring the noise amplitude down below the level of the signal as does the i.f. silencer method. They are ineffectual with shock excitation of a previous high-selectivity circuit. (Refer to article by H. A. Robinson, February, 1936, *QST*, for details.)

Noise-Suppressor Audio Circuit

The audio noise-suppressor circuit dia-

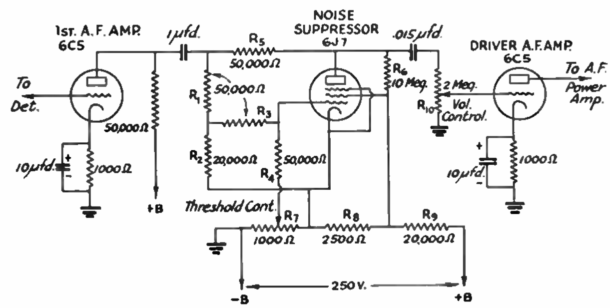


FIG. 755 — NOISE-SUPPRESSOR CIRCUIT FOR AUDIO AMPLIFIERS

grammed in Fig. 755 is adapted from the system used in the RCA ACR-111 receiver. As with the systems previously described, it operates on pulse-type noise interference and is adaptable to receivers in which high-selectivity circuits are not used prior to the audio amplifier. It may be adapted to regenerative autodyne receivers as well as to superhets. In this circuit, the suppressor is a 6J7 or similar pentode tube whose plate circuit effectively shunts the input of the following audio stage. The audio signal voltage across R_6, and consequently across the input circuit of the following stage, will depend on the ratio of the plate impedance of the pentode suppressor tube to the resistance of R_5, the series combination being essentially

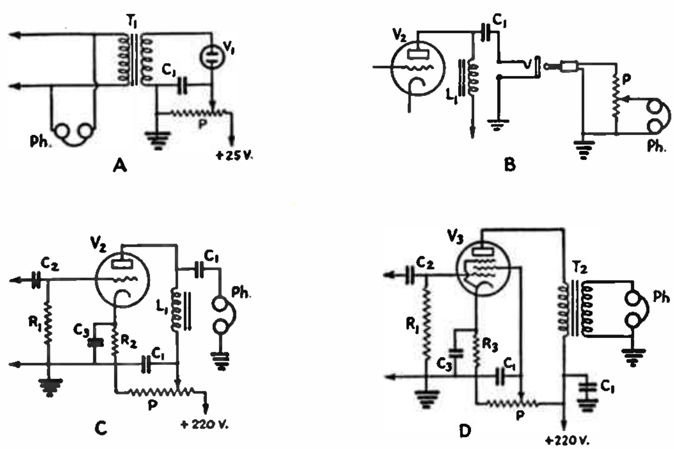


FIG. 754 — OUTPUT LIMITER CIRCUITS

C_1 — 0.25 µfd.
C_2 — 0.01 µfd.
P — 50,000-ohm limiter control (preferably wire wound).
R_1 — 0.5 meg.
R_2 — 2000 ohms.
R_3 — 600 ohms.
V_1 — 1-watt neon tube (see text).
V_2 — 56 or 76.
V_3 — 41 pentode.
T_1 — Step-up transformer (high ratio interstage).
T_2 — Output transformer.
L_1 — 15-henry choke.
Ph — Telephones (20,000-ohm impedance; 2000-ohm resistance).

World Radio History

a voltage-dividing network. When the plate impedance is high, the ratio will be high, so that practically the total audio voltage developed across R_1 and R_2 will appear across the suppressor tube's plate circuit and be applied to the following stage. With low plate impedance (reduced negative bias on the suppressor), however, the input to the following stage will be practically shorted. In operation, the control-grid bias on the suppressor tube is adjusted just below the point of plate current cut-off by means of the potentiometer R_7, so that the desired signal is unimpaired by the suppressor. Then short-duration noise impulses of greater amplitude, tending to make the grid more positive, will cause the suppressor plate impedance to drop to a very low value during each pulse, with a consequent reduction of input to the following stage (and reduction of noise output) during these intervals.

ANTENNA TUNING UNITS

Obviously the signal to noise ratio will be improved by a means which makes the signal strength at the receiver input as large as possible. This can be done by tuning the antenna system to the incoming signal, a process which is also favorable to the image ratio, as has already been pointed out. A separate antenna tuning unit, designed to couple between antenna and receiver, therefore is a desirable addition to the receiving equipment. It is especially useful when, as is becoming common practice, the transmitting antenna is used for receiving.

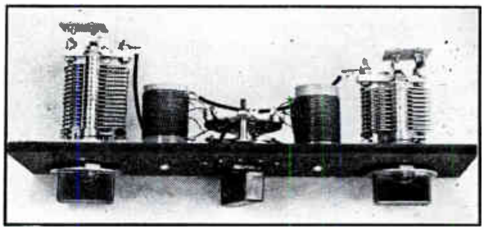


FIG. 757 — RECEIVING-TYPE ANTENNA COUPLER USING THE CIRCUIT OF FIG. 756-A

A two-section tap-switch is used to vary the inductance of L_1 and L_2. Input and output terminals are mounted on the rear of C_1 and C_2.

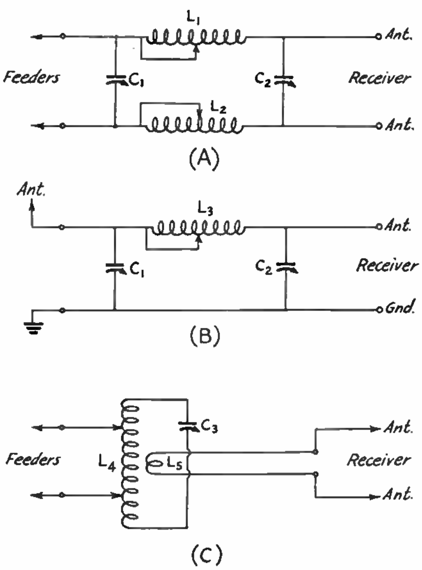


FIG. 756 — THREE TYPES OF CIRCUITS FOR COUPLING ANTENNA TO RECEIVER

A, balanced pi-section network; *B*, single-ended pi-section network; *C*, tuned circuit with taps for matching impedances.

C_1 — 150-μμfd. variable.

C_2 — 100-μμfd. variable.

C_3 — 50-μμfd. variable or larger.

L_1, L_2, L_3 — 25 turns No. 26, spaced to occupy 1-inch length on 1-inch diameter form; tapped at 2nd, 5th, 9th, and 15th turns.

L_4 — Proportioned to resonate with C_3 in the desired band.

L_5 — 3 or 4 turns wound on L_4; see text.

Typical couplers of this type are shown diagrammatically in Fig. 756. At *A* is the balanced pi-section matching network, applicable to antenna systems using two-wire feeders. Specifications suitable for average conditions are given. A unit of this type is shown in Fig. 757. Adjustment is simple; the taps on L_1 and L_2 are varied simultaneously so that the same inductance is in use in each branch, with trial settings of C_1 and C_2 until the signal strength on the desired frequency is maximum. With the average antenna system the settings are not critical, although slight readjustment may be necessary when going from one end to the other of a wide band.

The single-ended pi-section filter is shown at *B*. This filter is intended for use with a single-wire antenna or other system worked against ground. The unit of Fig. 757 may be used with the coil on the ground side shorted out.

A parallel-resonant circuit with provision for impedance matching is shown at *C*. The coil L_4 should be constructed so that the turns readily may be tapped. The pickup coil, L_5, may consist of three or four turns wound around the center of L_4, for the usual receiver having approximately 500-ohm input impedance. The feeder taps on L_4 should be adjusted for maximum signal strength when C_3 is tuned to resonance. In case a single-wire antenna is used, L_5 should be coupled to the bottom of L_4, which in turn is connected to ground. The antenna is tapped on L_4 at the point giving maximum signal as before.

World Radio History

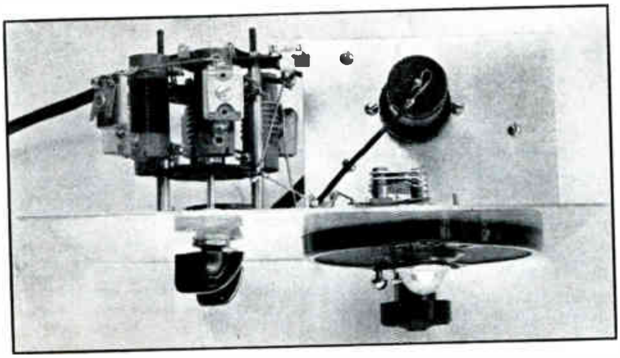


FIG. 758 — TOP VIEW OF THE REGENERATIVE PRESELECTOR, SHOWING TUBE AND TUNING UNIT

A REGENERATIVE PRESELECTOR

INEXPENSIVE superhet-type receivers in which the mixer is coupled to the antenna usually have poor image ratios, especially at 14 and 28 Mc. On the latter band, in fact, even a tuned r.f. stage ahead of the mixer leaves much to be desired in image suppression. Also, it is often helpful to secure more over-all amplification, with sets having a small number of tubes. A separate preselector stage, adapted to working into the receiver's antenna input terminals, is helpful in such cases.

A simple regenerative preselector, suitable for use with practically any type of super-het receiver, is shown in Fig. 758.[10] Any r.f. pentode-type tube may be used; the circuit is quite similar to that used in the two-tube receiver described earlier in the chapter, but with the parallel-fed plate circuit of the tube capacity-coupled to the receiver antenna-input circuit. Coil switching is used to facilitate band-changing, but plug-in coils may be substituted if desired; the coil assembly shown is a manufactured unit intended for regenerative receivers.

To adjust the circuit so that the desired amateur band is properly located on the tuning dial when the switch is set at the correct position, mica-dielectric trimming condensers, C_2, are connected in parallel with the tuning coils.

In the circuit diagram, Fig. 759, it will be noted that the antenna is coupled through a variable condenser, C_1. This is a mica-dielectric unit of the trimmer type, and is supplied as part of the commercial assembly.

Blocking condenser C_4, resistor R_1, and the r.f. choke in series with R_1 form the cathode bias circuit of the amplifier. No control is specifically provided for r.f. gain, although a 2000-ohm variable resistor could be added in series with the 300-ohm bias resistor for this purpose if desired. However, a wide range of amplification is available with the regeneration control resistor, R_3, in addition to the range provided by the r.f. gain control in the receiver.

The grid leak and grid condenser are removed from the coil-condenser assembly and replaced by a grid lead approximately 2½ inches long. The single wire connection to the tuning condenser is left intact. Two lug terminals are provided at the rear of the band switch; the one nearer the tuning condenser is the cathode-tap switch terminal and must be connected to the cathode blocking condenser, C_4, while the terminal farther from the tuning condenser is wired through the antenna condenser, C_1, to the grid connection of the coil switch. This terminal is used for the antenna connection post on the preselector.

Two lug strips are screwed to the aluminum chassis. One strip with a single lug is used to support the end of C_6 opposite the plate terminal of the tube, and at the same time to provide a terminal for the connection to the antenna post on the receiver. A second strip, with four insulated lugs, provides anchorage for the other connections which must be insulated from the chassis.

The regeneration control resistor, R_3, is mounted directly below the coil switch.

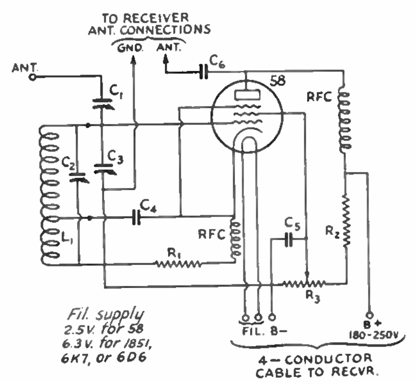


FIG. 759 — CIRCUIT DIAGRAM OF THE REGENERATIVE PRESELECTOR

(When a metal tube is used the shell should be grounded.)

C_1 — 5-25-μμfd. variable mica trimmer.
C_2 — 5-25-μμfd. variable mica trimmer (one for each coil).
C_3 — 15-μμfd. variable air-tuning condenser.
C_4, C_5 — 0.01-μfd. fixed, tubular paper or mica.
C_6 — 250-μμfd. fixed mica.
R_1 — 300-ohm, 1-watt carbon.
R_2 — 50,000-ohm, 1-watt carbon.
R_3 — 25,000-ohm receiving-type carbon-element potentiometer.
L_1 — (Browning Laboratories Unit). See Coil Table.
RFC — 2.5-millihenry receiving-type r.f. chokes.

World Radio History

Power may be taken from the receiver through a four-conductor cable. If the receiver uses 6.3-volt tubes, a 6K7 tube may be used in the preselector; a 58 may be used if the receiver is equipped with 2.5-volt tubes.

The preselector should be placed as near the receiver as possible to provide for short connections between its output and the receiver antenna terminals. With the antenna connected to the receiver, some amateur station in the 20- or 40-meter band should be tuned in. The antenna connection should then be moved from the receiver to the preselector, and the output of the latter connected to the receiver. Then, with the switch of the preselector set for the band on which the receiver is tuned and the tuning condenser dial set at approximately half-scale, the trimmer on the coil in use should be adjusted for maximum signal strength by means of a screwdriver. If the regeneration-control resistor is moved from minimum to maximum screen-voltage position during this adjustment process, it will be found that the preselector can be made to oscillate. In operation, R_3 should be set just below the oscillating point; at this adjustment, the tuning is quite sharp, the trimmer condenser, C_2, then should be set so that the band is centered on the tuning dial.

This procedure, which should be repeated on the other amateur bands, need be followed through only once for a single antenna. However, a change of receiving antennas may necessitate slight readjustment of at least the antenna coupling condenser, and possibly of the various trimming condensers as well. The antenna coupling condenser should be set to give a good balance between sensitivity and freedom from blocking. Because only one antenna condenser is used, the final setting is determined by the general operation of the preselector on all bands, or on the bands on which its operation is considered most important.

SIGNAL STRENGTH AND TUNING INDICATORS

A useful accessory to the receiver is an indicator which will show relative signal strength. Not only is it an aid in giving reports, but it also is helpful in aligning the receiver circuits, in conjunction with a test oscillator or other steady signal.

Three types of indicators are shown in Fig. 761. That at A uses an electron-ray tube, several types of which are available. The grid of the triode section is usually connected to the a.v.c. line as shown; however, it may also be connected to a diode signal rectifier as in Fig. 741. The particular type of tube to use will depend upon the voltage available for its grid; where the a.v.c. voltage is relatively large, a remote-cutoff type tube should be used in preference to the sharp-cutoff type such as the 6E5. The cathode-ray tuning indicator is an inexpensive addition to a superhet receiver, and is useful for tuning and lining-up purposes. It is not readily calibrated for signal-reporting purposes, however.

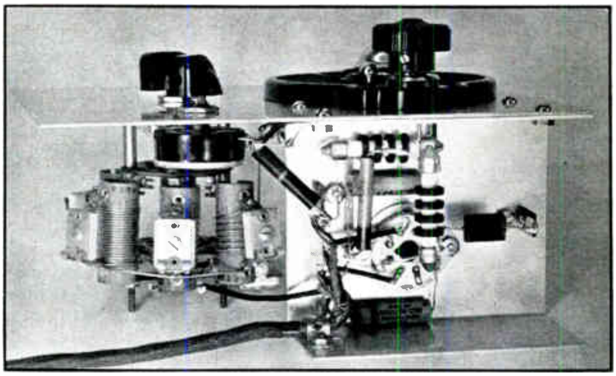


FIG. 760 — BOTTOM VIEW OF THE REGENERATIVE PRESELECTOR

PRESELECTOR COIL DATA

All coils wound on bakelite forms, 5/8-inch diameter by 1 5/8-inch length.

Frequency	*Total No. Turns*	*Turns from Ground to Tap*	*Wire*	*Spacing, or Winding Length*
1.7 Mc.	135	9.5	34*	Close-wound
3.5 Mc.	55	3.5	27*	Close-wound
7 Mc.	20	1.5	22	7/8″ length
14 Mc.	9	1.5	18	13/16″ length
28 Mc.	6	1.5	18	1/2″ length

* Enamelled.

In B, a milliammeter is connected in series with the d.c. plate leads to the r.f. and i.f. tubes whose grids are controlled by a.v.c. Since the plate current of such tubes varies with the strength of the incoming signal, the meter will indicate relative signal intensity and may be calibrated in "S" points. The scale range of the meter should be chosen to fit the number of tubes in use; the maximum plate current of the average remote-cutoff r.f. pentode is from 7 to 10 milliamperes. The disadvantage of this system is that the meter reading decreases with increasing signal strength. The sensitivity also is limited and cannot easily be controlled.

World Radio History

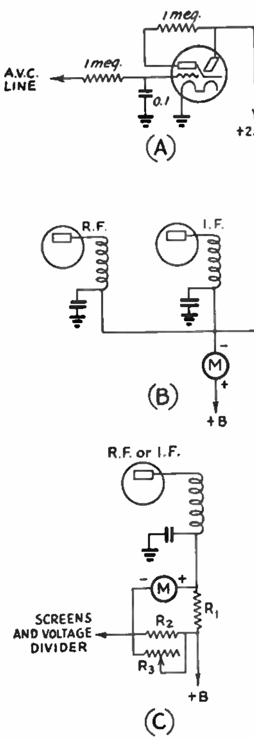


FIG. 761 — TUNING INDICATOR OR "S"-METER CIRCUITS FOR SUPERHET RECEIVERS

A, electron-ray indicator; *B*, plate-current meter for tubes on a.v.c.; *C*, bridge circuit for a.v.c. controlled tube. In *C*, representative values are: R_1, 250 ohms; R_2, 350 ohms; R_3, 1000-ohm variable (National Co.).

The system at *B* uses a 0–1 milliammeter in a bridge circuit arranged so that the meter reading and signal strength increase together. The current through the branch containing R_1 should be approximately equal to the current through that containing R_2. In some manufactured receivers this is brought about by draining the screen voltage-divider current and the current to the screens of three r.f. pentodes (r.f. and i.f. stages) through R_2, the sum of these currents being about equal to the maximum plate current of one a.v.c. controlled tube. Typical values for this type of circuit are given. The sensitivity can be increased by making R_1, R_2 and R_3 larger. The initial setting is made with the manual gain control set near maximum, when R_3 should be adjusted to make the meter reading zero with no signal.

HETEROTONE C.W. RECEPTION

The c.w. beat-note obtained with a heterodyne oscillator is a piercing tone of practically a single frequency, with unmodulated c.w. transmission. This is somewhat fatiguing in long sessions of operation, although the pitch may be varied by adjustment of the beat-oscillator frequency. The character of the sound as well as its actual audio power may be improved by adding double-sideband tone modulation in an i.f. amplifier stage preceding the final detector.[11] This is accomplished by using an audio-frequency oscillator to modulate one of the i.f. amplifier tubes. A practical circuit which has been used successfully to modulate the screen of an i.f. stage following the crystal filter in an S.S. superhet receiver is shown in Fig. 762. The effect is much the same as if the modulation had been applied to the signal at the transmitter. The tone should be heard only when a signal passes through the i.f. amplifier, of course, since the tuned i.f. circuits will not transmit the audio frequency except as sidebands on the signal carrier. The actual audio output from the second detector is greater when the modulated signal is heterodyned by the beat oscillator than for the same signal unmodulated, because additional audio power is produced by beats between the c.w. oscillator and the sidebands produced by the tone modulation, while the aural effect makes the signal sound much louder. The tone modulation should be applied in a stage following the crystal filter; otherwise, the sidebands will be largely attenuated by the selectivity of the filter circuit. In applying this heterotone system to a receiver, particu-

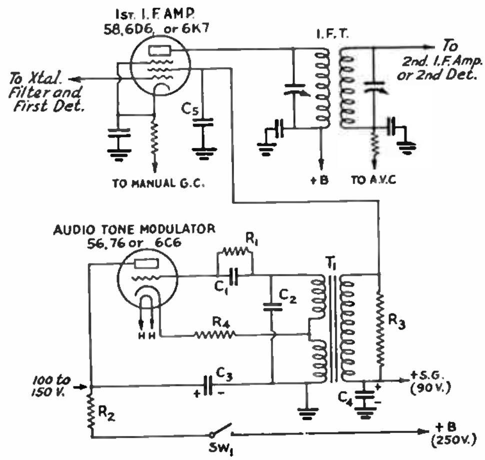


FIG. 762 — THE HETEROTONE MODULATOR CIRCUIT

T_1 — Push-pull input type audio transformer.
C_1 — 0.002-μfd. fixed condenser (paper).
C_2 — 500-μμfd. primary tuning condenser (various sizes should be tried until tone is between 500 and 1000 c.p.s.).
C_3 — 1- to 4-μfd. plate by-pass condenser (paper or electrolytic).
C_4 — 1- to 4-μfd. screen-supply by-pass.
C_5 — 0.002-μfd. screen-grid r.f. by-pass.
R_1 — 100,000-ohm grid leak.
R_2 — 100,000-ohm plate-voltage dropping and filtering resistor.
R_3 — Audio load resistor (100,000-ohm or smaller).
R_4 — 20,000-ohm or smaller cathode resistor.
SW_1 — Single-pole toggle switch (audio "On-Off").

World Radio History

lar care must be taken to prevent output of the tone oscillator from reaching the audio circuits directly, and to prevent c.w. beat oscillator voltage from reaching the earlier i.f. circuits. Otherwise, strong continuous tone output will result whether a signal is present or not.

SERVICING SUPERHETERODYNES

In addition to the general receiver servicing suggestions already given, there are a few others for troubles peculiar to superhet type receivers. Generally poor performance, characterized by broad tuning and poor sensitivity, calls for checking of the circuit tuning and alignment as previously described. The procedure is to start with the receiver output (audio) and work back through the second detector, i.f., and high-frequency circuits, in the order named.

In case of oscillation in high-frequency amplifier and first detector circuits, as evidenced by squeals or "birdies" with varying of their tuning, look for poor connections in the common ground circuits, especially to the tuning condenser rotors. Inadequate or defective by-pass condensers in cathode, plate and screen-grid circuits also can cause such oscillation. In some cases it may be advisable to provide a baffle shield between the stators of pre-r.f. amplifier and first-detector ganged tuning condensers, in addition to the usual tube and inter-stage shielding. A metal tube with an ungrounded shell will cause this trouble. Improper screen-grid voltage, as might result with a shorted or too-low screen-grid series resistor, also could be responsible.

Oscillation in the i.f. circuits, independent of high-frequency tuning and indicated by a continuous squeal when the gain is advanced with the c.w. beat oscillator on, will result from similar defects in i.f. amplifier circuits. Inadequate cathode resistor by-pass capacitance is a very common cause of such oscillation. Additional by-pass capacitance, 0.1 to 0.25 μfd., usually will remedy it. The same applies to screen-grid by-passes of i.f. tubes.

"Birdies" and "mush" occurring with tuning of the high-frequency oscillator may indicate that it is "squegging" or oscillating simultaneously at high and low frequencies. This may be caused by a defective tube, too-high oscillator plate or screen-grid voltage, excessive feed-back in the oscillator circuit or excessive gridleak resistance.

Excessive "hiss" may be caused by a defective h.f. or i.f. tube, by an open grid circuit, or by misalignment of high-frequency or i.f. circuits. It may be helpful in some cases to reduce the oscillator screen voltage, in the case of an electron-coupled oscillator, or the plate voltage in the case of a triode. The same symptoms and remedies apply to the c.w. beat oscillator and its coupling to the second detector. There should be some increase in hiss when the latter is switched on, as a result of the i.f. noise components beating with the carrier it furnishes in the second detector.

High-frequency harmonics from the c.w. beat oscillator will show up as steady "carriers" which tune in like signals. These can be identified by disconnecting the antenna. If they remain the same with antenna on or off, they are almost certainly traceable to the beat oscillator, and are prevented by the design precautions which have been given. Other "birdies" which show up in the operation of the receiver are likely to result from image interference. An image beat with an on-tune signal can be identified in two ways: First, it will seem to tune twice as fast as a proper signal; that is, the beat note will go through the audible range with about half as much tuning dial movement. Second, with a single-signal receiver an image will "peak" on the opposite side of zero beat to the side on which normal signals peak as the receiver is tuned. The last method gives positive image identification with the receiver's beat oscillator on.

If a receiver equipped with a.v.c. blocks on moderately strong signals when the a.v.c. is supposed to be on, check to make certain that it *is* in operation. If a separate a.v.c. tube is used, check to see that it has not burned out or failed otherwise. If motorboating occurs with a.v.c., a defective tube, open load resistor or leaky by-pass condenser may be at fault. Insufficient time constant (too-small by-pass capacitance) and inadequate r.f. filtering in the a.v.c. feed circuits also can cause this trouble. On excessively strong signals, sufficient to drive the grid of a controlled tube positive, the same effect is likely where a.v.c. is applied to only 1 or 2 stages. It is not probable with the full range a.v.c. available in the better type receivers.

A similar motorboating effect may occur with high-selectivity receivers, especially where a crystal filter is used. It is most noticeable with a.v.c. in operation. Its source is principally instability in the high-frequency oscillator. Slight changes in plate supply voltage cause the i.f. signal to fluctuate in and out of i.f. resonance as the consequence of this instability. The changes in supply voltage, in turn, are caused by variation in load on the supply with variation of plate current on the stages having a.v.c. applied — so that the oscillator frequency "hunts" about the proper value which would keep the intermediate frequency constant on resonance. This trouble can be eliminated by improving the voltage regulation of the supply and the stability of the oscillator.

World Radio History

JUDGING RECEIVER PERFORMANCE

While complete quantitative information on the characteristics of a superhet would require a number of measurements with laboratory equipment, a qualitative estimate of relative sensitivity, stability and band-spread can be made without special means. These rough checks may be used for comparison of receivers in purchasing manufactured models, or in arguments concerning amateur-built types.

Sensitivity: The limiting factor determining the effective sensitivity of a receiver is its own noise ratio. For a given degree of selectivity (band width) this is determined by the gain in the first circuit. With the antenna disconnected, a rough check on this gain can be made by shorting the first tuned circuit of the receiver, leaving the other circuits unaffected, and noting the variation in noise output on a rectifier-type voltmeter connected across the output terminals. The c.w. beat oscillator should be switched on to furnish a carrier in the second detector of a superhet, gain should be full-on and a.v.c. should be switched off. The noise output should decrease with detuning, showing that the first circuit has appreciable impedance as evidenced by thermal agitation voltage. If it does not decrease, the gain of this circuit is negligible. This test should be made on each frequency band. Little change is likely on 14 Mc., but should become appreciable on 3.5 and 1.7 Mc. The test should be made on r.f. amplifier and detector stages. Unchanged noise with the first detector input shorted would indicate that the first detector is the principal source of noise and that there is little gain ahead of it.

Stability: With the beat oscillator on and a steady signal tuned in, vary the manual r.f. gain control rapidly. This will affect the oscillator plate supply voltage, as a result of varying r.f. stage plate current load. The beat note should vary but a few hundred cycles. Another check can be made for temperature stability by noting the change in beat note for a quarter-hour or so after "cold start" of the receiver. Mechanical stability can be checked by jarring the receiver and pushing against its panel and the sides of its cabinet, noting the shift in c.w. beat note.

Band-Spread: Band-spread on each amateur band can be judged by the tuning rate and the calibration spread. Tuning rate is the average number of kilocycles covered with each rotation of the tuning knob, while calibration spread is the average number of kilocycles represented by each of the smallest tuning scale divisions. Tuning rate of approximately 50 kilocycles per knob rotation is generally satisfactory in high-selectivity s.s. receivers, assuming a knob of "natural" size (approximately 2-inch diameter). Calibration spread of 10 kc. or less per scale division is satisfactory for reset and logging purposes.

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World Radio History

CHAPTER EIGHT

TRANSMITTER DESIGN AND CONSTRUCTION

Principles of Transmitter Operation — Considerations in Design — Determination of Coil and Condenser Dimensions — Tuning Procedure — Crystal and Electron-Coupled Oscillators — Construction of Exciters and Amplifiers — Band-Switching — Gang Tuning

A RADIO transmitter is a device for converting d.c. or low-frequency a.c. power into power at the high frequencies used in radio communication and delivering it to a suitable radiating system. In the case of a radiotelephone transmitter, the output of the transmitter must be properly modulated at voice frequencies. Besides delivering radio-frequency power to the antenna, an amateur transmitter must be designed to meet certain requirements imposed by present-day operating conditions. It must have high frequency stability; that is, the generated radio frequency must not vary appreciably from a fixed value. Its output must be free from supply-frequency modulation, which means that the signal must sound as though the transmitter were powered from batteries even though the actual source may be the a.c. mains. The latter condition is met by the use of suitable types of power supply. Power-supply design and systems for modulating the output at voice frequencies for radiotelephony will be discussed in later chapters. This chapter will deal only with the radio-frequency circuits of the transmitter.

FUNCTIONAL UNITS

RADIO-FREQUENCY circuits performing three distinctly different functions are commonly found in amateur transmitters. The *oscillator* is the fundamental frequency-generating unit. It is sometimes used to deliver the radio-frequency power generated to the antenna, although, more often, it is used in conjunction with a *power amplifier* which increases the power level at the oscillator frequency before delivering it to the antenna.

The third functional type is the *frequency multiplier*. As its name implies, it is used frequently as a convenient means of increasing the frequency delivered to it by the oscillator or a preceding frequency multiplying stage. Since the multiplier is seldom used for a multiplication greater than two in amateur transmitters, the term *frequency doubler* or simply *doubler* will be encountered most frequently. Frequency doublers are usually followed by a power amplifier which delivers power to the antenna, although instances will be found in which a high-power doubler feeds the antenna directly. Before studying these functional circuits in detail, let us consider some of the various units which commonly comprise these circuits. Most of them will be found in circuits of all three types.

Circuit Components

The principal parts which are frequently found in the r.f. circuits of a transmitter are: the *tuning condenser, tank coil, grid leak, cathode resistor, series voltage-dropping resistor, voltage divider, filament center-tap resistor, by-pass condenser, blocking condenser, r.f. choke, coupling condenser, coupling link* and *neutralizing condenser.*

Tank Circuits

The basic transmitter circuit, shown in Fig. 801, consists of a vacuum tube with a tuned circuit connected between grid and cathode and another tuned circuit between plate and

World Radio History

cathode. The condensers C_1 and C_2 are termed *tuning condensers* or *tank condensers* while the coils L_1 and L_2 are referred to as *tank coils*. The combination of condenser and coil is usually called the *tank circuit* because of its ability to store energy and deliver it to the load circuit during intervals in which no plate current flows.

The chief functions of the plate tank circuit are to provide a proper load for the tube to which it is connected, to filter out harmonics and, often, to provide a suitable means of

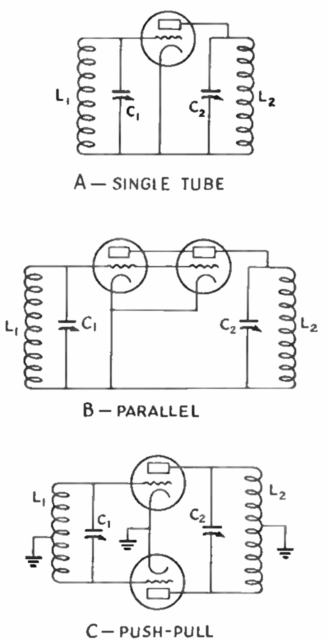


FIG. 801 — BASIC CIRCUITS

A — For single tube. B — Tubes in parallel. C — Tubes in push-pull. C_1–L_1 and C_2–L_2 comprise the grid and plate tank circuits respectively.

coupling energy to a succeeding stage or to an antenna. In self-controlled oscillator circuits (to be discussed later), the plate tank circuit, or a tank circuit common to both grid and plate also determines the frequency at which the oscillator generates.

The tuned circuit connected to the grid is required to provide a high-impedance between grid and cathode so that maximum r.f. voltage will be delivered to the grid. In many cases, it affords a means of impedance matching.

In r.f. circuits, tubes of the same type may be operated in parallel, push-pull or push-pull-parallel for greater power output than that obtainable from a single tube. With parallel operation, the circuit is the same as for one tube since the same elements in each of the parallel tubes are simply connected together as shown in Fig. 801-B. When tubes are connected in parallel, it is obvious that the total electrode capacity will double; therefore, the parallel connection is not often found in higher-frequency circuits where it is important that these capacities be minimized. Tubes of low input and output capacities may be paralleled successfully at the lower frequencies.

The push-pull circuit uses a balanced tank circuit; the center point is at ground potential. The typical circuit is shown in Fig. 801-C. In a circuit of this type, the tube capacities are effectively in series and, therefore, in general, this connection is preferable to the parallel connection for the higher frequencies, although the theoretical power output will be the same with either.

The push-pull-parallel circuit is the same as the push-pull circuit except that two tubes are connected in parallel on each side of the circuit. Since it is usually more feasible to use two tubes of higher power rating than four of a lower power rating, this type of circuit is rare in amateur design. The tube capacities combine to have the same effective value as the capacity of a single tube or twice the effective capacity of the simple push-pull arrangement.

Certain modifications of the basic circuit, which will be discussed later, will be encountered occasionally; certain oscillator circuits make use of a common tank circuit for both grid and plate, while the plate tank circuit of an amplifier or oscillator may also serve as the grid tank circuit of a following stage. Tank circuits may be *balanced*, if the ground point is at the center of the tank coil or condenser, or *unbalanced* if grounded at some other point. The principles involved remain the same, however. Since factors involved in the design of the tank circuit depend upon the functional type of circuit in which it is to be used, they will be discussed later in specific relation to each of these types.

Vacuum-tube circuits must be supplied with d.c. voltages from external sources and certain branches must be added to the basic circuit to

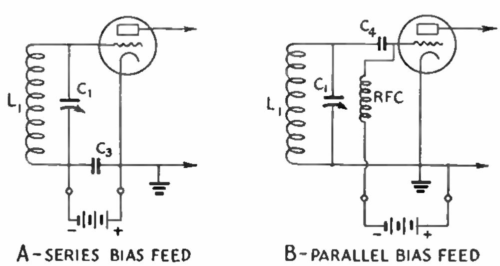


FIG. 802 — METHODS OF INTRODUCING GRID-BIASING VOLTAGE

World Radio History

permit introduction of these d.c. voltages without hampering the operation of the r.f. circuit. D.c. voltages to grid or plate or both may be either *series-fed* or *parallel-fed*, depending upon whether the voltages are fed to the electrode through the associated tuned circuit or through a choke coil effectively in parallel with the tuned circuit.

All components found in transmitter circuits aside from the tank circuits comprising the basic circuit of Fig. 801 and the neutralizing condenser are for the purpose of permitting the introduction of the required potentials to the various electrodes of the tube while limiting the flow of r.f. currents to the basic circuit.

The *grid leak*, *cathode resistor*, *voltage-dropping resistor* and *voltage divider* are resistances inserted at proper points to adjust the d.c. voltages of the various electrodes of the tube to proper operating values.

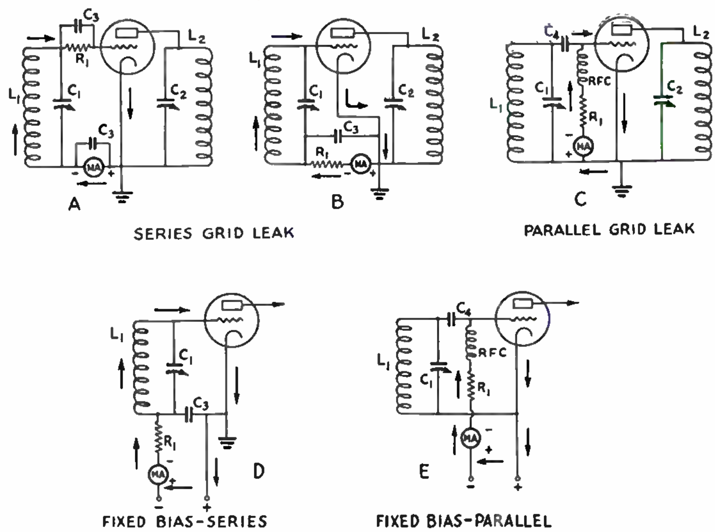


FIG. 803 — SYSTEMS FOR OBTAINING GRID-BIASING VOLTAGE FROM GRID LEAK

The path of rectified grid current is shown by arrows

Feeding the Grid

As explained in the chapter on vacuum tubes, all oscillators, amplifiers and frequency multipliers require a d.c. biasing voltage between grid and cathode. Therefore, a branch must be added to the basic circuit by means of which this d.c. bias may be introduced without interfering with operation of the basic circuit. This may be accomplished by introducing a biasing voltage from an external source, such as a battery or low-resistance power pack connected in series with the grid tank circuit as shown in Fig. 802-A, or by parallel-feeding through an r.f. choke which offers high impedance to the flow of r.f. currents although permitting unimpeded flow of d.c. as shown in Fig. 802-B.

Grid-Leak Bias

Grid bias may also be obtained by means of a resistance connected in any of several ways as shown in Fig. 803. When used in this manner, the resistance is called the *grid leak* and is designated in the diagrams of Fig. 803 as R_1. When the r.f. signal at the grid is of sufficient magnitude to drive the grid positive over a portion of the excitation cycle (as it must in all oscillators and r.f. power amplifiers), rectified grid current flows from grid to cathode, in the manner of a rectifier, and thence through the grid-leak resistance back to grid, as indicated by the arrows, causing a voltage drop between cathode and grid, across the resistance, placing the grid at an average negative potential in respect to the cathode. At A and B (Fig. 803), the grid is series-fed. Circuit B is preferred by some because the condenser across the resistance and the resistance itself may have some capacitance to ground and, therefore, raise the minimum capacitance in parallel with the tank coil. The arrangement at A will be found most frequently in low-power oscillator circuits where the physical size of the units is small. At C the grid is parallel-fed.

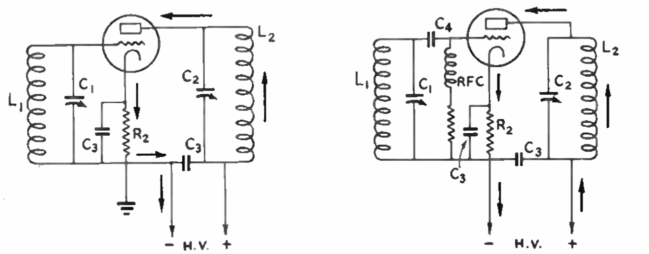
In many instances, it is desirable to provide fixed bias from an external source in addition to that provided by the grid leak so that the grid-biasing voltage will not fall to zero when the r.f. excitation voltage is removed. This fixed biasing voltage may be connected in series with the grid leak as shown at D and E (Fig. 803). The resistance of the external biasing source must be taken into consideration as explained in Chapter 14 because its resistance will have the same effect as that of the grid leak.

In all cases, the rectified grid voltage developed across the grid leak may be calculated by inserting a d.c. milliammeter in the circuit, as indicated in the diagrams, and multiplying this current in milliamperes by the resistance of the grid leak in ohms and dividing by 1000, adding to this calculated value the value of any fixed bias connected in series with the grid leak to determine the total grid-biasing voltage.

Grid-leak values used in practice vary widely depending upon tube characteristics and the

World Radio History

function of the circuit. They may range from 5000 to 100,000 ohms in oscillator circuits and from 1000 to 20,000 ohms or so in amplifier circuits. Tubes with a high amplification factor usually require the lower values of grid-leak resistance. Suitable values for most power tubes are given in the tables in Chapter 5. A tube used as a doubler will usually function more efficiently if a higher value of grid-leak resistance is used than when the same tube is used as a straight amplifier.



A-CATHODE BIAS-SERIES FEED

B-CATHODE AND GRID-LEAK BIAS-PARALLEL-FEED

FIG. 804 — METHODS OF OBTAINING BIASING-VOLTAGE FROM CATHODE RESISTANCE

R_2 — Cathode biasing resistance.

Two tubes in parallel or push-pull will require a grid-leak resistance of one-half the value recommended for a single tube; four tubes in push-pull-parallel will require one-quarter of the value for a single tube. Grid-leak bias alone, or in combination with a protective amount of fixed bias, is ideal for most cases of operation since the biasing voltage developed varies with excitation and, therefore, the biasing adjustment is automatic over a fairly wide range of excitation.

Cathode Biasing Resistor

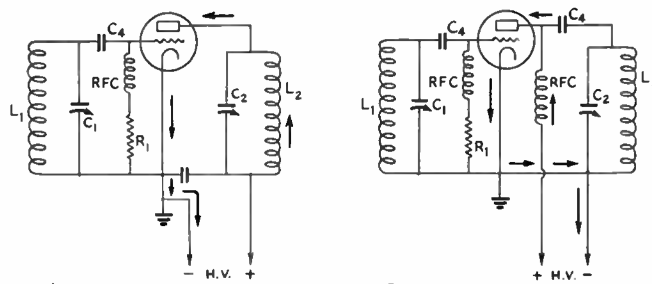
The *cathode resistor* is used also, under certain circumstances, to provide the grid-biasing voltage. It is connected, as shown in Fig. 804, in such a position in the circuit that not only rectified grid current but also plate current flows through the resistance as indicated by the arrows. Since the total current flowing through the cathode resistance is much higher than in the case of the grid leak, a lower value of resistance may be used for the same voltage drop. Most of the voltage drop across the cathode resistor is taken from the effective plate voltage which is one of the disadvantages of the system when used in connection with low-μ tubes requiring high biasing voltages. A cathode resistance is sometimes used in conjunction with the grid leak previously described.

Feeding the Plate

Vacuum tubes also require a supply of d.c. voltage between plate and cathode. This is obtained, of course, from a high-voltage supply, such as a battery, generator or transformer-rectifier system, all of which are discussed in Chapter 14. This voltage may be fed to the plate in series with the plate tank circuit, as shown in Fig. 805-A, or in parallel, as shown in Fig. 805-B.

Series Voltage-Dropping Resistor and Voltage Divider

Occasions may arise in which a small amount of power at a lower voltage than that delivered by the power supply is required. The power required may be so small as to hardly warrant the use of a separate power supply for the purpose. In this case, a *series voltage-dropping resistor* is often used. Typical cases are shown in Fig. 806. At A, a resistance R_3 is used in series with the screen-grid of a tetrode or pentode tube and the positive terminal of the power unit supplying plate voltage to the tube. At B, a similar resistance is used to drop the plate voltage applied to a high-power stage to supply the plate of a second tube requiring less plate voltage. The value of resistance required in any case is equal to the *drop* required in volts divided by the current in amperes drawn by the electrode to be supplied, in these instances the screen at A and the plate at B. The series voltage-dropping resistance is of practical use only in cases where the current drawn by the electrode in series with the resistance is fairly constant or where the voltage drop required is small because voltage regulation is extremely poor. If the current drawn by the electrode supplied through the resistance is cut



A-SERIES PLATE FEED

B-PARALLEL PLATE FEED

FIG. 805 — METHODS OF FEEDING HIGH VOLTAGE TO PLATE

A — Series feed. B — Parallel feed.

off, the voltage drop through the resistance is zero and full power-supply voltage is applied to the electrode.

This disadvantage is overcome to a certain extent by connecting a second resistor as shown at C and D (Fig. 806). The combination is known as a *voltage divider*. The additional resistance draws current through the first, preventing the current through the first falling to zero at any time. While the voltage regulation of the voltage divider is superior to that of the simple series resistor, it is still very poor unless appreciable power is wasted by using resistances of low value. The design of voltage dividers is discussed in detail in Chapter 14.

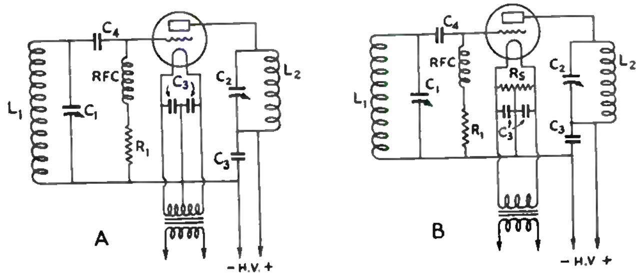


FIG. 807 — METHODS OF MAKING RETURN CONNECTIONS TO FILAMENT CENTER-TAP TO PREVENT FILAMENT-SUPPLY MODULATION

Center-Tap Resistor

As explained in Chapter 5, all high-power tubes employ directly-heated filaments or cathodes in contrast to the indirectly-heated cathodes found in most receiving tubes and many low-power transmitting tubes. To prevent hum with filament-type tubes it is necessary to return the grid and plate circuits to the electrical center of the filament circuit, as shown in Fig. 807. Most filament transformers are provided with a tap at the center of the secondary winding as shown at A. When no center-tap is provided, a resistance of 50 to 100 ohms may be used for the same purpose as shown at B.

The By-Pass Condenser

The next three circuit components to be discussed are the *by-pass condenser*, the *blocking condenser* and the *radio-frequency choke*. The common function of these is to limit the flow of r.f. currents to the basic circuit of Fig. 801. The *by-pass condenser* offers a low-impedance path to r.f. currents while it acts as an insulator in d.c. circuits. It may therefore be connected across points in the circuit at which the power supply is introduced as shown at C_3, Figs. 802 to 807, to prevent r.f. currents flowing back into the power supply, or across resistances, which might offer a high-impedance path to r.f. currents, without short-circuiting either the power supply or the resistances. Although little r.f. voltage should appear across r.f. by-pass condensers, condensers with a peak-voltage rating 25 to 50 per cent greater than the d.c. voltage across which it is placed should be chosen as a safety measure; when placed across circuits carrying modulation as well as d.c., the peak-voltage rating should be three to four times the d.c. voltage.

Capacity values of by-pass condensers are not critical; values between 0.001 and 0.01 μfd. are commonly used. The larger values should be used especially when the r.f. circuit is operating at the lower frequencies. Any condenser by-passing a modulated circuit should be limited to 0.002 μfd. to prevent by-passing of the higher audio frequencies as well as the r.f. currents. For voltages up to 500, tubular paper condensers are satisfactory if of the non-inductive type; at higher voltages, molded mica condensers are recommended. A by-pass condenser

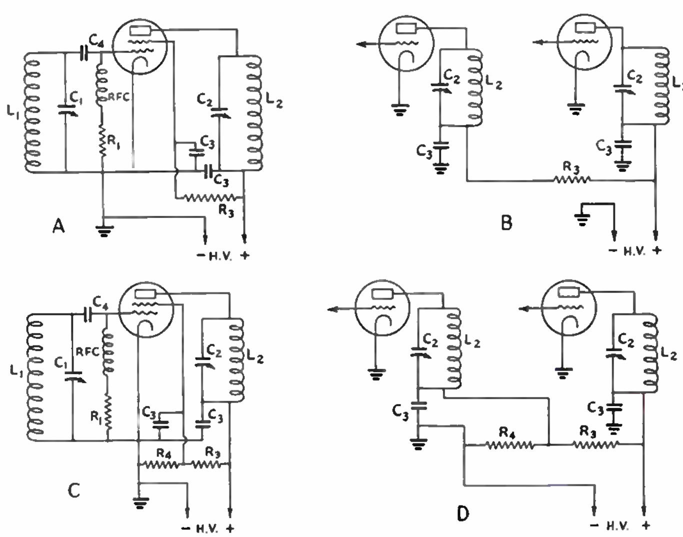


FIG. 806 — ILLUSTRATING USE OF SERIES VOLTAGE-DROPPING RESISTANCE AND VOLTAGE DIVIDER

R_3 is the voltage-dropping resistance while R_4 completes the voltage divider.

World Radio History

should be connected as close as possible to the point to be by-passed and grounded to the nearest available point on the metal chassis or ground-potential wire.

The Blocking Condenser

A *blocking condenser* is used for the purpose of insulating a circuit for d.c. and yet permitting the unimpeded flow of r.f. currents. It is found most frequently in parallel-fed circuits such as some of those shown in Figs. 802 to 807. The blocking condenser is labelled C_4. It permits the flow of r.f. currents through the plate circuit of the tube and yet prevents short-circuiting of the d.c. plate-voltage supply through the tank coil. Its function is actually the same as that of the by-pass condenser although it is considered in a somewhat different sense. Because the blocking condenser should have low capacity to ground when mounted near a grounded metal surface such as the chassis or metal base upon which the transmitter may be constructed, mica condensers are preferable for the purpose. Commonly used values are 0.001 to 0.005 μfd. Voltage ratings should be similar to those recommended for by-pass condensers.

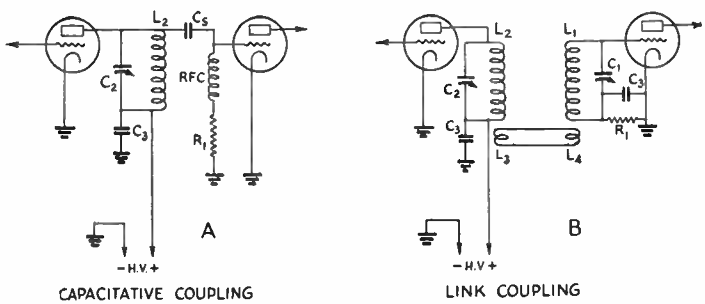


FIG. 808 — ILLUSTRATING USE OF COUPLING CONDENSER AND COUPLING LINK

C_5 — Coupling capacity. L_3 — coupling link.

The Radio-Frequency Choke

The *radio-frequency choke* is a winding offering high impedance to the flow of r.f. current but low resistance to the flow of d.c. It is used most commonly in parallel-fed circuits where it is inserted in the power-supply feed line to prevent the flow of r.f. currents through the power supply. It is used frequently between the grid of a tube and the grid leak for the same purpose, or to provide a return path for d.c. without short-circuiting the tuned circuit for r.f. It is used as shown in Figs. 802 to 807 where it is labelled *r.f.c.* The most effective types of r.f. chokes are those which are machine-wound in sections. These are available at reasonable prices from several manufacturers. They are designed to be effective at all of the lower-frequency bands used by amateurs.

Coupling Condenser and Link

The *coupling condenser* is used to couple the plate circuit of one tube to the grid circuit of another. When a condenser is used as the coupling medium between stages of a transmitter, the stages are said to be coupled capacitively. The circuit most frequently encountered is shown in Fig. 808-A where C_5 is the coupling condenser.

The *coupling link* is a small winding, L_3 in Fig. 808-B, coupled inductively to the tank coil. It serves to feed a low-impedance transmission line coupling two stages of a transmitter. These two components, as well as the neutralizing condenser, will be discussed later at more appropriate points.

FUNCTIONAL CIRCUITS

The Oscillator

As mentioned previously, the oscillator is the fundamental frequency-generating unit of the transmitter. All oscillators operate on the principle of energy feedback from the plate circuit to the control-grid circuit as explained in Chapter 5. Common practice, however, divides oscillators into two groups: those in which the oscillation frequency is determined by the circuit constants — called "self-controlled" oscillators — and those in which the frequency of oscillation is principally determined by an electro-mechanical device, the piezo-electric crystal. The latter are called "crystal-controlled" oscillators. The relative ease of securing excellent frequency stability with the crystal oscillator has led to its universal adoption. For that reason self-controlled oscillators will be discussed only briefly.

Self-Controlled Oscillators

Although many circuits and variations are possible, the three shown in Fig. 809 are the most generally satisfactory. These are the Hartley, tuned-plate tuned-grid, and the push-pull tuned-plate tuned-grid.

Tuned-Plate Tuned-Grid Oscillators

The basic circuit of Fig. 801 will be immediately recognized in the tuned-plate tuned-grid circuit shown in Fig. 809. The two tank cir-

World Radio History

cuits are not coupled inductively, the grid-plate capacity of the tube being utilized to provide the coupling between the grid and plate circuits.

The grid and plate tank circuits of the t.p.t.g. oscillator are tuned approximately, but not exactly, to the same frequency. The frequency of oscillation is controlled chiefly by the constants of the plate tank circuit. The chief function of the grid tank is that of controlling the feed-back or excitation, although its tuning does have some effect on the frequency. It should be set to a slightly lower frequency than the plate tank in normal operation.

The push-pull arrangement of the same circuit is also shown in Fig. 809.

The Hartley Oscillator

In the Hartley oscillator, the tuned circuit is common to both grid and plate; its ends are connected to the grid and plate of the tube. The filament circuit of the tube is connected to the coil at a point between the grid end and the plate end. The frequency of oscillation is determined chiefly by the constants of the tank circuit, L_1C_1. It is influenced to some extent, however, by the interelectrode capacities of the tube, which are connected across the tank. The amount of feed-back or grid excitation is adjusted by moving the tap on L_1; as the tap is moved nearer the plate end of L_1 the excitation increases. With most tubes the proper setting for the tap will be found to be with half to two-thirds the number of turns on L_1 included between the tap and the plate end.

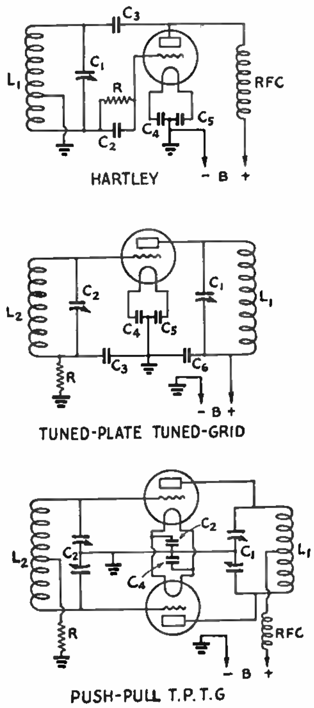


FIG. 809 — SELF-CONTROLLED OSCILLATOR CIRCUITS

Tank circuit constants should be such that the actual capacity in use will be approximately 500 μμfd. at 1.75 Mc., 350 μμfd. at 3.5 Mc., 250 μμfd. at 7 Mc., 150 μμfd. at 14 Mc., and 100 μμfd. at 28 Mc. in the push-pull circuit, the capacity referred to is each section of the condenser.

Coils should be proportioned correspondingly. The grid leak, R, should be adjusted to give the best note and most stable operation as indicated by a monitor. In general, it will be in the vicinity of 10,000 to 20,000 ohms with medium-μ tubes, and 25,000 to 50,000 ohms with low-μ tubes.

Grid and plate blocking condensers should be 100 to 250 μμfd.; filament by-pass condensers, .01 μfd.

Frequency Stability

The oscillation frequency of a self-controlled oscillator is dependent not only upon the tank constants, but also upon the tube capacities (which become, in effect, part of the tank), the plate voltage, and the load.

If the tube capacities vary during operation, as they do with heating, the frequency will change. This is also true of the tank constants; the coil, particularly, will show changes in inductance with changes in temperature. These temperature changes cause a continuous shift in frequency, or "creep." Creep can be minimized by operating the tube well below its ratings so that heating is reduced, although there always will be some creep during the period while the tube is warming up.

Frequency changes with changes in plate voltage can be minimized by using a tank circuit having a large capacity-inductance ratio (high-C). A well-filtered plate supply having good voltage regulation also is essential.

If the oscillator is coupled to an antenna, it is important that rather loose coupling be used so that slight changes in the system caused by swinging wires will not cause the oscillator frequency to shift appreciably.

A self-controlled oscillator always should be built and mounted so that it is insulated, in so far as possible, from mechanical vibration. Vibration of circuit components or tube elements will cause the signal to be modulated.

The Electron-Coupled Circuit

In the electron-coupled circuit, shown in Fig. 810, the control-grid, cathode and screen-grid of a screen-grid tube are combined in a Hartley circuit with the screen at ground potential for r.f. voltage. The output of the oscillator is taken from the plate through a separate tank circuit. With a well-screened tube the coupling between the "oscillator" and "output" portions is almost entirely through the electron stream so that capacity effects are absent.

The constants of the grid tank circuit deter-

World Radio History

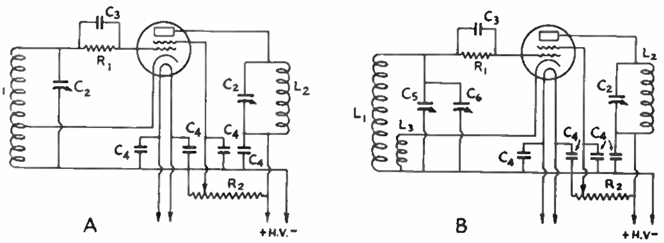
mine the frequency of oscillation while the tuning of the plate tank circuit should have relatively little effect upon the frequency, although accurate tuning to resonance may be required to prevent "chirpy" keying. Resonance is indicated by a dip in plate current.

If frequency stability approaching that of the crystal-controlled oscillator is to be obtained, extreme care must be exercised in the design and adjustment of the circuit. A tube with excellent screening is desirable for use in the e.c.o. Of prime importance is a grid tank circuit of high capacity; a capacity of not less than 500 μμfds. should be used for 1.75 Mc., 350 μμfds. for 3.5 Mc. or 200 μμfds. for 7 Mc. A portion of the capacity may be fixed with the remainder in the form of a variable capacity which will tune across the band conveniently. At 1.75 and 3.5 Mc. a fixed capacity of 350 μμfds. and a 140-μμfd. midget variable condenser will give full-scale bandspread with a coil of appropriate size. If a mica condenser is used for the fixed capacity, it should be of the "low-drift" type. A low value of capacity may be used in the plate tank circuit; 100 μμfds. is a common value.

The position of the cathode tap, which controls the excitation, affects the output of the oscillator as well as frequency stability when the oscillator is keyed. The portion of coil between tap and ground should be roughly one-fifth to one-third of the total number of turns in the grid coil. It may be necessary to adjust the position of the tap carefully to obtain best results. Sometimes, adjustment of the tap is facilitated by the use of a separate cathode tickler winding as shown in Fig. 810-B. This coil should be wound over the ground end of the grid winding to provide tight coupling. The number of turns to be used will run somewhere between one-fifth and one-third of the number of turns on the grid winding.

The value of grid-leak resistance also has some effect upon stability, a value of 50,000 to 100,000 ohms being common. The screen voltage must be adjusted carefully and a separate power supply with good voltage regulation is recommended for the oscillator.

For best stability, it is advisable to tune the plate circuit to the second harmonic of the fundamental frequency generated in the grid circuit. Occasionally an untuned r.f. choke is used in the plate circuit as shown in Fig. 810-C. The power output of the oscillator is reduced considerably with this arrangement, however.



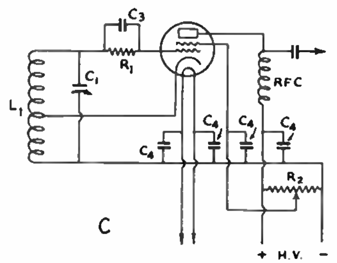


FIG. 810 — ELECTRON-COUPLED OSCILLATOR CIRCUITS

A — Common circuit. B — Separate cathode tickler. C — Untuned plate circuit.
Important values are given in text.

Unusual care should be exercised in stabilizing succeeding amplifier stages to prevent feedback which may ruin the performance of an otherwise excellent oscillator.

Components should be arranged so that no coupling exists between plate and grid circuits. This is especially important where grid and plate circuits are operated at the same frequency when shielding is invariably necessary.

The tube and associated equipment should be provided with good ventilation and the power input limited to a low value to prevent "creeping" in frequency because of heating. The unit should be provided with a shock-proof mounting to eliminate any modulation of the output by physical vibration.

PIEZO-ELECTRIC CRYSTALS

BEFORE discussing crystal oscillator circuits, it is essential that the reader have some understanding of the properties of the piezo-electric crystals which control the output frequency of most amateur transmitters. Although some other substances could be used, the most suitable material for crystals for transmitting purposes is crystalline quartz. An oscillating crystal is a thin plate cut from raw quartz crystal.

Crystal Cuts

A quartz crystal has three major axes, designated *X* (electric), *Y* (mechanical) and *Z*

World Radio History

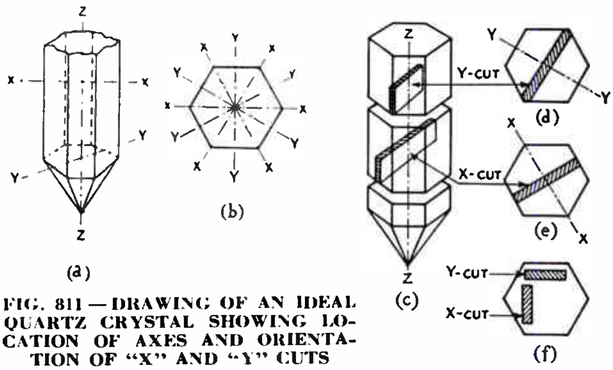


FIG. 811 — DRAWING OF AN IDEAL QUARTZ CRYSTAL SHOWING LOCATION OF AXES AND ORIENTATION OF "X" AND "Y" CUTS

(optic). A plate cut with its major surfaces perpendicular to an *X* axis is known as an X-cut plate, while plates cut with their major surfaces parallel to an *X* axis are known as Y-cut plates. In Fig. 811 is a drawing of a quartz crystal of ideal shape with the three major axes indicated. The drawing also shows the way in which X- and Y-cut crystal blanks are taken from the raw crystal.

In addition to the X and Y cuts, many other cuts are possible. Some of these possess special characteristics; for example, the "AT" cut, derived from the Y cut but with the face of the crystal making an angle with the *Z* axis instead of being parallel to it as shown in the drawing, is a zero-temperature coefficient crystal. Its oscillation frequency is practically unaffected by temperature changes, which is not the case with X- and Y-cut crystals. Another special cut known as the "V" cut also has a temperature coefficient of practically zero.

Crystal Grinding

Reliable crystals are available at reasonable prices, so that the ordinary amateur does not attempt to cut and grind his own crystals. However, it is sometimes desired to change the frequency of an already-ground crystal, so that a working knowledge of the method of grinding crystals often is helpful.

Fig. 812 gives the frequency-thickness relationships for various cuts. A good micrometer such as the Starrett No. 218-C, ½ inch, should be used for making measurements. This tool also can be used to make sure that the crystal is the same thickness at all points and that bumps or hollows are not being ground in.

Grinding can be done by rotating the crystal in irregular spirals on a piece of plate glass smeared with a mixture of No. 200 carborundum and water. Even pressure over the whole area of the crystal is essential for flat grinding. The crystal should be tested frequently for oscillation in the circuit in which it is to be used. If it should stop oscillating during the grinding process, grinding the edges slightly may make it start again. The frequency can be checked by listening to the signal in a receiver and measuring the frequency as described in Chapter 16. When the frequency is within a few kilocycles of the desired value it is well to use a finer grade of carborundum powder for finishing. The FF and FFF or No. 900 grades are suitable for the final grinding.

Temperature Effects

X- and Y-cut crystals show some change of frequency with temperature. The temperature coefficient of a Y-cut crystal usually is positive — that is, the frequency of oscillation increases as the crystal temperature is increased — although with some crystals it may be negative. It can have a wide range of values, varying from plus 100 cycles per million per degree Centigrade to minus 20 cycles per million per degree C. The temperature coefficient of an X-cut plate is negative — frequency decreases with an increase in temperature — and lies between minus 15 and minus 25 cycles per million per degree C. For example, if through heating the temperature of an X-cut 7-Mc. crystal changes from 70 deg. F. to 120 deg. F., the frequency change may be nearly

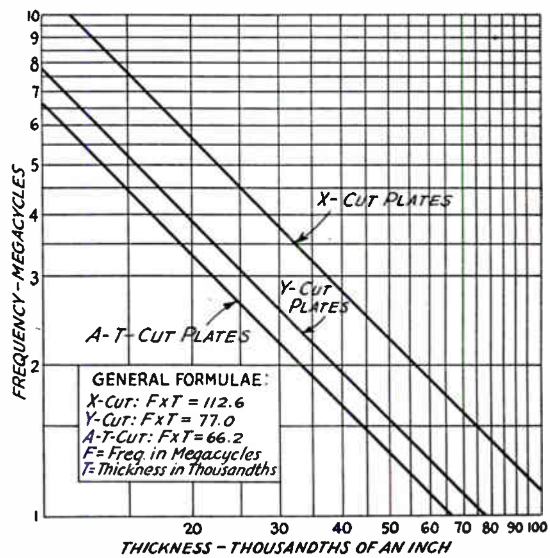


FIG. 812 — FREQUENCY-THICKNESS RELATIONSHIPS OF X-, Y- AND A T-CUT PLATES

World Radio History

five kilocycles. Should the crystal be followed by a doubler to 14 mc., the frequency change on the higher-frequency band would be twice as great — enough to shift the signal out of audibility. AT- and V-cut crystals have very low temperature-frequency coefficients, as do some other cuts, so that the frequency change with temperature is practically negligible.

Since some temperature rise occurs in all crystal oscillator circuits developing appreciable power, it is evident that in choosing a crystal frequency near the edge of an amateur band the probable "drift" in frequency must be taken into account, remembering that an X-cut crystal drifts to a lower frequency and a Y-cut to a higher frequency as the crystal warms up. With other than zero-temperature coefficient crystals it is best not to attempt "crowding the edge" of a band.

Power Limitations

Heating is greater the greater the amplitude of the crystal vibration; in other words the greater the r.f. voltage across the crystal. When the vibration amplitude is high the internal stresses may be great enough to shatter the crystal, hence the power-handling capabilities of the crystal are limited.

Since the vibration amplitude is a function of the r.f. voltage appearing across the faces of the crystal, it is essential that this voltage be limited to a value safe for the type of crystal used. It is difficult, however, to measure r.f. voltage, so that it is more common to use the r.f. current flowing in the crystal circuit as a measure of the power dissipated. A current of 100 milliamperes (0.1 amp.) r.f. usually is considered safe for X- and Y-cut crystals ground for the 1.75- and 3.5-Mc. bands. A somewhat lower value is the maximum for 7-Mc. crystals. AT-cut crystals can operate safely with currents as high as 200 ma. The current depends on the plate voltage and type of tube and circuit used.

Crystal Mountings

To make use of the piezo-electric oscillation of a quartz crystal, it must be mounted between two metal electrodes. There are two types of mountings, one in which there is an air-gap of about one-thousandth inch between the top plate and the crystal and the other in which both plates are in contact with the crystal. The latter type is generally used by amateurs. It is essential that the surfaces of the metal plates in contact with the crystal be perfectly flat.

Grit or an oily film on the surface of a crystal will sometimes prevent oscillation. The crystal should be cleaned whenever erratic behavior or non-oscillation gives evidence of a dirty condition. Carbon tetrachloride or alcohol are the best cleaning fluids. Soap and water will do quite well, however. Handling of the crystal is especially likely to give it an oily surface, and the crystal should always be cleaned after it has been touched by the hands.

A holder having a heavy metal bottom plate with a large surface exposed to the air is advantageous in radiating quickly the heat generated in the crystal and thereby reducing temperature effects. Such a holder is especially advantageous with X- and Y-cut plates.

The type of holder used will have some effect on the frequency of oscillation of the crystal. Different plate sizes, pressures, etc., will cause slight changes, amounting to perhaps a kilocycle or so, so that if a crystal is being ground to an exact frequency it should be tested in the holder and with the same oscillator circuit with which it will be used in the transmitter.

In the air-gap type of holder, the frequency of oscillation depends to some extent upon the size of the gap between the top plate and crystal. This property can be used to advantage with the AT-cut crystal so that by using a holder with a top plate with closely adjustable spacing a controllable frequency variation can be obtained. A 3.5-Mc. crystal will oscillate without perceptible variation in power output over a range of about 5 kc. X- and Y-cut crystals are not generally suitable for this type of operation because they have a tendency to "jump" in frequency with different air gaps.

CRYSTAL OSCILLATOR CIRCUITS

The simplest crystal oscillator circuit is the triode circuit shown in Fig. 813. This circuit is the equivalent of the tuned-plate tuned-grid circuit since the crystal is the equivalent of the tuned-grid tank circuit. When the plate tank circuit is tuned to a frequency slightly higher than the natural frequency of the crystal, the feed-back through the grid-plate capacity of

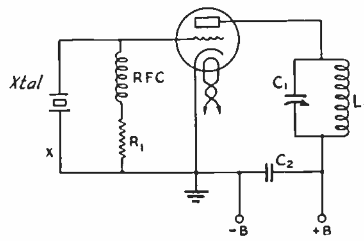


FIG. 813 — TRIODE CRYSTAL OSCILLATOR

The tank condenser, C_1, may be a 100-$\mu\mu$fd. variable, with L_1 proportioned so that the tank will tune to the crystal frequency. C_2 should be .001 μfd. or larger. The grid leak, R_1, will vary with the type of tube; high-μ types take lower values, 2500 to 10,000 ohms, while medium and low-μ types take values of 10,000 to 25,000 ohms.

World Radio History

the tube excites the grid circuit, and the crystal oscillates at approximately its natural frequency.

The power obtainable from the crystal oscillator will depend upon the type of tube used, the plate voltage, and the amplitude of the r.f. voltage developed as a result of the mechanical vibration. In the simple triode oscillator circuit of Fig. 813, the limit of plate voltage that can be used without endangering the crystal is about 250 volts for X- and Y-cut crystals.

With the r.f. crystal current limited to a safe value of about 100 milliamperes, as measured by an r.f. galvanometer or low-range r.f. ammeter inserted in series with the crystal (at "X" in the diagram) the power output obtainable from triode crystal oscillators is about five watts. The oscillation frequency is dependent to a greater extent on the plate tank tuning than is the case with circuits using tetrodes or pentodes. The simple triode oscillator has been generally superseded by more suitable types.

The Tetrode or Pentode Oscillator

Since the r.f. voltage amplitude (which determines the power output of the oscillator tube) generated by the crystal is limited by the safe vibration amplitude, obviously the greatest power output can be secured without danger to the crystal by choosing a tube of high power sensitivity. The power pentode or "beam" tetrode is such a tube, hence we find that pentodes and beam tubes are widely used as crystal oscillators in amateur transmitters. Along with high power-sensitivity, the presence of the screen grid reduces the grid-plate capacity of the tube so that the feed-back voltage is less than would be the case with an equivalent triode operating at the same plate voltage. As a result, pentode or tetrode crystal oscillators can be operated at higher plate voltages than triodes.

The pentode and tetrode tubes designed for audio power work, such as the 47, 2A5, 41, 42, 6V6G, 6L6G, 6L6, 48 and 6F6, are excellent crystal oscillator tubes. For a given plate voltage the crystal heating will be less than with a triode as the oscillator tube; alternatively, for the same amplitude of crystal vibration, higher plate voltages can be used, resulting in greater power output.

Fig. 814 shows a typical pentode or tetrode oscillator circuit. The suppressor or third grid in the pentode is not shown, since this grid normally is connected to the cathode inside the tube and is not connected to a base pin. A tube having an indirectly-heated cathode is shown; of the crystal oscillator tubes in common use only the 47 has a directly-heated cathode or filament. Filament connections for the 47 would be through the usual filament center-tapped resistor or transformer, with by-pass condensers.

The cathode resistor R_2 and its associated by-pass condenser C_4 may be omitted when the tube is operated at low plate and screen volt-

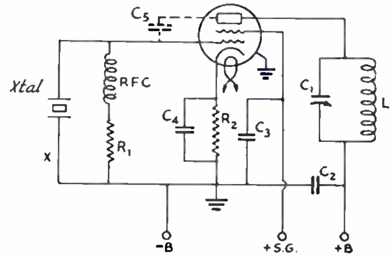


FIG. 814 — TETRODE OR PENTODE CRYSTAL OSCILLATOR

The plate tank is the same as with triode oscillators, Fig. 813. Bypass condensers C_2, C_3 and C_4 may be .001 or larger; .01 is a common value for low-voltage operation. R_1 should be 10,000 to 50,000 ohms, best value being determined by trial for the plate voltage and operating conditions chosen. R_2 should be 250 to 400 ohms; it may be omitted with 250 volts or less on the plate. C_5 is described in the text.

ages, in which case the cathode is connected directly to ground. Their use is advisable when the screen voltage exceeds 100 to 125 volts, or in cases where the crystal oscillator is to be keyed. The feedback condenser, C_5, may be needed with well-screened tubes in order to insure that the oscillator "starts" under load. This condenser, when trial of the circuit shows that it is necessary, should have a capacity of 1 $\mu\mu$fd. or less, and may be made by facing two small metal plates about one-half inch square about one-quarter inch apart. Just enough capacity should be used to ensure reliable operation; excess feedback may damage the crystal.

Circuit Constants

Typical circuit constants for the tetrode or pentode oscillator are given in Fig. 814. The plate tank circuit should have a fairly large ratio of inductance to capacity (low-C); a tuning condenser having a maximum capacity of 100 $\mu\mu$fd. will be satisfactory. The inductance of the tank coil, L, should be such that the tank circuit will be resonant at the crystal frequency at some setting of C_1. Dimensions can be taken from the coil chart given in this chapter. The coils can be wound with small-gauge wire, since the tank current will not be large when handling the amount of power developed by the usual crystal oscillator.

Since quartz is an insulator, the grid circuit must be parallel fed. The grid leak, R_1, which provides most of the bias (all, in cases where R_2 is omitted) may range in value from 10,000

World Radio History

to 50,000 ohms; there is little difference in output within this range in practical operation, although crystal current is generally lower with the lower values of grid leak. The cathode resistor, R_2, should be 250 to 400 ohms for practically all receiving tubes.

In general, it is advisable to operate receiving tubes at about the plate voltage ratings they carry for audio power service. Those having 250-volt ratings may be operated at voltages as high as 300 provided the plate current is not above the rated value. Excessive input will cause overheating and unstable operation. The 250-volt tubes should be operated with low screen voltage — 100 to 125 volts — and without the cathode resistor. The screen voltage may be obtained from a voltage divider across the plate supply, or from a simple series voltage-dropping resistor of about 50,000 ohms connected between the plate supply and the screen.

The larger beam tubes — 6L6 and 6L6G — should be operated at 400 volts on the plate and 250 on the screen for maximum output. The cathode resistor should be used, under these conditions, to prevent excessive plate current and possible damage to the tube should the circuit go out of oscillation. A thermo-galvanometer may be connected in series with the crystal at "X" to measure crystal current. In lieu of such an instrument, a low-current (60-milliampere) dial light may be used; such a light also will act as a fuse in case the crystal current runs dangerously high. The use of such a dial light in regular operation is excellent protection for the crystal.

Tuning Tetrode or Pentode Oscillators

Tuning a tetrode or pentode oscillator is chiefly a matter of obtaining the optimum amount of output power.

Using a plate milliammeter as an indicator of oscillation (a 0–100 ma. d.c. meter will have ample range for all low-power oscillators), the plate current will be found to be steady when the circuit is in the non-oscillating state, but will dip when the plate condenser is tuned through resonance at the crystal frequency. Fig. 815 is typical of the behavior of plate current as the tank condenser capacity is varied. As the capacity is increased from minimum, there will be a rather gradual decrease in plate current after oscillations commence. This continues until the point A is reached, when there will be a sharp rise in plate current, followed by cessation of oscillations. An r.f. indicator, such as a small neon bulb touched to the plate end of the tank coil, will show maximum at point A. However, when the oscillator is delivering power to a load it is best to operate in the region B-C, since the oscillator will be more stable and there is less likelihood that a slight change in loading will throw the circuit out of oscillation. This is likely to happen when operation is too near the critical point, A. Also, the crystal current is lower in the B-C region.

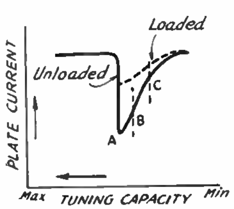


FIG. 815 — D.C. PLATE CURRENT VS. PLATE TUNING CAPACITY WITH THE TRIODE OR PENTODE CRYSTAL OSCILLATOR

When power is taken from the oscillator, the dip in plate current is less pronounced, as indicated by the dotted curve. The greater the power output the less is the dip in plate current. If the load is made too great, oscillations will not start. The load may be an antenna or a following amplifier stage; methods of adjusting loading will be considered later in the chapter.

The greater the loading, the smaller the voltage fed back to the grid circuit for excitation purposes. This means that the r.f. voltage across the crystal also will be reduced, hence there is less crystal heating when the oscillator is delivering power than when operating unloaded. For this reason it is possible to operate a loaded oscillator at higher plate voltage than is possible with an unloaded oscillator for the same crystal heating.

Pentode oscillators operating at 250 volts will give 4 or 5 watts output under normal conditions. The beam types 6L6 and 6L6G will give 15 watts or more at maximum plate voltage.

Harmonic Generation — The Tri-Tet

Many circuits have been devised to obtain harmonic output from the oscillator tube. One of the most successful is the "Tri-tet" oscillator, which utilizes a multi-element tube to act both as oscillator and frequency multiplier. The circuit is shown in Fig. 816, in two versions arranged for use with pentodes and beam tetrodes. In the Tri-tet oscillator circuit the screen grid is operated at ground potential while the cathode assumes an r.f. potential above ground. The screen-grid acts as the anode of a triode crystal oscillator, while the plate or output circuit is simply tuned to the oscillator frequency or a multiple of it.

If the output circuit is to be tuned to the same frequency as the oscillator, a fairly well-screened tube must be used, otherwise there may be excessive feedback and danger of fracturing the crystal. The tubes specified in Fig. 816 meet this condition with the exception of the 6L6G and 6V6G, which are recommended

World Radio History

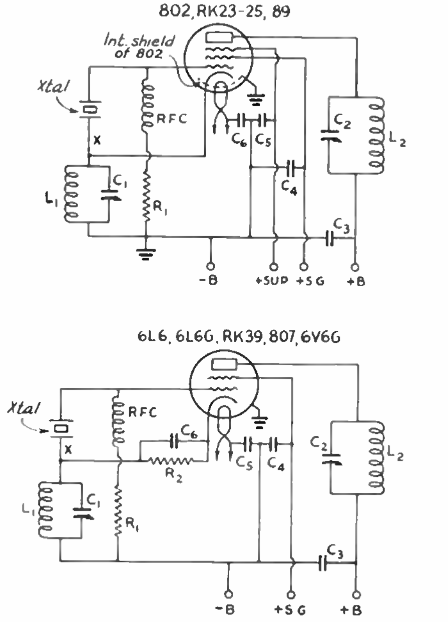


FIG. 816 — TRI-TET OSCILLATOR CIRCUIT, USING PENTODES OR BEAM TETRODES

C_1 and C_2, 100-$\mu\mu$fd. variables, receiver spacing; C_3, C_4, C_5, C_6, 0.001 to 0.01 μfd. by-passes, not critical; R_1, 50,000 to 100,000 ohms; R_2, 400 ohms for 400- or 500-volt operation.

Following specifications for cathode coils, L_1, are based on a coil diameter of 1½ inches and length 1 inch; turns should be spaced evenly to fill the required length. For RK-23, RK-25, 6L6, 6L6G and 6V6G tubes: 1.75-Mc. crystal, 20 turns; 3.5 Mc., 10 turns, 7 Mc., 5 turns. The 6L6G and 6V6G tubes are recommended only for second harmonic operation. For 802, 807, RK-39, and 89 tubes: 1.75-Mc. crystal, 28 turns; 3.5 Mc., 14 turns; 7 Mc., 7 turns.

At maximum recommended plate voltages (500 volts for transmitting types, 400 volts for 6L6 and 6L6G) the screen voltage should be 250. The 89 and 6V6G types may be operated with 300 plate volts and 150 volts on the screen.

The L-C ratio in the plate tank, L_2C_2, should be adjusted so that the capacity in use is 75 to 100 $\mu\mu$fd. for fundamental output and about 25 $\mu\mu$fd. for second harmonic output.

only for harmonic operation in the Tri-tet circuit.

The cathode tank circuit, L_1C_1, is not tuned to the frequency of the crystal, but to a considerably higher frequency. Recommended values for L_1 are given under the diagram. C_1 should be set as near minimum capacity as is consistent with good output. This reduces the crystal voltage.

With pentode-type tubes having separate suppressor connections, the suppressor may be tied directly to ground or may be operated at about 50 volts positive. The latter method will give somewhat higher output than with the suppressor connected to ground. More than 50 volts usually does not increase the output perceptibly. A cathode resistor, R_2, always should be used with the beam tetrodes.

Besides harmonic output, the Tri-tet circuit has the feature of buffering action attributable to electron-coupling between crystal and output circuits. This makes the crystal frequency less susceptible to changes in loading or tuning and hence improves the stability.

Tri-tet Circuit Constants and Tuning

The correct cathode tank circuit constants in the Tri-tet oscillator have been described in the preceding section. The constants of the plate tank circuit, C_2L_2, will resemble those of ordinary crystal oscillators. For harmonic generation, the tuning condenser need not have a maximum capacity of more than 50 $\mu\mu$fd., the inductance being proportioned accordingly for the frequency used.

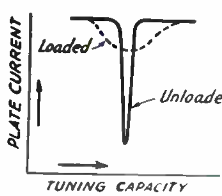
The tuning procedure is as follows: With C_1 at about three-quarters scale, turn C_2 until there is a sharp dip in plate current, indicating that the plate circuit is in resonance. The crystal should be oscillating continuously regardless of the setting of C_2. Set C_2 so that the plate current is minimum. The load circuit may then be coupled and adjusted so that the oscillator delivers power. The minimum plate current will rise; it may be necessary to retune C_2 when the load is coupled, to bring the plate current to a new minimum. Fig. 817 shows typical behavior of plate current with plate condenser tuning.

After the plate circuit is adjusted and the oscillator is delivering power, the cathode condenser C_1 should be readjusted to obtain optimum power output. The setting of C_1 always should be as far toward the low-capacity end of the scale as is consistent with good output; it may in fact be desirable to sacrifice a little output since doing so reduces the current through the crystal and thus reduces heating.

The tuning procedure is the same for both fundamental and harmonic operation. The oscillator gives good output on the second harmonic, but the output drops off rapidly on higher harmonics.

With transmitting pentodes or beam tubes an output of 15 watts can be obtained on the fundamental and very nearly as much on the second harmonic.

FIG. 817 — D.C. PLATE CURRENT VS. PLATE TUNING CAPACITY WITH THE TRI-TET OSCILLATOR



World Radio History

Other Types of Oscillators

Many variations of the foregoing oscillator circuits are in use, mostly designed for harmonic output; nearly all use regeneration in one form or another. Space does not permit their description, and in the long run the operating complications, not only in adjustment but also in changing bands, when the complete transmitter is to operate on more than one frequency, make them less desirable than the simpler circuits.

One further type of circuit is worthy of mention because it has the feature of giving excellent output, within the tube capabilities, with very low crystal current. The diagram is given in Fig. 818. In appearance it resembles the Tri-tet, but with two major differences — the crystal is connected between grid and ground instead of between grid and cathode, and the cathode tuned circuit, L_2C_2, is tuned to a *lower* frequency than that of the crystal.

The plate tank circuit is tuned to the crystal frequency or a harmonic, and is the same in design as the similar circuits in the oscillators already described. In the cathode circuit, a fixed capacity of 100 $\mu\mu$fds. for C_2 and a 2.5-millihenry r.f. choke for L_2 have been found to work satisfactorily with all amateur-band crystals.

This circuit is a persistent oscillator, gives high output on the fundamental with low crystal current and delivers satisfactory output at the second harmonic; it requires but one tuning control. Ordinary tetrode or pentode oscillators readily can be converted to this circuit simply by inserting the fixed tank circuit in series with the cathode lead. Plate tuning is similar to that of the Tri-tet oscillator described in the preceding section.

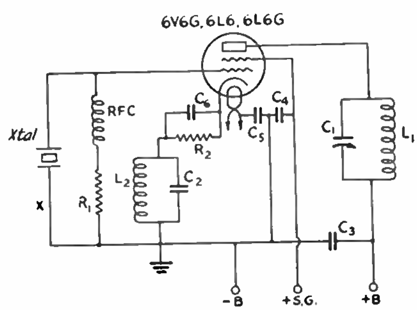
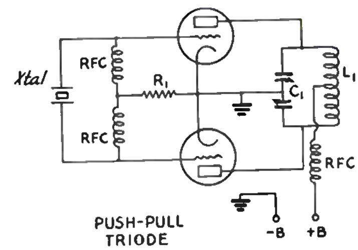


FIG. 818 — CRYSTAL OSCILLATOR CIRCUIT WITH GRID-PLATE CRYSTAL CONNECTION

The screen functions as the plate of a triode oscillator with output taken from the normal plate through a separate tank circuit. Constants are the same as in Fig. 816 with the exception of the cathode tank circuit, L_2C_2. C_2 should be approximately 100 $\mu\mu$fd., fixed; for 1.75-Mc. crystals, L_2 should have 90 turns; 3.5 Mc., 40 turns; 7 Mc., 20 turns; coil diameter 1½ inches, length 1½ inches.



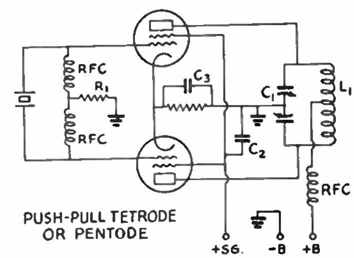


FIG. 819—PUSH-PULL CRYSTAL OSCILLATOR CIRCUITS

Circuit values are similar to those in other oscillator circuits. The grid leak, R_1, should have half the value normally used with one tube; the plate tank condenser when split-stator as shown in the diagrams should have in each section the capacity commonly used for single-tube oscillators (100 $\mu\mu$fd. per section).

Push-Pull and Parallel Circuits

The simple triode or tetrode-pentode circuit is readily adaptable to push-pull operation. Typical push-pull circuits are shown in Fig. 819. Circuit constants are similar to those already given except that each section of the split-stator condenser should have the same capacity as the single condenser in the single-ended circuits.

Push-pull crystal oscillators are not in general use because they are not so well suited to multi-band transmitters as the single-ended types. The push-pull connection cancels the even-harmonic output. The r.f. voltage across the crystal is higher with the crystal connected between the two grids than with a single tube operating at the same plate voltage, so that for the same crystal heating the power output is not doubled, as might be expected from the fact that two tubes are used. The push-pull oscillator can be used to advantage where the following stage requires balanced excitation, although even in this case suitable coupling methods are available for getting balanced output from a single-ended oscillator.

Tubes also may be used in parallel, but this method of connection also increases the crystal current.

World Radio History

R.F. POWER AMPLIFIERS

The purpose of the r.f. power amplifier is to increase the power level of the transmitter output. The output of the oscillator or preceding amplifier is coupled to the grid circuit of the power amplifier by one of a number of methods to be discussed and the r.f. voltage serves to excite the grid of the amplifier. Several stages are sometimes used in cascade, each exciting the following stage, before the output power is of the magnitude desired.

Amplifier tubes as well as oscillator tubes may be connected in push-pull, in parallel or in push-pull-parallel and the d.c. operating voltages are introduced in the same manner as that described earlier in this chapter.

The basic circuits of the amplifier are the same as those shown in Fig. 801. Since the circuit is identical with that for the tuned-plate tuned-grid oscillator (Fig. 809), it is obvious that the stage will oscillate and generate power on a frequency independent of the oscillator or exciting amplifier unless steps are taken to prevent it. Oscillation may be prevented by a process known as *neutralization* which will be discussed presently.

Interstage Coupling Systems

At this point, let us consider the various means which may be employed to couple the oscillator to a succeeding amplifier or frequency multiplier. The same coupling arrangements are also used between amplifier stages.

Many types of inter-stage coupling have been devised to transfer power efficiently from the driver to the grid circuit of the amplifier. Coupling methods may be divided into three general classes, capacitive or direct, inductive, and transmission line.

The problem of coupling two stages is complicated by the differing characteristics of different types of tubes and by the use of single- and double-tube stages, the latter often being balanced or push-pull stages. Thus we may have coupling from single tube to single tube, from single tube to push-pull, from push-pull to push-pull, and push-pull to single tube.

Although tubes in parallel may be considered to be equivalent to one tube so far as drawing the circuit is concerned, in actual practice parallel operation may call for modification of the coupling system.

Capacitive Coupling

Capacitive coupling systems are probably the simplest of all and require the least amount of apparatus. Several systems are shown schematically in Fig. 820. In these circuits, the plate tank circuit of the driver serves as the grid tank for the following stage.

In circuit *A*, coupling is through condenser *C*, known as the *coupling condenser*, from the plate tank of the driver to the grid of the amplifier. The plate of the driver is series-fed; condenser *C* serves both to provide r.f. coupling and, as a blocking condenser, to insulate the grid of the amplifier tube from the d.c. plate voltage on the driver stage. Grid bias for the amplifier is supplied through an r.f. choke. Since the negative side of the driver plate supply and the positive side of the amplifier bias supply meet at the common filament connection between the two tubes, the coupling condenser *C* must have insulation good enough to stand the sum of these two voltages without breakdown. The fact that the condenser also is carrying a considerable radio-frequency current makes it desirable that it have a voltage rating giving a factor of safety of at least 2 or 3.

In circuit *B* the coupling condenser has been

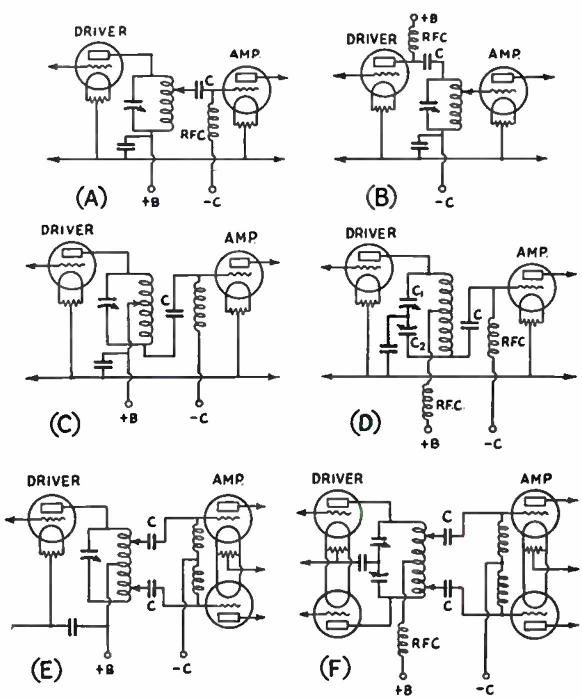


FIG. 820 — DIRECT-OR CAPACITY-COUPLED DRIVER AND AMPLIFIER STAGES

Coupling condenser capacity may be from 50 $\mu\mu$fd. to 0.002 μfd., not critical, except under conditions described in the text.

World Radio History

moved to the plate circuit of the driver tube and the radio-frequency choke appears at the plate of the driver. This simply shifts the driver to parallel plate feed, and permits the use of series feed to the amplifier grid. In both circuits the excitation can be controlled by moving the tap on the tank coil; the nearer the tap is to the plate end of the coil the greater will be the excitation voltage up to the limit of the driver output.

These circuits have the advantage of simplicity, but have the disadvantage that the interelectrode capacities of both the driver and amplifier tubes are connected across the tuned circuit, thus necessitating a reduction in the L-C ratio of the driver tank circuit and reducing the efficiency at the very high frequencies. They operate quite satisfactorily with ordinary tubes at frequencies of 7 Mc. and lower, and at 14 Mc. with tubes having low interelectrode capacities. The variable tap for regulating excitation is sometimes responsible for parasitic oscillation in the amplifier at a frequency removed from the operating frequency, a condition which is harmful to efficiency and a source of unnecessary interference.

The effect of paralleling the input and output capacities of driver and amplifier tubes can be avoided by using circuits like those of Fig. 820-C and -D. Since the ground point is between the two ends of the tank, the tank is "hot" on both ends. The amplifier is coupled from the end opposite the plate of the driver, hence its input capacity is across only part of the driver tank while the output capacity of the driver is across the other part. So far as tuning the driver tank is concerned, these two capacities are in series and the resultant capacity is less than that of either tube alone.

The difference between C and D is in the method of splitting the tank circuit. In C excitation can be adjusted by moving the ground tap on the coil, while in D excitation is adjusted by varying the relative capacities of C_1 and C_2, keeping the total capacity constant to maintain resonance.

A balanced driver circuit can be used for coupling to a following push-pull amplifier, as shown in Fig. 820-E. Since the center of a balanced circuit is at zero r.f. potential, there is a phase difference of 180 degrees between the ends of the tank, hence such a tank circuit is suitable for exciting a push-pull amplifier. Excitation can be regulated by adjusting the taps on the tank coil, keeping them equidistant from the center-tap to maintain the balance. A split-stator condenser can be used to balance the circuit, replacing the center-tap on the coil, if desired.

The use of capacity coupling between push-pull stages is shown in Fig. 820-F. The taps are equidistant from the center in this circuit also.

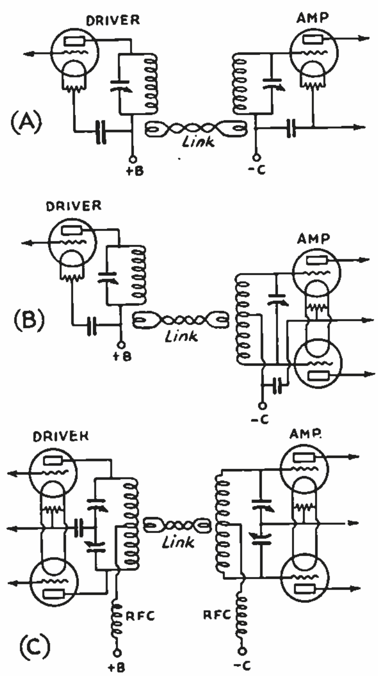


FIG. 821 — LINK COUPLING, USING A LOW-IMPEDANCE TRANSMISSION LINE

The link may be twisted lamp cord or consist of a pair of closely-spaced, but not twisted, wires.

Capacity-Coupling Considerations

Since it consumes power, the grid circuit of the amplifier has a definite impedance (*input impedance*), which may be high or low according to the type of tube used. A high-μ tube usually will have low input impedance, because grid current starts to flow at relatively low exciting voltages. Conversely, a low-μ tube will have relatively high impedance, because a considerably larger r.f. exciting voltage is required for the same grid-current flow. If the driver is to work at optimum efficiency the impedance represented by its loaded tank circuit must lie within definite limits, which may or may not be near in value to the grid impedance of the following stage. The coupling system must transform the grid impedance of the amplifier to a value suitable for loading the driver tube.

With capacity-coupling systems this impedance "matching" is effected by adjusting the position of the excitation tap on the tank coil. The higher the optimum driver load impedance and the lower the amplifier grid input impedance, the nearer the excitation tap will be to the ground point on the tank coil. Conversely, with relatively low driver load resistance and high amplifier grid impedance, the tap will be nearer the high-potential end of the coil. The object, of course, is to deliver as much power as possible to the grid circuit of the amplifier.

While a satisfactory coupling value usually can be obtained, the tap on the coil often introduces a circuit difficulty in that the turns included between tap and ground end of the coil may cause parasitic oscillations which impair the operation of the amplifier as previously mentioned. For this reason it may be necessary to couple directly from the end of the tank, in which case overloading of the driver can be prevented only by the use of a very small coupling condenser, preferably variable for adjustment purposes. This reduces the coupling efficiency.

Link Coupling

At the higher frequencies it is advantageous to use separate tank circuits for the driver plate and amplifier grid. This avoids paralleling the tube capacities across one circuit and, when the two are coupled through an untuned low-impedance transmission line, offers a ready means for adjustment of coupling. This method of coupling also has some constructional advantages, in that separate parts of the transmitter may be constructed as separate units without the necessity for running long leads at high r.f. potential.

The form of transmission-line coupling utilizing a low-impedance line (such as a twisted pair) with coupling loops of a turn or two at each end is popularly known as "link" coupling. The transmission line may be of any convenient length — from a few inches to several feet — without appreciable loss of power in the transfer.

Circuits for link coupling are shown in Fig. 821. The coupling ordinarily is by a turn or two of wire, its ends connected to the twisted pair, closely coupled to the tank inductance. Because of the low impedance of the line, one turn often suffices if the coupling is tight enough; however, sometimes more than one is needed for maximum power transfer. The link should preferably be coupled to the tank circuits at a point of low r.f. potential, as indicated in the diagrams. It is also advisable, especially with high-power stages, to have some means of varying the coupling between link and tank coil. The link turn may be arranged to be swung in relation to the tank coil or, when it consists of a large turn around the outside of the tank coil, can be split into two parts which can be pulled apart or closed somewhat in the fashion of a pair of calipers. If the tank coils are wound on forms, the link may be wound close to the main coil.

With fixed coupling, the only adjustment of excitation is by varying the number of turns on the link. If the coupling between link and tank is variable, change of physical separation of the two coils also will give some adjustment of excitation. In general the proper number of turns for the link must be found by experiment.

Under certain circumstances, proper impedance matching may require tapping the grid at some point other than the top of the coil.

NEUTRALIZING

As we have already explained, a three-electrode tube used as a straight radio-frequency amplifier will oscillate because of radio-frequency feed-back through the grid-plate capacity of the tube unless that feed-back is nullified.

Neutralization really amounts to taking some of the radio-frequency voltage from the output or input circuit of the amplifier and introducing it into the other circuit in such a way that it effectively "bucks" the voltage operating through the grid-plate capacity of the tube, thus rendering it impossible for the tube to supply its own excitation. For complete neutralization it is necessary, therefore, that the neutralizing voltage be opposite in phase to the voltage through the grid-plate capacity of the tube and be equal to it in amplitude.

The out-of-phase voltage can be obtained quite readily by using a balanced tank circuit in either grid or plate, taking the neutralizing voltage from the end of the tank opposite that to which the grid or plate is connected. The amplitude of the neutralizing voltage can be regulated by means of a small condenser, the *neutralizing condenser*, having the same order of capacity as the grid-plate capacity of the tube. Circuits in which the neutralizing voltage is obtained from a balanced grid tank and fed to the plate through the neutralizing condenser are termed *grid-neutralizing* circuits, while if the neutralizing voltage is obtained from a balanced plate tank and fed to the grid of the tube, the circuit is known as a *plate-neutralized* circuit.

Plate-Neutralizing Circuits

Several plate-neutralizing circuits are given in Fig. 822. In the circuit shown at A the tank coil is center-tapped, with the tank condenser connected across only the upper half of the coil. The neutralizing portion of the coil is connected back to the grid of the tube through the neutralizing condenser, C_n. The circuit of B is similar, differing, however, in that the tank condenser is connected across all of the tank coil. This method of connection is prefer-

World Radio History

able in that it tends to keep a better voltage balance over a range of frequencies.

In both the circuits already described the division of r.f. voltage between plate and neutralizing portions of the circuit has been by balancing the tank coil. The balance also can be capacitive, by the use of a split-stator tank condenser with grounded rotor, as shown in Fig. 822-C. The r.f. potential across the tank coil divides in the same way, a node (point of zero voltage) appearing at its center. Hence the plate voltage is introduced at the center of the coil. The r.f. choke in the plate voltage lead is for the purpose of isolating the center of the coil from ground for r.f., since a ground through a by-pass condenser, if not exactly at the point of zero potential, might cause circulating currents which would reduce the plate efficiency of the amplifier.

The fixed condenser between the rotor plates of the tank condenser and ground is not required, but it has certain advantages which are discussed later in connection with the selection of a tank condenser of proper voltage rating.

The push-pull neutralizing circuits shown at D and E are known as "cross-neutralized" circuits, the neutralizing condensers being cross-connected from grid of one tube to plate of the other. With proper physical arrangement of parts, a more exact balance can be obtained with push-pull than with a single tube because both sides of the circuit are symmetrical. Hence these circuits often are easier to neutralize than single-tube circuits. The split condenser circuit of E is to be preferred for push-pull amplifiers.

Grid Neutralization

Typical grid-neutralizing circuits are shown in Fig. 823. They resemble closely the plate-neutralizing circuits except that the neutralizing voltage is obtained from a balanced input tank and fed to the plate of the tube. Circuit A is used with capacity coupling between driver and amplifier. The grid-coupling condenser, being large in comparison to the tube and neutralizing capacities in most circuits, will have negligible effect on the operation of the neutralizing circuit.

Grid neutralizing systems are well adapted to use with transmission line or link-coupled amplifiers, since the separate grid tank offers a ready means for obtaining the neutralizing voltage. It may be somewhat harder to drive a tube with a balanced input tank, however, because only half the r.f. voltage developed in the tank is available for the grid-cathode circuit of the amplifier. This can be overcome to some extent by using the largest possible L-C ratio in the grid tank in order to build up the r.f. voltage to the highest possible value.

From an operating standpoint, plate neutralization usually is to be preferred. The use of grid neutralization is relatively infrequent, and only when some special purpose is served.

Values in Neutralizing Circuits

In all these circuits, by-pass condensers and parts not particularly a part of the neutralizing arrangement will have the usual values. In most cases the neutralizing voltage will be equal to the r.f. voltage between the plate and grid of the tube so that for perfect balance the capacity required in the neutralizing condenser theoretically will be equal to the grid-plate capacity of the tube being neutralized. If, in the circuits having tapped tank coils, the tap is more than half the total number of turns from the plate end of the coil, the required neutralizing capacity will increase approximately in proportion to the relative number of turns in the two sections of the coil.

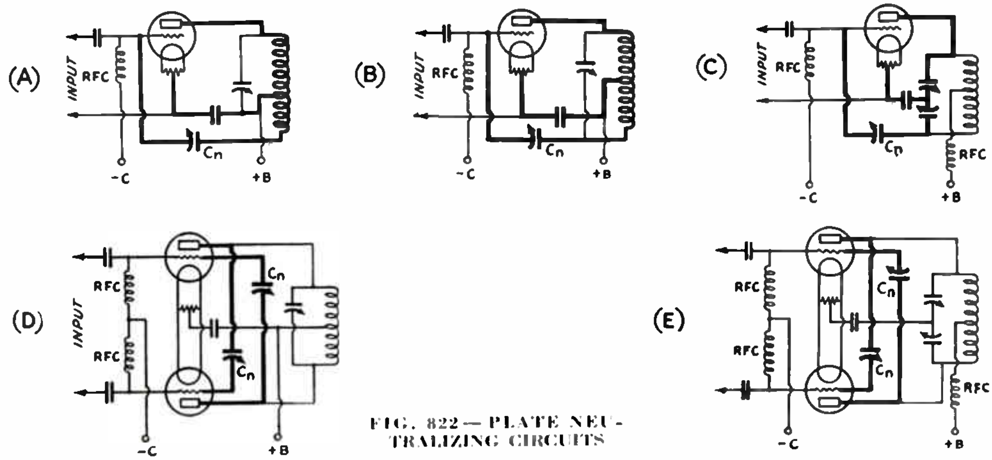


FIG. 822 — PLATE NEUTRALIZING CIRCUITS

World Radio History

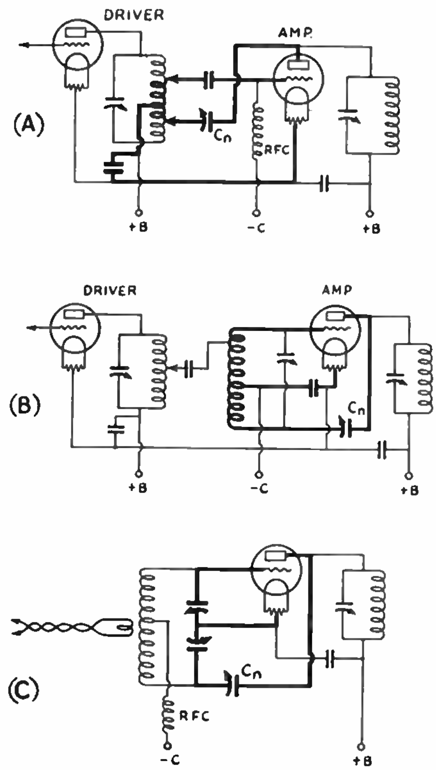


FIG. 823—GRID NEUTRALIZING CIRCUITS

For those tubes having grid and plate connections brought out through the bulb, a condenser having at about half scale or less a capacity equal to the grid-plate capacity of the tube should be chosen. Where the grid and plate leads are brought through a common base, the C_n capacity needed is greater because the tube socket and its associated wiring adds some capacity to the actual inter-element capacities. In such cases a slightly larger condenser should be used.

When two or more tubes are connected in parallel, the neutralizing capacity required will be in proportion to the number of tubes.

Comparison of Neutralizing Circuits

Aside from the considerations already mentioned in the discussion of neutralizing circuits there are certain practical aspects of neutralizing which should be kept in mind in deciding what type of circuit to employ. These apply particularly in neutralized single-ended stages.

The most commonly-used circuits are those given in Fig. 822 at *B* and *C*. With the split-coil method at *B*, exact neutralization can be obtained at only one frequency in a single-ended amplifier, because the various stray capacities shunting the coil destroy the balance when the circuit is detuned slightly. With detuning, the circuit becomes regenerative and may result in non-linear operation if the amplifier is modulated. For c.w. work, the unbalance is small enough so that satisfactory performance can be obtained. Another disadvantage is the fact that both sides of the single-section tank condenser are "hot" so that hand-capacity effects are marked.

The balanced condenser arrangement at *C* lacks regeneration, but this circuit also is likely to go out of balance with tuning if the plate-filament capacity of the tube is appreciable with respect to the capacity of the condenser section connected across it. At the higher amateur frequencies, therefore, the circuit functions best with a tube having low output capacity, and with a split-stator condenser having moderately large "in-use" capacity in each section. The effect of the tube output capacity can be eliminated by connecting a small condenser across the opposite condenser section to simulate a second tube balancing the first. The additional condenser should be adjusted to equal the effective output capacity of the tube.

The split condenser circuit has two advantages over the split coil: the effective input capacity of the circuit is smaller, permitting an increase in the *L-C* ratio of the grid tank circuit, and harmonics are more effectively suppressed because the condenser section between plate and filament offers much lower impedance to harmonics than the upper coil section in the circuit of *B*. The lack of regeneration in the split-condenser circuit may cause an amplifier neutralized by this method to appear harder to drive than when the split-coil system is used, especially if the driver power output is low, because the regenerative effect of the latter system tends to maintain the grid current at a higher value under load. Comparisons of the two circuits in a properly designed transmitter, however, show that with moderate excitation the same output can be obtained with either despite the difference in behavior of grid currents; the split-condenser circuit often, in fact, shows better plate efficiency because of the reduction of harmonic output. Since the rotor of the split-stator condenser is grounded, there are no hand-capacity effects with this circuit. The process to be followed in neutralizing will be discussed later in connection with tuning and adjustment.

SCREEN-GRID AMPLIFIERS

The screening in all transmitting tetrodes and pentodes is sufficiently complete to reduce the plate-to-grid capacity to a value which will not permit coupling by this means; therefore,

World Radio History

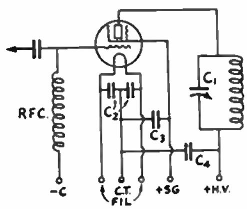
neutralization is not necessary and the circuits of screen-grid amplifiers are relatively simple. It should be noted, however, that the receiving type beam tubes, such as the 6L6, 6L6G, and 6V6G, frequently used in the low-power stages of transmitters, are not sufficiently well screened and require neutralization if input and output circuits are to be tuned to the same frequency. Since the plate-to-grid capacity is very small, difficulty is sometimes encountered in arriving at a neutralizing adjustment which will hold well. To avoid this, the tubes mentioned above are sometimes converted into triodes by connecting screen to control-grid or to the plate. With this connection, operation is similar to that of other triodes.

The operation of a screen-grid amplifier is essentially the same as that of a neutralized triode. Since neutralization is not required, the circuits of screen-grid amplifiers are relatively simple. Typical circuits for tetrodes and pentodes are given in Fig. 824.

The rules for interstage coupling also are applicable to these circuits. Chief points about the screen-grid amplifier are the necessity for thorough grounding of screen (and suppressor) for r.f. through the use of bypass condensers close to the tube itself, and the prevention of stray couplings between input and output circuits.

Screen-grid pentodes and beam tetrodes have high power sensitivity and usually require much less grid driving power for full output than do triodes of comparable ratings. Although these tubes are shielded from internal feedback, their high power sensitivity makes them prone to self-oscillate, so that particular care must be used to prevent feedback external to the tube itself. In cases where low-loss circuits are used, it may be impossible to prevent oscillation unless the input and output circuits are carefully shielded from each other and the input circuit shielded from the tube itself. A short cylindrical shield extending from the base of the tube up to a point level with the lower edge of the tube plate is commonly used to shield the plate lead from the grid wiring in the stem and base of the tube.

Old-type screen-grid tubes such as the 865, 860 and 861 do not have the power sensitivity of the more modern tubes and are seldom seen in use to-day.



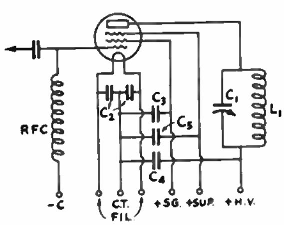


FIG. 824 — TYPICAL SCREEN-GRID AMPLIFIER CIRCUITS

The upper diagram is used with filament-type screen-grid power tubes such as the 865, 860, 282-A, 850, 254-A, 254-B, 807, RK39-47-48, 814, 813 etc. Important points to observe in the operation of the screen-grid amplifier are that the screen by-pass condenser, C_3, should have low impedance at the operating frequency (capacity of at least .002 μfd. for amateur transmitters) and that the output tank circuit L_1C_1 must be isolated from the input circuit, either by shielding or by physical spacing great enough to prevent feed-back. By-pass condensers C_2 and C_4 may be the usual values used in power-tube circuits; .002 μfd. will be sufficient. Any type of input coupling may be used in place of the capacity coupling shown.

The lower diagram is for use with screen-grid pentodes. It is essentially the same as the upper circuit except for the additional connections for the suppressor grid, which should be supplied a small positive voltage for maximum output. Values are the same for similarly-labelled components in both circuits. C_5 should have the same value as C_3.

AMPLIFIER OPERATION

For efficient operation, it is necessary that the grid of a power amplifier be driven positive during part of the cycle of r.f. excitation voltage. The grid therefore consumes power, and rectified current flows in the grid circuit. The excitation power required depends upon the type of tube, the power output and plate efficiency desired, the grid bias, and to some extent upon the operating frequency. In r.f. amplifiers, the power amplification ratio ordinarily is not very high in comparison with the ratios encountered in audio-amplifier practice. On the other hand, the plate efficiency is considerably higher than is possible in audio work, because wave-form distortion is not a factor. An r.f. amplifier works into a tuned tank circuit, resonant only to the operating frequency, so that the flywheel effect of the tank eliminates most of the distortion. In any event, distortion of an r.f. cycle is not objectionable in the sense that similar distortion of an audio-frequency cycle is objectionable; even when the amplifier is modulated, r.f. distortion, being at frequencies far beyond audibility, does not affect the audio-frequency modulation. R.f. distortion, however, causes harmonics of the fundamental frequency to be generated, and these harmonics can be radiated to cause unnecessary interference. For example, an amplifier working on a frequency of 3700 kilocycles will have harmonics at 7400; 11,100; 14,800 kc., etc. It is desirable, therefore, to take all possible precautions to prevent the harmonics from being radiated by the antenna, even though they are unavoidably generated by the tube itself.

In all amplifiers provision must be made for applying the r.f. power obtained from the preceding stage, or *driver*, to the grid-cathode circuit of the amplifier tube, and for supplying a suitable tank circuit in the plate-cathode circuit of the tube so that the power output capabilities of the tube can be realized. With triodes, a neutralizing circuit also is necessary, as already mentioned. Besides circuit considerations, optimum performance is realized only when proper attention is paid to the operating conditions, which include adjustment of grid bias, excitation power, and output coupling.

Parallel and Push-Pull

A power amplifier stage may consist of a single tube, two or more tubes in parallel, or two tubes in push-pull. With parallel operation, the circuit is the same as for one tube, since the same elements in each of the paralleled tubes are simply connected together. It is customary to refer to a single-tube or parallel amplifier as *single-ended*, while push-pull circuits are known as *double-ended*, having a tube plate connected to each end of the tank circuit. The push-pull circuit uses *balanced* tank circuits, a balanced circuit being one in which the ground point is at the center of the tank. Both ends of the balanced tank therefore are at high r.f. potential with respect to ground, or are "hot" — so called because in power amplifier circuits it is possible to draw sparks off parts of the circuit at high r.f. potential. An *unbalanced* circuit is one in which one end of the tank is connected to ground while the other end is "hot." Balanced tank circuits often are used in neutralizing single-ended amplifiers although, since the tube is connected across only half the circuit, the balance may not be exact. Push-pull circuits, being symmetrical throughout with respect to ground, give excellent balance.

Under similar operating conditions, the power output from two tubes will be the same whether they are connected in parallel or push-pull. The same is true of the power required from the driver.

At the higher frequencies a limit is placed on parallel operation by the shunting effect of tube capacities in increasing the minimum capacity of the circuit to such an extent that a tank circuit of reasonable efficiency cannot be secured. However, at ordinary amateur frequencies several tubes designed for high-frequency work (the types with low interelectrode capacities) can be paralleled successfully.

It is an inherent property of the push-pull connection that even harmonics are balanced out. Thus only the odd harmonics are present in the output, assuming that the circuit is well balanced and that tubes having identical characteristics are used. The third harmonic, which is the one of greatest importance, is relatively small compared to the second harmonic. Thus push-pull operation is advantageous from the harmonic radiation standpoint.

A push-pull circuit is often easier to handle than a single-ended circuit, especially at high frequencies. This is particularly true of neutralized amplifiers; at 14 Mc. and higher, perfect neutralization is difficult, if not impossible, in a single-ended stage, with any tubes except those having very low interelectrode capacities and with grid and plate leads brought out separately, not through the tube base. The symmetry of the push-pull stage balances out the effects of stray capacity between tube elements and between other parts of the circuit, and permits easy and practically perfect neutralization. For this reason many amateurs prefer to use two tubes in push-pull rather than a single tube of twice the power rating.

AMPLIFIER DESIGN

Regardless of the circuit or type of tube used, certain principles must be observed if the amplifier is to give its best performance. For efficient operation, it is important that the load on the tube be adjusted to the proper value, that sufficient excitation be supplied to the grid, and that the correct value of grid bias be used. In addition, the constants of the plate tank circuit must be correctly chosen.

Tank Circuit Impedance — Coupling Efficiency

So far as the plate efficiency of the tube itself is concerned, it does not matter how the load resistance is obtained; that is, the tube will work equally well into an actual resistor or into a tank circuit having any practicable constants so long as the resistance or impedance represented by the tank is the desired value. However, the distribution of the power output between the tank circuit and the load is affected by the inherent (unloaded) impedance of the tank circuit.

The impedance of the unloaded tank circuit at resonance is equal to L/CR, where L is the inductance, C the capacity, and R the effective resistance. The higher the ratio of the unloaded tank impedance to the optimum load impedance for the tube, the greater the proportion of power transferred to the load. The impedance of the tank alone should be at least ten times the optimum load impedance for high transfer

World Radio History

efficiency. The unloaded tank impedance can be made high in two ways: by lowering the resistance through the construction of low-loss coils and by careful placement of parts, or by raising the *L-C* ratio. With practicable circuits, it is much easier to obtain high tank impedance by using a high *L-C* ratio than by attempting to reduce the resistance, although every effort should of course be made to reduce losses.

Tank Impedance and Harmonic Output

When a high-impedance tank circuit is used, along with high grid bias and large values of excitation voltage, a large proportion of the power output is on harmonics of the fundamental frequency. The harmonic power is not useful for signalling purposes and often is radiated by the antenna system, causing interference on other frequencies. Since our bands are not wholly in harmonic relation, at some operating frequencies this may mean that the transmitter is radiating on a frequency not assigned to amateurs.

Should the circuit conditions be such that the harmonics cause circulating currents, there is a power loss which reduces the overall efficiency of the amplifier. In general, it will be found that any means employed in the output circuit to reduce harmonics also will result in an improvement in efficiency.

Optimum L-C Ratios

Because high transfer efficiency requires high unloaded tank impedance (high *L-C* ratio) while harmonic reduction calls for considerable flywheel effect and consequently for a fairly large ratio of capacity to inductance, in practice a compromise must be made between these two conflicting factors. Another consideration which militates against the use of too high an *L-C* ratio is the fact that considerable flywheel effect is needed to insure linearity when the amplifier is to be modulated. The importance of linear action is discussed in Chapter Ten. A fair amount of flywheel effect also improves the stability of the amplifier and makes its tuning more satisfactory.

Best engineering practice is to adjust the *L-C* ratio so that under operating conditions, with the amplifier fully loaded, the tank circuit "Q" is about 12. The optimum *L-C* ratio to be used then depends upon the relation between the d.c. plate voltage and d.c. plate current in the amplifier stage. For a given power input, the higher the plate voltage and the lower the plate current, the higher the *L-C* ratio, and vice versa. It is therefore necessary to know only the plate voltage and plate current at which the amplifier is to operate in order to determine the amount of capacity which should be in use in the tank circuit. The capacity value is inversely proportional to the frequency or, conversely, directly proportional to the wavelength. The latter relation permits expressing the required capacity in "micro-microfarads per meter" of wavelength. Using round figures (close enough for practical purposes) the wavelengths with which amateurs are concerned are 10, 20, 40, 80 and 160 meters. For example, if the transmitter is in the 3.5-Mc. band (80 meters) the required tank capacity would be found by multiplying the "$\mu\mu$fd. per meter" value by 80.

Fig. 825 is a chart giving $\mu\mu$fd. per meter as a function of the d.c. plate voltage divided by the plate current (in milliamperes) for various types of circuits. The circuits themselves will be discussed later. As an example, suppose an amplifier is intended to be operated at 1500 volts and 150 ma. plate current. The plate-voltage plate-current ratio is 1500/150, or 10. Assuming the circuit at the top is employed, curve A should be used. For a ratio of 10, the $\mu\mu$fd. per meter value as read from curve A is 2.5. For 7-Mc. output, the tank capacity therefore should be 40 x 2.5, or 100 $\mu\mu$fd.; for 14-Mc. output, 20 x 2.5, or 50 $\mu\mu$fd., and so on. Where double-section or split-stator condensers are used, the values given by the curve are for *each section* of the condenser. The capacity values so obtained are the actual values which should be used, not simply the maximum capacity of the condenser in the transmitter. If, for example, the chart calls for a capacity of 50 $\mu\mu$fd., a 100-$\mu\mu$fd. condenser should tune to resonance at about half scale.

Multi-Band Operation

The use of one transmitter for work in several bands is customary for obvious reasons. Provided only three adjacent bands are covered by a single transmitter, it is generally possible to design the tank circuit of the final stage so that the optimum *L-C* ratio is used on each band. However, the limitations of circuit components are such that it is difficult, if not impossible, to use the best tank circuit for each band when the same amplifier must work over four or five bands. Particularly, a tank condenser having the right minimum-maximum capacity range for 14 and 28-Mc. operation will not have nearly enough capacity for 1.75 Mc., and a condenser suitable for the latter band will not have a low-enough minimum capacity for efficient 28-Mc. work.

Nevertheless, some constructors insist on having data on operating a single amplifier or transmitter on all five bands. To do it, some compromise must be made in the *L-C* ratios, so that optimum performance cannot be secured at the extremes of the frequency range. Some of the amplifiers to be described in this chapter are examples of such compromise. We

World Radio History

strongly recommend, however, that separate transmitters — or at least separate final amplifiers — be used when bands of such widely-different requirements as 1.75 Mc. and 28 Mc. are to be used. To get optimum *L-C* ratios, it may be necessary to use single-section condensers on the low frequencies where split-stator condensers are recommended in the circuit diagrams; in single-tube plate-neutralized circuits this simply means changing the plate tank circuit from that of Fig. 822-C to 822-B, and in push-pull circuits from Fig. 822-E to 822-D. Since the differences between the neutralizing circuits are most apparent at the higher frequencies, the change in circuit is of less consequence at 1.75 and 3.5 Mc. and on these bands the one which permits use of the optimum *L-C* ratio should be used.

In the amplifiers described in the constructional section of this chapter, optimum capacity at 1.7 Mc. is obtained by the use of a fixed padding capacity.

Determination of Tank-Condenser Voltage Rating

Graphs showing the values of peak r.f. voltage which may be expected across a tank-condenser section depending upon the power input and tank-circuit *L-C* ratio are given in Fig. 826. If the stage is to be plate-modulated, the peak r.f. voltage across each section will be twice that shown by the graph for 100% modulation. While the value of tank-condenser capacity in micromicrofarads-per-meter of wavelength for an optimum *L-C* ratio may be determined from the graphs of Fig. 825, as previously explained, the graphs of Fig. 826 apply equally to other *L-C* ratios, of course. The capacity is that actually in use at resonance.

In circuits making use of a single-section tank condenser, the peak r.f. voltage mentioned above will be the only voltage to appear across the condenser plates. In circuits in which a split-stator condenser is used with rotor grounded, the d.c. plate voltage and, if the stage is plate-modulated, the peak audio voltage (equal to the d.c. plate voltage for 100% modulation) must be added to the peak r.f. voltage per section, still bearing in mind that the peak r.f. voltage doubles with plate modulation.

The d.c. and a.f. voltages may be removed from across the plates of a split-stator condenser by the use of a blocking condenser as shown in Fig. 827. This places the rotor at full plate voltage above ground, however, requiring the use of a suitably insulated control. The condenser should have a capacity of 0.001 to 0.002 μfd. and a peak voltage rat-

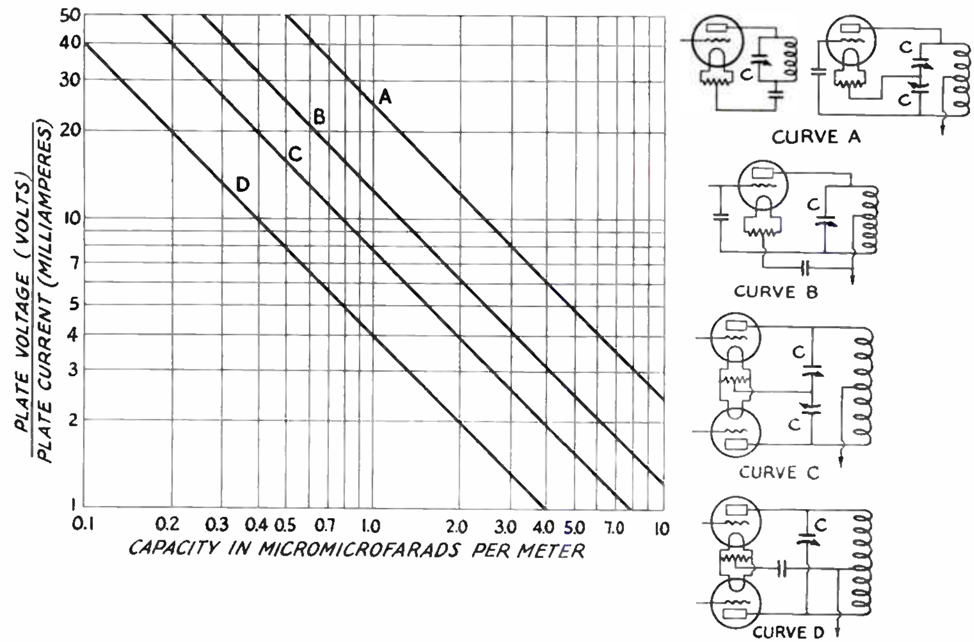


FIG. 825 — OPTIMUM PLATE TANK L-C RATIOS MAY BE DETERMINED FROM THESE CURVES FOR THE VARIOUS TYPES OF CIRCUITS SHOWN AT THE RIGHT

The correct L-C ratio is of particular importance in the final-amplifier tank circuit. Method of using chart is explained in the text.

World Radio History

ing of about four times the d.c. plate voltage.

Taking the example previously cited in connection with Fig. 825, i.e. an amplifier operating at 225 watts input (1500 volts, 150 ma.), we obtain an optimum capacity value of 1.25 $\mu\mu$fds. per meter for a single-section condenser or 2.5 $\mu\mu$fds. per meter for each section of a split-stator condenser. The ratio to be used in Fig. 826 for the single-section condenser will be 225/1.25 or 180, corresponding to a peak r.f. voltage of 1250. Adding a safety factor of 25%, we obtain a value of 1565 volts. If the stage is to be used for c.w. only, the value obtained from the graph will be the total voltage across the condenser. If the stage is to be plate-modulated, however, this value must be multiplied by 2 bringing it to 3130 volts.

If a split-stator condenser is to be used, the ratio will be 225/2.5 or 90, corresponding to a peak voltage of 625 volts. Adding the 25% safety factor brings the voltage per section to 785. If a blocking condenser is used and the stage is not to be plate-modulated, this will be the total voltage across each section of the condenser. If the blocking condenser is used and the stage plate-modulated, the above value must be multiplied by two bringing it to 1570 volts per section. If no blocking condenser is used, the d.c. plate voltage must be added for c.w. operation bringing it to 2656 volts per section (625 plus 1500 plus 25%). With plate modulation, the peak audio voltage (equal to the plate voltage for 100% modulation) must also be added bringing the total voltage per section to 5312 [(625 × 2) plus (1500 × 2) plus 25%.] The advantage of the use of the blocking condenser is quite apparent. These values are those to be expected with the amplifier loaded. Since a plate-modulated stage is always operated with a load, the estimated values should be satisfactory. A c.w. transmitter is sometimes operated without load during the process of tuning. While it is always advisable to tune first with voltage reduced, keying surges sometimes occur which would make it advisable to use a condenser with the same spacing as that determined for plate modulation.

The spacing required to withstand a certain estimated value of voltage will depend upon the design of the condenser. Most manufacturers specify peak-voltage ratings for each of their condensers.

Determining Inductance

Once the required tank capacity for the amplifier and frequency is determined, the tank coil dimensions can be found. This may be done with the help of the L-C and inductance formulas in Chapter Four, or if standard coil forms are used, the charts of Figs. 828 and 829 will give the required number of turns directly. Using the chart which applies for the type of coil form or coil in question, read on the appropriate frequency curve the number of turns required for the tank capacity value already determined. The optimum tank L-C ratio will result.

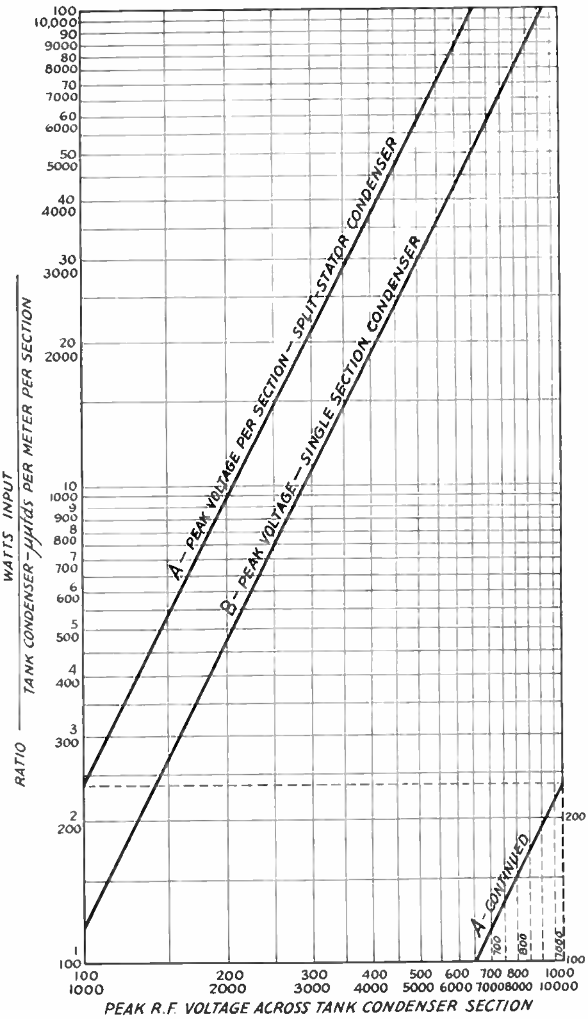


FIG. 826 — CHART FOR USE IN DETERMINING VOLTAGE RATING OF TANK CONDENSER FOR GIVEN L-C RATIO AND POWER INPUT

Curve A for one section of split-stator tank condenser. Curve B for single-section tank condenser. Circumstances may require adding plate and audio voltages to graph values. (See text.)

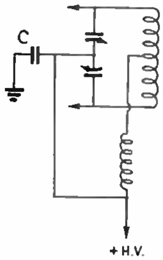


FIG. 827 — USE OF BLOCKING CONDENSER PERMITS SMALLER PLATE SPACING WITH SPLIT-STATOR CONDENSERS

Condenser control must be suitably insulated. (See text.)

Fig. 828 is for coils wound on receiving-type forms having a diameter of 1½ inches and ceramic forms having a diameter of 1¾ inches and winding length of 3 inches (National XR13). Such coils would be suitable for oscillator and buffer stages where the power to be carried is not over 50 watts. In all cases the number of turns given must be wound to fit the length indicated; the turns should be spaced out evenly either by winding wire or string of suitable size between turns, or, in the case of those having few turns, by hand.

Fig. 829 gives data on coils wound on transmitting-type ceramic forms. Five popular types of forms are indicated. In the case of the smallest form, extra curves are given for double-spacing; that is, winding turns in alternate grooves. This is sometimes advisable in the case of 14- and 28-Mc. coils when only a few turns are required. In all other cases it is assumed that the specified number of turns is wound in the grooves without any additional spacing.

The plate tank circuit, together with the apparatus coupled to it (an antenna or following amplifier stage) constitutes the plate load for the tube. When the tank is tuned to resonance with the exciting frequency, it is practically equivalent to resistance only, so that it is customary to refer to the load circuit as a resistance or impedance. The value of equivalent resistance represented by the tank circuit is dependent upon the ratio of inductance to capacity, upon the inherent r.f. resistance of the coil and condenser making up the tank, and upon the effective resistance coupled into the tank from the external circuit to which it is supplying power. The tank resistance or impedance decreases as the coupling to the external circuit is increased, and also decreases as the ratio of inductance to capacity is decreased.

The value of load resistance or impedance which will give optimum power output and efficiency depends upon the grid bias and excitation voltage.

Measurement of Excitation

Measurement of r.f. excitation voltage is difficult without special apparatus such as a vacuum-tube voltmeter, so it is customary to take the rectified grid current as a measure of the r.f. voltage and power supplied to the grid circuit of the amplifier. Under a given set of conditions, the higher the grid current the greater is the excitation voltage. However, a change in load resistance or a change in fixed bias or grid-leak resistance will cause a change

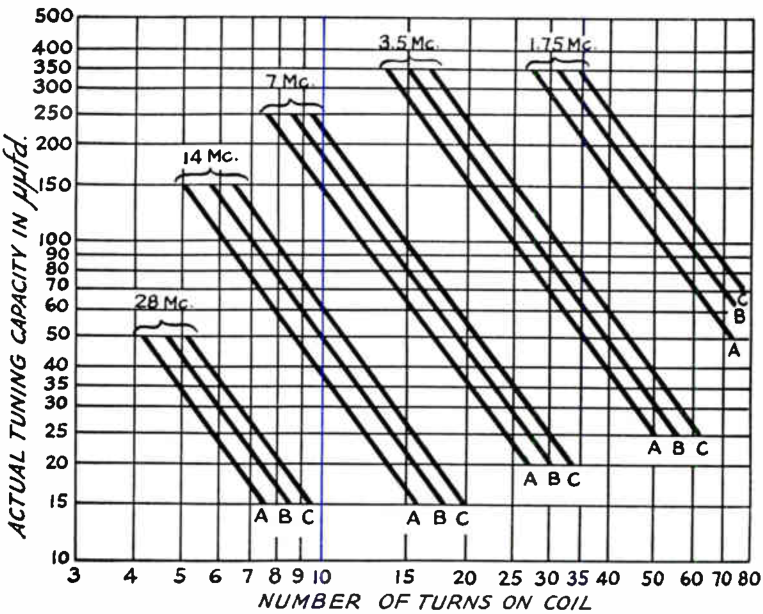


FIG. 828 — COIL-WINDING DATA FOR RECEIVING-TYPE FORMS, DIAMETER 1½ INCHES

Curve A — winding length, one inch; Curve B — winding length, 1½ inches; Curve C — winding length, 2 inches. After determining the number of turns for the capacity and frequency band to be used, consult the wire table in the Appendix to find the wire size which will fit in the space available. No. 18 wire is about the largest size that need be used; larger sizes are difficult to handle on this type of form. Curve C is also suitable for coils wound on 1¾-inch diameter ceramic forms with 3 inches of winding length.

World Radio History

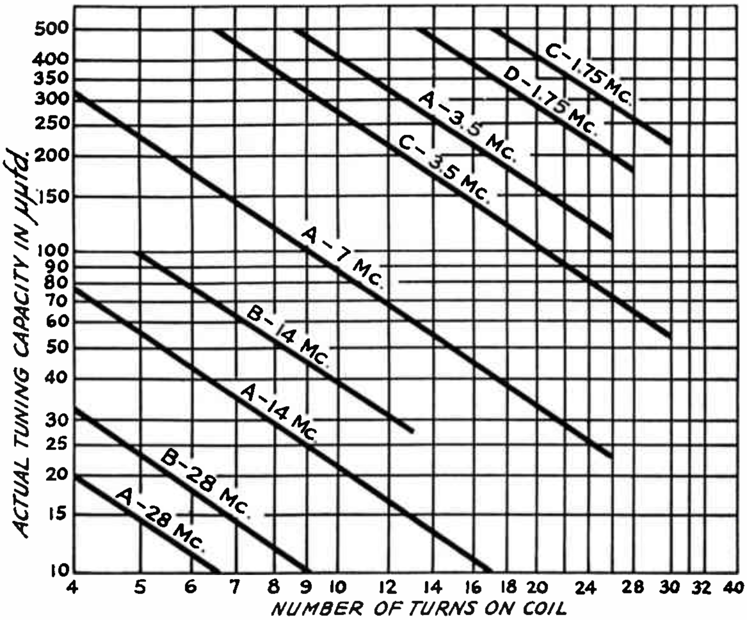


FIG. 829—COIL-WINDING DATA FOR CERAMIC TRANSMITTING-TYPE FORMS

Curve A — ceramic form 2½-inch effective diameter, 26 grooves, 7 per inch; Curve B — same as A, but with turns wound in alternate grooves; Curve C — ceramic form 2⅞-inch effective diameter, 32 grooves, 7.1 turns per inch, app.; Curve D — ceramic form 4-inch effective diameter, 28 grooves, 5.85 turns per inch, app.; Curve E — ceramic form 5-inch effective diameter, 26 grooves, 7 per inch. Coils may be wound with No. 12 or No. 14 wire.

in the value of d.c. grid current for the same excitation voltage, so that readings taken under different operating conditions are not comparable.

Fig. 803 shows how a milliammeter may be connected in the circuit for reading grid current.

Effect of Excitation

A typical set of performance curves, showing power output, power amplification ratio, driving power and efficiency as a function of d.c. grid current is shown in Fig. 830. Fixed values of load resistance and grid bias are assumed. The curves show that output and efficiency increase rapidly at first as the excitation is increased, then more slowly. The grid driving power curve rises rapidly beyond the maximum power amplification ratio, showing that a relatively large increase in excitation is necessary to produce a comparatively small increase in power output and efficiency once the optimum point — just to the right of the bend in the output and efficiency curves — is passed.

Assuming fixed plate voltage and load resistance, there is an optimum bias value which will give best results for every value of excitation voltage. The greater the excitation, the greater should be the bias. The power consumed in the amplifier grid circuit also is greater under these conditions. The grid power, furnished by the driver, is dissipated in the grid-filament circuit of the tube, appearing as heat at the grid, in the bias supply, and also, particularly at the higher frequencies, as dielectric loss in the glass of the tube.

The curves of Fig. 830 are typical for the neutralized triode amplifier. In the case of the beam tetrodes and pentodes, the power output actually decreases after excitation exceeds a rather critical value. Since the driving power required by tubes of these types is quite small, care must be taken to avoid over-driving.

Efficiency and Output

The attainable plate efficiency is of great importance in determining the operating conditions for the amplifier. If the safe plate dissipation rating of the tube were the only consideration, it would be desirable to obtain the highest possible plate efficiency, since the power output would be limited solely by the efficiency. For example, a tube having a plate dissipation rating of 100 watts operating at a plate efficiency of 90% could handle an input of 1000 watts, giving 900 watts output, while the same tube at 70% efficiency could handle an input of only 333 watts, giving an output of 233 watts. The plate dissipation — the difference between input and output — is the same in both cases, 100 watts.

There are other considerations, however, which limit the useful plate efficiency. Assuming that the *total* plate input is not to exceed the manufacturer's ratings for the tube, the difference between 70% and 90% efficiency is not so great. For instance, taking the same 100 watt tube and assuming that the 70% efficiency condition corresponds with the rat-

World Radio History

ings, an efficiency of 90% would increase the output to only 300 watts (333 watts input). The additional 67 watts of output, an increase of about 27%, would require inordinately large driving power because, as shown by Fig. 830, the efficiency increases very slowly beyond the optimum point, while the reverse is true of the driving power required.

A second factor which limits the usable efficiency is the fact that high values of efficiency are attained only through the use of high values of load resistance, which in turn requires the use of very high plate voltage. Not all tubes are suited to operation at plate voltages much above their normal ratings, while from an economic standpoint a high-voltage power supply may represent greater cost than the installation of a second tube operating at lower voltage to give the same order of total power output, but at lower plate efficiency.

Grid Bias

For efficient tube operation, it is essential that plate current be drawn in pulses which occupy only a small part of the complete r.f. cycle, and that the peak value of the plate current pulse be several times the average d.c. plate current value as read by a milliammeter. This requirement is met by using grid bias considerably larger than that necessary to cut off plate current (without excitation) at the operating d.c. plate voltage. It is customary to operate with grid bias equal to twice the cut-off value, and where higher than ordinary efficiency is to be obtained, with even larger values. This method of operation requires correspondingly large grid excitation voltage and power.

Maximum plate efficiency will result when high bias, large excitation power, and a high value of load resistance or impedance are used. If the excitation is low, both grid bias and plate load impedance must be reduced for maximum output, although the efficiency will be comparatively low. The greatest power amplification ratio and maximum output with small excitation usually result when the bias is set at the cut-off value. Under these conditions the plate efficiency seldom exceeds fifty to sixty per cent. Plate efficiencies of 75% are usual when the bias is twice cut-off and the tube is adequately excited.

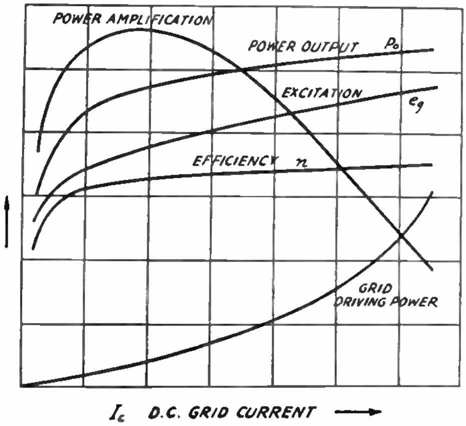


FIG. 830—EFFECT OF GRID EXCITATION ON POWER AMPLIFIER PERFORMANCE

Grid-Bias Supply

In nearly all the units shown in this chapter connections for external grid bias have been indicated. The combination of fixed and leak bias is desirable both for obtaining optimum performance and for tube protection.

Where fixed bias has been indicated, it has been assumed that the bias voltage will be constant under all operating conditions. This is true only when the bias source has negligible internal resistance. "B" batteries satisfy this requirement, and when bias of the order of 50 or 100 volts is all that is needed, one or two 45-volt blocks form an inexpensive and thoroughly practical "C" supply. The life is practically the same as the shelf life, since no power is taken from the batteries, provided the grid current does not greatly exceed the normal current rating of the battery. For standard-size blocks, about 25 milliamperes, and for heavy-duty blocks about 50 milliamperes, will be safe grid-current ratings. The end of useful life is indicated by a falling off in grid current from the normal value, evidence that the internal resistance of the battery is becoming appreciable.

A bias power pack has the advantage of indefinite life, but comparatively high internal resistance. In most cases, however, satisfactory bias packs can be constructed. Special features in their design are covered in Chapter Fourteen.

Cathode bias, similar to that used with receiving tubes, may be employed, as mentioned previously, when the tube is indirectly heated, or has a separate filament transformer, if of the directly-heated type. Cathode bias is often used with crystal-oscillator tubes, as already described. The method can be applied to amplifiers, although it has the disadvantage that the plate voltage is reduced by the amount of bias developed in the cathode resistor as explained previously; with many tubes a value of cathode resistance which will hold the plate current to a safe value without excitation absorbs far too much voltage under operating conditions. For this reason, it is most satisfactory with high-μ tubes. A separate fixed-bias source is generally preferable.

World Radio History

TUNING AN AMPLIFIER

THE general method of tuning applies to any type of amplifier or circuit. Triodes, of course, have to be neutralized, while screen-grid tubes do not. Aside from neutralization, the tuning process consists of adjusting the input circuit for maximum excitation, and the output circuit for optimum power output and efficiency.

When triode amplifiers are used, it is essential that the tube or tubes be carefully neutralized before attempting to take power output from the circuit. Neutralization is therefore the first step in the tuning process.

Neutralizing Adjustments

The procedure in neutralizing is the same for all tubes and circuits. The filament of the tube should be lighted and the excitation from the preceding stage should be fed to the grid circuit, ***but the plate voltage should be off.*** Couple any r.f. indicator such as a neon bulb or a flashlight lamp connected to a loop of wire, to the plate tank circuit (if a neon bulb is used, simply touch the metal base to the plate terminal) and tune the plate circuit to resonance, which will be indicated by a maximum reading of the r.f. indicator. Then, leaving the plate tank condenser alone, find the setting of the neutralizing condenser which makes the r.f. in the plate tank drop to zero. Turning the neutralizing condenser probably will throw off the tuning of the driver tank slightly, so the preceding stage should be retuned to resonance. In push-pull amplifiers both neutralizing condensers should be adjusted together, keeping their capacities equal.

Now couple the r.f. indicator to the plate tank once more and again tune the plate circuit to resonance. Probably the resonance point will occur at a slightly different setting, and the second reading on the r.f. indicator will be lower than the first one. Retune the preceding stage once more and go through the whole procedure again. Continue until the r.f. indicator gives no reading when the plate tank circuit is tuned in the region of resonance. When this has been accomplished the circuit is neutralized.

The object of neutralizing adjustments is to find the setting of the neutralizing condenser or condensers which eliminates r.f. in the plate circuit when the plate tank is tuned to resonance. It is not at all difficult to neutralize an amplifier after a few practice trials, provided the circuit is laid out properly and provided the neutralizing condenser has the right capacity range. It sometimes happens that while a setting can be found which gives a definite point of minimum r.f. in the plate circuit, the r.f. is not completely eliminated; in such a case stray coupling between the amplifier and driver tank coils, or stray capacities between various parts of the amplifier circuit tending to upset the voltage balance, probably will be found to be responsible. A better layout with short, widely-spaced leads, or with coils so placed that coupling between them is minimized — usually when the axes of the coils are at right angles — should be tried. Shielding of the amplifier often will eliminate troubles of this sort.

Neutralizing Indicators

In the neutralizing procedure outlined above, the use of a neon bulb or other r.f. indicator has been assumed. In circuits in which the neutralizing bridge is entirely capacitive, as in those circuits using split-stator condensers, touching the neon bulb to a high-potential point of the circuit may introduce enough stray capacity to unbalance the circuit slightly, thus upsetting the neutralizing. This is particularly noticeable with high-power amplifiers, where the excitation voltage is considerable and a slight unbalance gives a noticeable indication. In such cases a flashlight lamp and loop of wire, tightly coupled to the tank coil, may give a more accurate indication of the exact neutralizing point. A thermo-galvanometer similarly connected to a wire loop has considerably greater sensitivity, but is expensive.

A d.c. milliammeter connected to read rectified grid current as shown in Fig. 803 makes a quite sensitive neutralizing indicator. If the circuit is not completely neutralized, tuning the plate tank circuit through resonance will change the tuning of the grid circuit and affect its loading, causing a change in the d.c. grid current. With push-pull amplifiers, or single-ended amplifiers using a tap on the tank coil for neutralization, the setting of the neutralizing condenser which leaves the grid current unaffected as the plate tank is tuned through resonance is the correct one. If the circuit is slightly out of neutralization the grid meter needle will give a noticeable flicker. With single-ended circuits having split-stator neutralization the behavior of the grid meter will depend upon the type of tube used. If the tube's output capacity is not great enough to upset the balance, the action of the meter will be the same as in other circuits. With high-capacity tubes, however, the meter usually

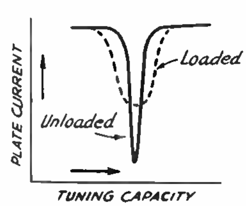


FIG. 831 — TYPICAL BEHAVIOR OF D.C. PLATE CURRENT WITH TUNING OF AN AMPLIFIER

will show a gradual rise and fall as the plate tank is tuned through resonance, reaching a maximum right at resonance when the circuit is properly neutralized. A sharp flicker at resonance indicates that the circuit is not neutralized.

Neutralizing Difficulties

If trouble is experienced in getting a triode amplifier completely neutralized, the circuit should be checked over carefully to make sure that all connections are good and that there are no shorted turns in the inductances. Different sizes of neutralizing condensers may also be tried, since circuit conditions vary considerably with different physical layouts. If a setting of the neutralizing condenser can be found which gives minimum r.f. in the plate tank circuit without completely eliminating it, the chances are that there is some magnetic or capacity coupling between the input and output circuits external to the tube itself. Short leads in neutralizing circuits are highly desirable, and the input and output inductances should be so placed with respect to each other that magnetic coupling is minimized. Usually this means that the axes of the coils should be at right angles to each other. In some cases it may be necessary to shield the input and output circuits from each other. Magnetic coupling can be checked for quite readily by disconnecting the tank from the remainder of the circuit and testing for r.f. in the plate tank circuit as the tank condenser is swung through resonance. The preceding stage must be running, of course.

Particularly with single-ended amplifiers there are many stray capacities left uncompensated for in the neutralizing process. The tube, for example, has capacity from grid to filament as well as from grid to plate; likewise there is capacity between plate and filament. Similarly, capacities existing between parts of the socket enter into the picture with tubes having all three elements brought out to the same base. With large tubes, especially those having relatively high interelectrode capacities, these commonly neglected stray capacities can prevent perfect neutralization. Symmetrical arrangement of a push-pull amplifier is about the only way to obtain a practically perfect balance throughout the amplifier.

Adjusting the Grid Circuit

After neutralizing is completed, the next step in the tuning process is that of adjusting the input circuit of the amplifier so that the maximum excitation will be delivered to the grid of the tube from the driver.

First adjust the driver stage plate tank to resonance. In the capacity-coupled systems, Fig. 820, the driver tank is common to the amplifier grid circuit so that this one adjustment suffices to tune the whole system to resonance. With capacity coupling, the one remaining adjustment is to determine the optimum coupling. If excitation is taken through a tap on the coil, the tap should be moved until the grid current is maximum. Each time the tap is moved, the tank condenser should be retuned for minimum plate current. If the excitation is taken directly from the end of the tank coil, the coupling can be varied by changing the capacity of coupling condenser C.

In the link-coupled systems of Fig. 821, two tank circuits must be tuned: the driver plate tank and the amplifier grid tank. In addition, the coupling between the two must be varied. Adjust the driver to resonance, then tune the amplifier grid tank for maximum grid current, and vary the coupling (with simultaneous "touching up" of each tank) until the highest value of grid current is secured. The coupling can be varied by changing the number of turns on one or both links or by varying the separation between a link coil and the tank coil to which it is coupled.

In adjusting the coupling, watch should be kept on the driver plate current. Too tight coupling may overload the driver, while too loose coupling will not give the amplifier the full excitation of which the driver is capable. If it is impossible to load the driver to its normal operating plate current with the tightest coupling available, tapping the grid connection at some intermediate point on the grid tank coil will often result in an improvement. If the driver in a capacity-coupled system cannot be loaded sufficiently, a change to link coupling usually will give the greater flexibility necessary properly to transfer the driving power to the amplifier grid.

Provided the driving stage is capable of adequate power output for exciting the amplifier tube, the grid current should be somewhat higher than that recommended for the set of operating conditions chosen (see Transmitting Tube Tables, Chapter Five), since grid current usually drops when plate voltage is applied. It should be possible to secure sufficient grid current — at the recommended grid-bias voltage — with the driver working at or below normal plate input. If this cannot be done, the driver is too small or, should the tube evidently be large enough for the job, is not being properly operated. The grid-leak circuit should be tested for excessive resistance.

Plate Tuning

After adjustments to the input circuit have been completed, plate voltage may be applied to the amplifier. In preliminary tuning it is desirable to use low plate voltage to avoid

World Radio History

possible damage to the tube. With excitation and plate voltage applied, rotate the plate tank condenser until the plate current dips: set the condenser at the minimum plate current point, which is resonance. When the resonance point is found, the plate voltage may be increased to its normal value. With the load — antenna or following amplifier grid circuit — connected, the coupling between plate tank and load should be adjusted to make the tube take rated plate current, keeping the tank always in resonance.

As the output coupling is increased, the minimum plate current will also increase about as shown in Fig. 831. Simultaneously, the tuning becomes less sharp, because of the increase in effective resistance of the tank. If the load circuit simulates a resistance, the resonance setting of the tank condenser will be practically unchanged with loading; this is generally the case since the load circuit itself usually is also tuned to resonance. A reactive load (such as an antenna or feeder system which is not tuned exactly to resonance) may cause the tank condenser setting to change appreciably with loading.

As the plate loading is increased, with its accompanying increase in plate current, the grid current usually will fall off somewhat, because as more electrons are drawn from the cathode by the plate, less are available for the grid if the exciting voltage remains constant. The decrease in grid current depends upon a number of factors: the value of plate current, the type of tube, the voltage regulation of the driver, the amount of excitation power available, and to some extent upon the circuit used. This last is particularly true of single-ended amplifiers, as was discussed in the section on neutralizing circuits.

The significant value of grid current is that which flows when the amplifier is loaded to rated plate current. The grid current figures given in the tube tables of Chapter Five are for *loaded* conditions at the recommended bias. Without plate voltage, the grid current may be considerably higher. If, when the plate load is adjusted to rated input, the grid current is lower than the figure specified for the particular set of operating conditions used, the driving stage is not delivering sufficient excitation power.

In a properly designed transmitter, the grid current usually will not drop more than 25% of its value without plate voltage applied to the tube.

As a check on the operation of an amplifier, its output may be measured approximately by coupling an ordinary 110-volt lamp to the output circuit. The usual methods are shown in Fig. 832. If the plate tank coil can be tapped each turn, the leads from the lamp are clipped across a few turns at the low-potential part of

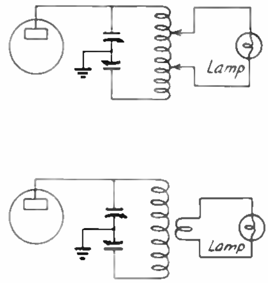


FIG. 832 — INCANDESCENT LAMP LOADS FOR CHECKING POWER OUTPUT

the tank, the number of turns used being adjusted so that the amplifier draws rated plate current. Alternatively a pickup coil of a few turns may be inductively coupled to the tank and the coupling adjusted to the same end. A lamp having a power rating about equal to the expected power output of the transmitter should be used. Comparison of the brightness of the lamp coupled to the transmitter with that of a similar lamp in a 110-volt socket will indicate whether the amplifier is delivering the output it should. If necessary, lamps may be connected in parallel to absorb the desired amount of power.

With reasonably efficient operating conditions, the minimum plate current with the amplifier unloaded will be a small fraction of the rated plate current for the tube, usually a fifth or less. If the excitation is low, the "dip" will not be very marked, but with adequate excitation the plate current at resonance without loading is just high enough so that the d.c. plate power input supplies all the losses in the tube and circuit. The higher the unloaded tank impedance, the lower the minimum plate current. For this reason, large *L-C* ratios give very low values of plate current; conversely, a fairly high-*C* tank will give somewhat larger values. As an indication of probable efficiency, the minimum plate current value should not be taken too seriously, however, especially when a fair amount of tank capacity is in use, because in the unloaded condition the circulating r.f. current in a high-*C* tank is large and, since the losses vary with the current squared, the losses under no-load conditions may be rather high compared to those in a very low-*C* tank. When the amplifier is delivering power to a load, the circulating current drops considerably and the tank losses correspondingly decrease, so that under load conditions the actual efficiency is about the same with a tank of optimum *L-C* ratio as with one having extremely low *C*.

FREQUENCY MULTIPLICATION

Frequency multipliers are universally used in amateur transmitters so that output can be

World Radio History

secured on higher-frequency bands than that for which the crystal is cut. Although crystals are available for fundamental operation on frequencies as high as the 28-Mc. band, the relatively lower cost of the 1.75-, 3.5- and 7-Mc. crystals favors the use of these crystal frequencies, with frequency multipliers for the other bands. In addition, usually it is more convenient, as well as less expensive, in multi-band transmitters to have all crystals ground for one low-frequency band.

The frequency multiplier or harmonic generator is a tube having its plate tank circuit tuned to a harmonic of the frequency applied to its grid. Otherwise, the circuit is the same as that of an ordinary power amplifier. Its effectiveness as a generator of harmonics depends upon the tube characteristics and the way in which it is operated. Since the amateur bands are in even-harmonic relation, the harmonics of chief interest are the second, fourth, eighth, and so on. In practice, the frequency multiplier is inefficient on harmonics higher than the second, so the second-harmonic multiplier or *doubler* is in most common use.

Since the input and output circuits of a doubler are not tuned to the same frequency there is no tendency toward self-oscillation, even with unneutralized triodes. Neutralization of doublers is quite common, however, because the same stage often is used as a straight amplifier; in addition, neutralization may actually improve the efficiency.

Doubler Operating Conditions

To obtain maximum output and efficiency from the doubler it is necessary to use high negative grid bias on the tube — considerably more than double cut-off — and excite it with a correspondingly high radio-frequency voltage. This accentuates harmonic generation in the plate circuit, as explained in Chapter Five. A low-C tank in the plate circuit is also desirable. In general, a tube having a relatively large amplification factor is to be preferred as a doubler because relatively low bias and excitation voltage will give high distortion. Pentodes, beam tetrodes and high-μ triodes all make good doublers.

The efficiency and output of a doubler can be increased by feeding some of the energy in the plate circuit back to the grid to cause regeneration, provided the process is not carried so far that the tube breaks into self-oscillation. One of the most satisfactory ways of introducing regeneration is through neutralizing the frequency multiplier by one of the methods in which the neutralizing voltage is fed from the plate circuit to the grid. The single-tube circuits of Fig. 822 are examples. When the tube is properly neutralized it cannot oscillate, yet the feedback at the harmonic frequency is sufficient to increase the output and efficiency of the doubler to a worth-while extent.

The grid leak for a doubler may in general have a resistance from two to five times that recommended for the tube as a straight amplifier. The driving power required for good doubling efficiency will be two or three times greater than that necessary for efficient straight amplification.

Push-pull amplifiers cannot be used as doublers because the second and other even harmonics are cancelled in the output. They can be used as triplers, however, the output circuit being tuned to the third harmonic. They are not very often used in this way because the frequency relations of the amateur bands are such that even-harmonic output is necessary.

Doubler Circuits

The simple triode doubler circuit is shown in Fig. 833-A. Screen-grid or pentode doubler circuits are exactly the same as the straight amplifier diagrams given in Fig. 824. The plate tank is simply tuned to the second harmonic instead of the fundamental frequency. Neutralized circuits such as those in Fig. 822 also can be used.

Special circuits for frequency doubling also have been employed; one which is often used

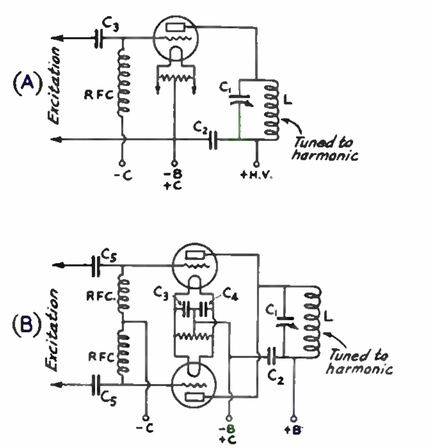


FIG. 833 — FREQUENCY-MULTIPLYING CIRCUITS

The regular doubler circuit (A) is the simplest. The plate tuned circuit should be fairly low-C for best results; the capacity actually in use at C_1 should not exceed 50 $\mu\mu$fd. at the lower amateur frequencies and 25 $\mu\mu$fd. at 14 Mc. and higher. C_2 is a plate bypass condenser having a capacity of about .002 μfd. Capacity of C_3, the grid coupling condenser, should be about 100 $\mu\mu$fd. Any of the recommended grid-coupling arrangements may be used instead of the simple capacity coupling shown.

Values in the "push-push" doubler (B) are in general identical with those in (A). This circuit requires push-pull input.

Suitable coil specifications for the capacity in use at C_1 can be found by referring to the coil charts, Figs. 828 and 829.

World Radio History

is shown in Fig. 833-B. In this circuit two tubes are used; the excitation is fed to the grids in push-pull while the plates of the tubes are connected in parallel. Thus the tubes work alternately, and the output circuit receives two impulses for each r.f. cycle at the grids, resulting in all second-harmonic output. This circuit gives quite good efficiency, although requiring two tubes. It is often called a "push-push" doubler. In low-power stages, twin triodes such as the 53 and 6A6 can be used as single-tube push-push doublers. The high amplification factors of these two types make them especially suitable for this purpose.

A circuit of this type is not suitable in cases where a stage is to be used both as a straight amplifier and a doubler, since it will not operate efficiently as a straight amplifier.

Tuning of Frequency Multipliers

Frequency multipliers are tuned in much the same way as straight amplifiers. Once the bias or grid-leak values are chosen, the input or grid circuit should be adjusted for maximum grid current just as with the straight amplifier. Then the plate voltage may be applied and the plate tank circuit tuned to the second harmonic, which will be indicated by the dip in plate current. The dip usually will not be as pronounced as with straight amplifiers, however. Once these adjustments have been made the load may be connected and adjusted for maximum output consistent with the plate current rating of the tube. Since the efficiency is lower, it may be necessary to use lower than rated plate current, especially if the plate of the tube shows color.

After the adjustments have been completed it is a good plan to change the bias voltage or the resistance of the grid leak to find the value which gives greatest output. Highest efficiency will result when the grid bias or grid leak are as high in value as is possible with the grid excitation available. Under optimum operating conditions, the plate efficiency of a doubler runs between 40% and 60%.

PARASITIC OSCILLATIONS

If the circuit conditions in an oscillator or amplifier are such that self-oscillations at some frequency other than that desired exist, the spurious oscillation is termed *parasitic*. The energy required to maintain a parasitic oscillation is wasted so far as useful output is concerned, hence an oscillator or amplifier having parasitics will operate at reduced efficiency. In addition, the behavior of plate current often will be erratic.

Parasitic oscillations may be higher or lower in frequency than the nominal frequency of the amplifier. Low-frequency parasitics often occur when r.f. chokes having about the same inductance value are used in both grid and plate circuits, the tube or tubes operating as a tuned-plate tuned-grid oscillator at about the resonant frequency of the chokes and associated capacities. In series-feed circuits, it is best not to use chokes but to depend upon the by-pass condensers to keep the r.f. where it belongs. In push-pull amplifiers having split-stator condensers, where chokes are used to avoid grounding the tanks at two places, it is generally possible to omit the grid choke and use the grid leak for the same purpose instead. In any circuit, a change which permits dropping a choke in either the grid or plate circuit will cure this type of oscillation.

Parasitic oscillations also occur at ultra-high frequencies because of the wiring associated with the tube and normal tank circuits. With u.h.f. parasitics, the tank condensers simply act as by-passes, and the lead lengths between tank and tube are the important factors. Usually such oscillations can be destroyed by breaking up any symmetry which exists in the leads. A generally effective cure is to insert small coils, consisting of about eight or ten turns about a half-inch in diameter, in each grid lead right at the tube socket.

Parasitic oscillations in an amplifier can be detected by first neutralizing the amplifier and then applying plate voltage with the grid-biasing voltage adjusted to permit the flow of a low value of plate current without excitation.

If parasites are present, the plate current usually will vary with tuning of the tank condensers, and a neon bulb will glow when touched to grid or plate. A wide-range absorption-type frequency meter will be useful for determining the frequency at which the amplifier is oscillating. A properly-neutralized amplifier free from parasites will show perfectly steady plate current under all tuning conditions when not excited.

NOTES ON TRANSMITTER DESIGN

Amateur transmitters are more and more being designed and built on the "unit" plan, under which separate transmitter sections are built as complete pieces of apparatus, any one of which may be replaced by more modern equipment as improvements in circuits and components make their appearance. Similarly, additions can be made to unit-style apparatus without seriously disturbing the existing transmitting layout. The installation of new unit-type equipment, or re-arrangement of old, is facilitated by the use of the relay rack, which is treated in detail in Chapter Six. Nearly all of the apparatus described in this chapter is built to standard relay-rack dimensions, hence practically any suitable combination of units

World Radio History

can be used for assembling transmitters from a few watts up to a full kilowatt. Because of its flexibility and convenience, relay-rack construction is highly recommended to the amateur constructor.

Essentially, a transmitter is simply an oscillator followed by a series of amplifiers to raise the power of output level to the desired figure. Some of the amplifiers will be frequency multipliers, if output is desired on a frequency higher than that on which the oscillator operates. The problem of designing a transmitter, therefore, is that of deciding upon the number of stages to use, the kind of tubes to use, and upon choosing correct operating conditions.

Transmitting Tubes

A great many types of transmitting tubes are available for amateur work. They are listed in the tube tables in Chapter Five, together with sets of typical operating conditions for the various types. When a tube capable of the desired power output is decided upon, the next step in laying out the transmitter is to select an oscillator circuit and to decide upon the band in which the crystals are to operate. The features of the various oscillator circuits have been treated earlier in the chapter. We then have the beginning and the end of the transmitter, and it becomes necessary to choose intermediate stages which will be sure to deliver enough power to the grid of the final tube to excite it properly. Reference to the tube tables will be of assistance.

In laying out any transmitter it is decidedly good practice to be conservative throughout. Be sure to provide more than just enough excitation for each stage; the driving-power figures given in the tube tables, for instance, do not include an allowance for losses in the grid tank circuit or in coupling between the driver and amplifier. Likewise, the power output figures are total output, and do not include tank losses. In every case the driver should be capable of supplying two to three times the driving power specified in the tube tables.

For straight amplifier exciting stages, it is best not to figure on more than about 60% overall efficiency, to include an allowance for losses in tank circuits and coupling devices. Doublers work at lower efficiency; 40% is a fairly conservative figure. Remember that a doubler requires high bias and hence more excitation than a straight amplifier, probably two or three times as much. With these figures in mind, it is not difficult to select a tube combination which will be sure to work.

EXCITER UNITS

When a transmitter is to work on several bands, it becomes necessary to supply the same amount of excitation power to the amplifier over a wide range of frequencies. There are several ways of meeting this problem, one of which is to use a series of small tubes as oscillators and doublers, taking output from the tube working on the desired frequency. The power level is then built up by straight amplifiers. Other methods employ only a few tubes but use special circuits such as the Tri-tet or grid-plate oscillator which can give output on harmonics as well as the fundamental crystal frequency. A unit designed for giving approximately the same output for excitation purposes on several bands is called an "exciter unit."

The output of an exciter unit may vary from a few watts to a hundred or so, depending upon the design. Usually the exciter covers at least three bands, although many can operate in five. It is evident that the exciter also can be used as a multi-band transmitter of low or moderate power output.

Exciter units may utilize plug-in coils for band changing or may achieve the same end by a switching arrangement. Often a combination of both is used. A good exciter is the first requisite of a multi-band transmitter.

Metering

Throughout this chapter frequent reference has been made to the use of meters for measuring plate and grid currents. Methods of inserting a milliammeter in the grid circuit has already been covered (Fig. 803). The plate meter usually is simply connected in series with the high-voltage lead to the tube whose plate current is being measured. The "plus" connection on the meter goes to the power-supply side of the circuit in that case.

When plate milliammeters are to be mounted on metal panels, care must be taken to see that the insulation is sufficient to withstand the plate voltage. Metal case instruments should not be mounted on a grounded metal panel if the difference in potential between the meter and panel is more than 300 volts; instruments with bakelite cases can be used under similar circumstances at voltages up to 1000. At higher voltages an insulating panel should be used, or the meter should be connected in the negative power supply return lead rather than the positive. A disadvantage of connecting the meter in the negative lead is that the meter reads the total current taken by all the tubes operating from the same plate supply, so that if the current in one stage only is to be measured, each stage must have a separate plate supply. Also, if the tube cathode is grounded, the negative power supply terminal cannot be grounded except through the meter.

Some amateurs connect the milliammeter in series with the cathode — particularly in the

World Radio History

center-tap return from the filament transformer with filament-type tubes — but the practice is not particularly recommended because the meter reads the sum of grid and plate currents. Not only does this give a false indication of plate input, but it also makes it impossible to determine how the grid current behaves with plate loading, since the two currents cannot be separated except by using a grid meter and subtracting its reading from that of the center-tap meter.

It is common practice to use one meter for measuring grid and plate currents in several stages. The time-honored method of shifting the meter is by the use of plugs and jacks, which is quite satisfactory in practice if the shifting need be done only in the original tuning process and the meter left more or less permanently in one jack thereafter. If it is necessary to switch the meter frequently from one stage to another, it is more convenient to use the switching system shown in Fig. 834, using a two-gang switch with as many points as there are circuits to meter. The resistors are left permanently in each circuit to complete the connection, and the meter is simply switched across each. This system has the advantage of completely isolating the meter from all but the circuit in which it is being used. For low-voltage circuits, an ordinary gang switch of the type used for band-switching in receivers will be adequate. Special switches with 1000-volt insulation are available for higher power.

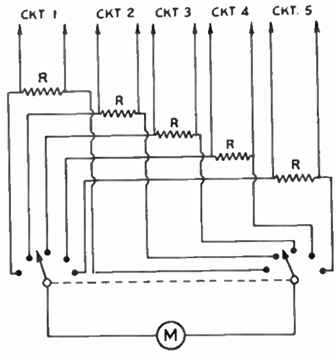


FIG. 834 — METHOD OF SWITCHING A MILLIAMMETER TO VARIOUS CIRCUITS

If the meter readings are taken directly, the value of each resistor should be at least ten times as great as the resistance of the meter itself; when *R* is ten times the meter resistance the readings will be about 9% low. The error will be less with still larger resistances. Ordinarily the meter resistance is low so that the introduction of the resistors into the circuit will not materially affect the operation of the transmitter. Alternatively, a low-range milliammeter may be used and each shunt resistance value selected to give an appropriate full-scale range of current. Thus the same meter could read 0–10 milliamperes for reading grid current in a low-power stage and 0–500 milliamperes for plate current of a high-power final. Methods of calculating shunt resistances for any predetermined full-scale current value can be found in Chapter Sixteen.

A filament voltmeter is an important transmitter accessory, especially if thoriated-filament tubes are used. The performance of the tube depends on the filament emission, which in turn depends upon the filament voltage, so that best results cannot be secured from the tube unless its filament voltage is maintained close to the manufacturer's ratings. Also, the tube life is adversely affected if the filament voltage is too low or too high. The filament voltage should always be measured right at the tube socket, an especially important point when tubes taking rather high filament currents are used. Do not operate a tube when the filament voltage is more than 5% below rating, or below the minimum value when an operating range is specified. Heater-type tubes are not quite so critical as to filament voltage, but will not give their best performance if the voltage is more than 5% below the rated value.

As a general rule, it is best practice not to build meters into transmitting units unless they can be well spaced from r.f. circuits, particularly those carrying considerable power. R.f. in the meter not only may destroy its accuracy, but often burns out the windings. For this reason, few of the units pictured in this chapter have meters built as an integral part. In relay rack construction, a separate meter panel, well separated from the r.f. units, is both desirable and convenient.

Grounds

When different parts of the circuit are shown as being grounded, it is assumed that there will be no r.f. potential difference between them. This means that the ground leads must possess negligible inductance and resistance at the operating frequency.

The best way to reduce inductance and resistance is to make the ground connections to a relatively large sheet of metal. When metal chasses are used, the grounds should be made directly to the chasses, making the leads as short as possible. In breadboard construction, a metal ground plate such as is used in some of the units described in this chapter, will suffice. As a general rule, when a metal plate is used as a ground, it is best not to make any two grounds to the same connection, but rather to use separate connections for each.

World Radio History

Components

In the descriptions of apparatus in this chapter not only the electrical specifications but also the manufacturer's name and type number have been given for all the components. This is for the convenience of the builder who may wish to make an exact copy of some piece of equipment. However, it should be understood that a component of different manufacture, but of equivalent quality and having the same electrical specifications, can be substituted wherever desired.

In most cases such substitutions will make no major modifications necessary, although slight wiring changes may be needed to take care of different terminal arrangements, etc.

MISCELLANY

Coupling to the Antenna

ALTHOUGH the antenna-coupling arrangement usually is an integral part of the transmitter, the choice of method and the adjustment procedure to be followed is so greatly a function of the antenna or feeder system employed that antenna-coupling methods are more logically treated in connection with the discussion of each particular antenna system. Information on coupling and tuning procedure is therefore given in Chapter Thirteen.

Practically all of the units in this chapter have been shown with links for carrying the r.f. output to the antenna. However, any of the antenna-coupling methods described in Chapter Thirteen can be applied to any of the various units shown. The link-coupled arrangement usually is desirable, especially in a rack-mounted transmitter, because the link construction is non-critical and avoids the necessity for carrying leads at high r.f. potential from one deck to the next. Another reason for using the link is that it fits in well with the use of transmitting coil forms as well as manufactured transmitting coils, none of which are very well adapted, mechanically, to variable inductive coupling. Most manufactured coils can be obtained with built-in links; some with links whose coupling to the tank coil can be varied.

Helpful suggestions on the constructional work involved in building the units to be described will be found in Chapter 6, while the arrangement of the equipment in the station and the installation of suitable control systems are discussed in Chapter 17.

6L6 OR 6L6G OSCILLATOR TRANSMITTER

ONE of the simplest practical transmitters is the two-band crystal oscillator shown in the

FIG. 835 — THE GRID-PLATE OSCILLATOR TRANSMITTER

The chassis measures 7" x 7" x 2" and is elevated 1 inch by fastening pieces of sheet metal 7" x 3" at front and rear. The output terminals are mounted on the right side of the chassis and key and power-supply terminals along the rear edge. The 5-prong crystal socket, 4-prong coil socket and octal tube socket are sub-mounted. The tuning condenser need not be insulated from the chassis.

photographs of Figs. 835 and 837. It is capable of supplying a power output of 10 to 15 watts on either of two bands with a single crystal and coil when operated at a plate voltage of 400 to 425. The higher output power is obtainable at the lower frequencies when the tube is not called upon to double frequency. The circuit, shown in Fig. 836, is the grid-plate crystal oscillator circuit, discussed earlier (Fig. 818), with parallel plate feed.

Construction

Suggestions for cutting holes for the sockets and terminal strips will be found in Chapter 6. R.f. wiring should be as short and direct as possible from point to point. By-pass condensers are connected directly to the points to be by-passed and grounded at the nearest convenient mounting screw. Care should be taken that all screws so used make good contact with the chassis. Coils are wound on Hammarlund 1½" diameter forms. Turns should be spaced out to occupy the required length. A link coil of a few turns closely coupled to the ground end of *L* should be provided to permit coupling to an antenna tuner (Chapter 13) or a following amplifier with link input. The number of turns for the necessary degree of coupling must be determined by experiment.

World Radio History

Power Supply and Tuning

The plate power supply should deliver 400 to 425 volts at not less than 100 to 125 ma. (See power-supply chart, Chapter 14). A filament transformer delivering 6.3 volts at 1 amp. or more will also be required. With the power supply connected to the terminals as marked, a crystal with appropriate coil, tube and meter with a scale of 100 to 150 ma. connected, and key open, the transmitter is ready for tuning. Useful output may be obtained at the second harmonic as well as the fundamental frequency of the crystal by the selection of an appropriate coil. Thus, a 3.5-Mc. crystal will give output at both 3.5 Mc. and 7 Mc. The tank condenser capacity has been chosen so that two bands may be covered by each coil. If, for instance, the 3.5–7-Mc. coil is used with the 3.5-Mc. crystal, both 3.5 and 7 Mc. may be covered without changing either crystal or coil. Care should be used when doubling frequency to select a crystal whose second harmonic does not fall outside the bands assigned to amateurs.

Closing the key should cause a rise in plate current to 60 ma. or more. If a coil is selected which covers both the crystal fundamental and its harmonic, tuning the tank condenser near maximum or minimum should cause a pronounced dip in plate current indicating resonance at the fundamental and harmonic respectively. The tuning of the plate circuit should not be allowed to remain off resonance

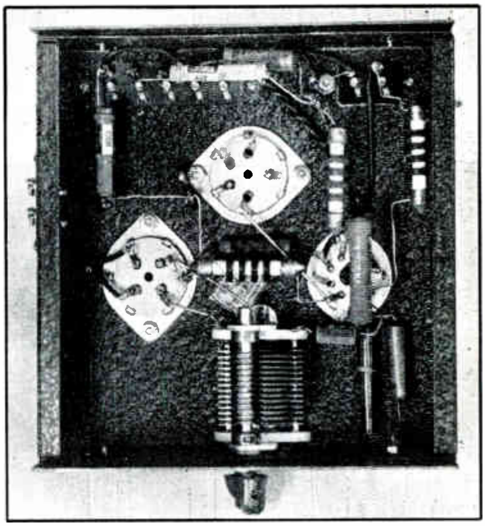


FIG. 837 — BOTTOM VIEW — CRYSTAL OSCILLATOR TRANSMITTER

The grid choke may be seen above the tuning condenser, the plate choke to the extreme right and the cathode circuit choke, with the 100-μμfd. mica condenser underneath it, to the left of the plate choke. The cathode resistor is at the top and grid leak in the upper left corner. The resistors of the screen voltage divider are in the lower right corner. Plate blocking condenser fastened to right rear of tuning condenser.

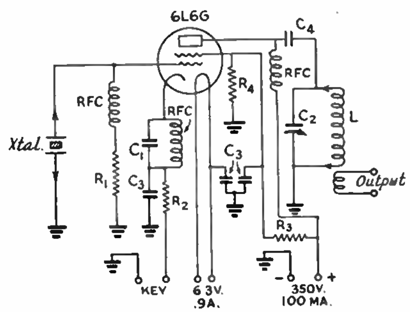


FIG. 836—CIRCUIT DIAGRAM OF 6L6 OSCILLATOR

R_1 — 0.1 meg., 1 watt, grid leak.
R_2 — 400 ohms, 2 watts, cathode biasing.
R_3 — 15,000 ohms, 10 watts, voltage divider.
R_4 — 50,000 ohms, 2 watts, voltage divider.
C_1 — 0.0001-μfd. mica, cathode-circuit-tuning.
C_2 — 0.0002-μfd. midget variable (Hammarlund MC-200-M) plate tuning.
C_3 — 0.01 μfd., 600-volt paper, by-pass.
C_4 — 0.002-μfd. mica, plate blocking.
RFC — National R100 r.f. choke.
L — 1.7 and 3.5 Mc. — 38 turns No. 22 d.s.c., 1½" diam., close wound.
3.5 and 7 Mc. — 20 turns No. 22 d.s.c., 1½" diam., 1⅛" long.
7 and 14 Mc. — 10 turns No. 18 d.c.c., 1½" diam., 1 3/16" long.

for any appreciable length of time, otherwise the tube will be damaged. If the coil dimensions given have not been followed carefully, it may be necessary to make slight alterations to bring the tuning range to the desired frequencies.

Coupling and tuning the antenna should cause a rise in plate current and probably some slight effect upon tuning of the oscillator so that readjustment of the tank tuning may be required to maintain resonance. The dip in plate current at resonance will be much less pronounced with the antenna coupled. It should be possible to load the oscillator up to 50 ma. or more plate current. The antenna should not be coupled so closely that all dip in plate current disappears. Slightly greater output may be obtained if a coil is selected which tunes to the desired frequency near minimum capacity.

Tubes

The 6L6 and 6L6G should give equal results. Smaller tubes such as the 6V6G, 6F6, etc., may be used at lower plate voltages without altering values. Correspondingly lower output power will be obtained, of course. If a metal tube is used, the shield (pin No. 1) should be connected to the chassis.

World Radio History

TWO-STAGE 6L6 TRANSMITTER OR EXCITER

THE addition of an amplifier-doubler to the 6L6 oscillator will permit greater output and the use of three bands with a single crystal. A transmitter in which the oscillator and amplifier are combined in a standard rack unit is shown in the photographs of Figs. 838 and 840. Since all sockets and the tuning condensers are sub-mounted (see Chapter 6 for suggestions on cutting holes in chassis), no wiring need appear above the chassis. Parts are so arranged that the r.f.-circuit components may be connected by short, direct, rigid pieces of wire. Push-back wire is used for the low-potential wiring. By-pass condensers are connected directly to the points to be by-passed and grounded at the nearest mounting screw which should make good contact with the chassis.

Referring to the circuit diagram of Fig. 839, it will be noticed that the screen and plate of the amplifier tube are connected together to form a triode, thus avoiding neutralizing difficulties sometimes encountered with the tetrode connection.

With the condensers specified, each tank coil may be tuned to two bands so that coils need not be changed frequently when changing bands of operation. Coils are wound on Hammarlund 1½" diameter forms and the dimensions given under the circuit diagram should be followed closely.

The plate-voltage supply should deliver 400 to 450 volts, 150 to 200 ma. (see power-supply chart, Chapter 14). A 6.3-volt filament transformer rated at 2 amp. or more and a source of 90 volts for biasing are also required. A pair of 45-volt batteries is recommended.

Tuning

Procedure to be used in tuning the oscillator is the same as that outlined previously for the oscillator transmitter. A meter with a scale of 150 to 200 ma. should be plugged into the oscillator jack and a dummy plug or ¼" diameter bakelite rod inserted temporarily in the amplifier jack removing the plate voltage from this stage. Since the oscillator is loaded by the grid circuit of the amplifier, the minimum plate-current at resonance, indicated by dip in plate current, will be 30 to 50 ma. When the oscillator has been tuned to resonance, the meter should be connected temporarily in series with the negative lead of the biasing battery with the positive terminal of the meter toward the negative terminal of the battery. When the key is closed, a grid-current reading of 15 to 20 ma. should be obtained. A coil which will tune to the same frequency as that of the oscillator output should be plugged into the amplifier plate circuit. Tuning the amplifier plate circuit should cause a dip in grid current. The neutralizing condenser is now carefully adjusted until all trace of dip in grid current, as the amplifier tank circuit is tuned through resonance, disappears and the stage is neutralized. The meter may now be removed from the grid circuit and plugged into the amplifier jack. When the key is again closed, the off-resonance amplifier plate current should be 150 ma. or more and 10 to 50 ma. tuned to resonance, the value depending upon whether or not the amplifier is doubling frequency.

A link winding of a few turns should be wound on each amplifier coil form in the space between the halves of the tank coil so that the output may be coupled to an antenna tuner

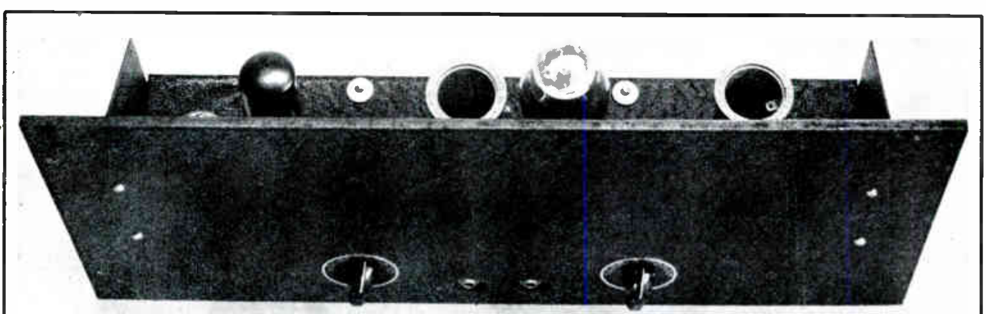


FIG. 838 — THE TWO-STAGE 6L6 TRANSMITTER

The steel chassis is 4" × 17" × 3" and the masonite panel 8¾" × 19" to fit standard rack. The five-prong sockets for the crystal and amplifier coil, the four-prong socket for the oscillator coil and the two octal tube sockets are all sub-mounted. The neutralizing-condenser shaft protrudes through the chassis behind the amplifier tube so that it may be adjusted with a screwdriver. The white insulators are the button-type insulators on which the tank condensers are mounted. Output terminals are at the right end of the chassis.

(see Chapter 13) or a following amplifier with link input. Antenna coupling should be adjusted to load the amplifier to draw a plate current of about 100 ma.

Since each coil may be tuned to two frequencies, care should be used in selecting the proper plate-current dip in each circuit for the desired frequency. The lower of the two frequencies covered naturally appears near the maximum capacity of the tuning condenser. Power output of 15 to 25 watts should be obtainable on all bands.

6L6-807 TRANSMITTER OR EXCITER UNIT

This unit is quite similar to the two-stage unit just described. The use of the 807 as the amplifier-doubler, however, eliminates the necessity for neutralizing and, when a plate voltage of 600 to 650 is used, appreciably greater power output may be obtained. Most of the constructional details are furnished by the photographs of Figs. 841 and 843 and their captions. (See Chapter 6 for suggestions on construction.) The circuit diagram and values are shown in Fig. 842.

The oscillator coils are wound on 1″ diameter forms mounted inside National PB10 shielded assemblies with 5-prong bases. One of the spare prongs is used to make connection between the shield can and chassis when the coil is plugged in. The crystal and 807 tube each require a 5-prong socket. The shield around the lower portion of the 807 tube is cut down from a large receiving-tube shield. It should come up level

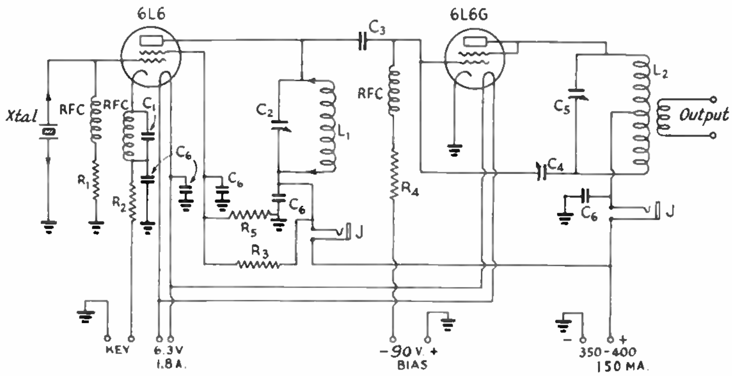


FIG. 839 — CIRCUIT DIAGRAM — TWO-STAGE 6L6 TRANSMITTER

R_1 — 0.1 meg., 1 watt, oscillator grid leak.
R_2 — 400 ohms, 2 watts, oscillator cathode resistor.
R_3 — 15,000 ohms, 10 watts, screen voltage divider.
R_4 — 10,000 ohms, 10 watts, amplifier grid leak.
R_5 — 50,000 ohms, 2 watts, screen voltage divider.
C_1 — 0.0001-μfd. mica, oscillator cathode circuit tuning.
C_2 — 200 μμfds. midget variable (Hammarlund MC-200-M).
C_3 — 0.0001 μfds. mica, coupling condenser.
C_4 — 12 μμfds. neutralizing condenser (National UM50) with alternate plates removed.
C_5 — 140 μμfds. midget variable (Hammarlund MC-140-M).
C_6 — 0.01 μfd., 600-volt paper, by-pass.
RFC — National R 100 r.f. choke.
J — Insulated closed circuit meter jack.
L_1 — 1.7–3.5 Mc. — 10 turns No. 22 d.s.c., 1½″ diam., 2″ long.
3.5–7 Mc. — 20 turns No. 18 d.c.c., 1½″ diam., 2″ long.
7–14 Mc. — 8 turns No. 18 d.c.c., 1½″ diam., 1¼″ long.
L_2 — 1.7–3.5 Mc. — 27 turns No. 22 d.s.c., close-wound each half, ½″ between halves, diameter 1½″.
3.5–7 Mc. — 13 turns No. 22 d.s.c., ⅞″ long each half, ½″ between halves, diameter 1½″.
7–14 Mc. — 7 turns No. 18 d.c.c., ⅞″ long each half, ½″ between halves, diameter 1½″.
14–28 Mc. — 2¾ turns ½″ long each half, ½″ between halves, diameter 1½″.

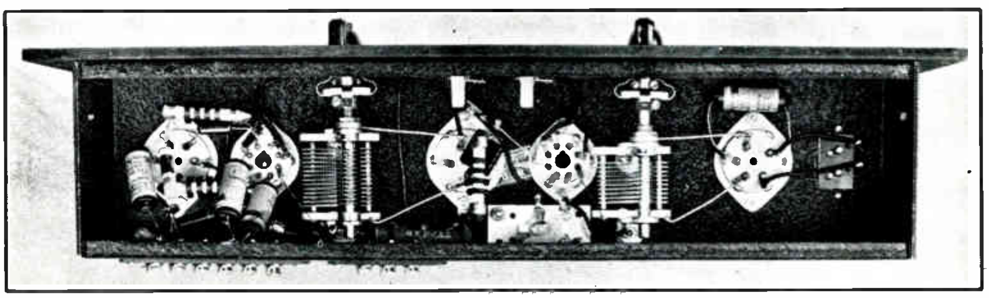


FIG. 840 — BOTTOM VIEW — TWO-STAGE 6L6 TRANSMITTER

The cathode-circuit r.f. choke is the one above the crystal and oscillator tube sockets. The neutralizing condenser is mounted on spacers between the two tank condensers. The insulated meter jacks are mounted on the front of the metal chassis and clearance holes are cut in the panel.

World Radio History

with the lower edge of the plate of the tube.

Coils wound on standard 1½″ diameter forms for the amplifier may be used at some sacrifice in efficiency, especially at the higher frequencies. If the substitution is desired, dimensions may be taken from the graphs of Fig. 828, basing the dimensions upon a capacity of 160 μμfds. for the lower of the two frequencies to be covered.

The plate-voltage power supply should provide 600 to 650 volts at 150 ma. or more (see power-supply chart, Chapter 14). The filament transformer should have a rating of 6.3 volts at 2 amperes or more. A source of 90 volts such as a pair of 45-volt batteries will be required for biasing the amplifier.

Tuning procedure will follow closely that recommended for the two-stage 6L6 transmitter previously described except that the amplifier is not neutralized. Each coil will cover two bands with the condensers specified.

Before applying plate voltage, both sliders on the main voltage-divider resistance should be set about two-thirds of the distance towards the positive high-voltage end. After the transmitter has been tuned up with a 25-watt lamp as a load for the amplifier, the sliders may be adjusted to provide 400 volts at the plate of the 6L6 and 300 volts at the screen of the 807. At these voltages, the oscillator off-resonance plate current should run 60 to 70 ma. dipping to 25 to 50 ma. at resonance. The plate current of the 807 should dip to 10 to 25 ma. with no load from an off-resonance value of 125 to 150 ma.

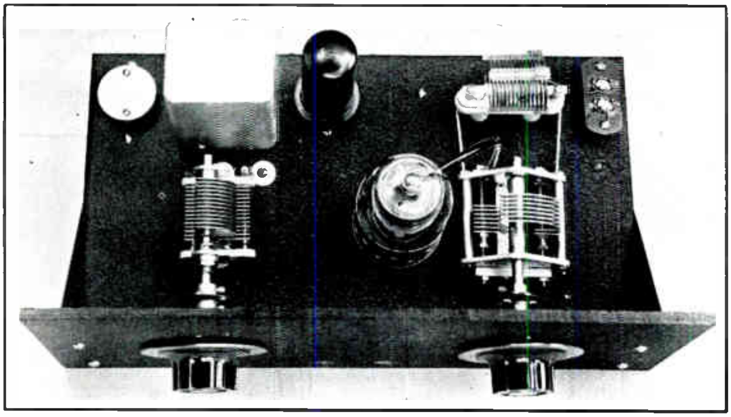


FIG. 811 — 6L6-807 TRANSMITTER OR EXCITER

The chassis measures 7″ × 13″ × 2″. A panel of standard rack dimensions may be substituted for the 7½″ × 14″ masonite panel shown. Insulated meter jacks are mounted on the front of the metal chassis and clearance holes cut in panel. Connection between oscillator tuning condenser stator and coil is made through a feed-through insulator. A short shield coming up level with lower edge of the plate is provided for the 807. Output terminals at right rear.

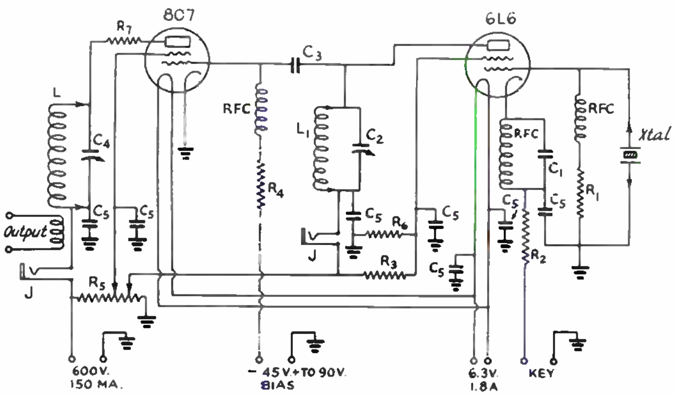


FIG. 812 — CIRCUIT DIAGRAM — 6L6-807

R_1 — 0.1 meg., 1 watt, oscillator grid leak.
R_2 — 400 ohms, 2 watts, oscillator cathode resistor.
R_3 — 15,000 ohms, 10 watts, oscillator screen voltage divider.
R_4 — 50,000 ohms, 2 watts, amplifier grid leak.
R_5 — 25,000 ohms, 100 watts — main voltage divider.
R_6 — 50,000 ohms, 2 watts, oscillator screen voltage divider.
R_7 — 25 ohms, 2 watts, parasitic suppressor. (See text.)
C_1 — 0.0001-μfd. mica, cathode circuit tuning.
C_2 — 200 μμfds. midget (Hammarlund MC-200-M), oscillator tuning.
C_3 — 0.0001-μfd. mica — coupling condenser.
C_4 — 150 μμfds. variable (National TMS-150) .026″ airgap, amplifier tuning.
C_5 — 0.01 μfd., 600-volt paper, by-pass.
RFC — National R 100.
J — Insulated closed circuit jack for meter.
L_1 — 1.7–3.5 Mc. — 45 turns No. 26 d.s.c., close-wound, 1″ diam.
3.5–7 Mc. — 24 turns No. 24 d.s.c., 1″ diam., 1⅛″ long.
7–14 Mc. — 11 turns No. 18 d.c.c., 1″ diam., 1″ long.
L_2 — National AR series — 3 turns removed on smallest coil.

Note: Substitute coils may be made by referring to charts of Figs. 828 and 829 basing dimensions on a capacity of 160 μμfds. for the lowest frequency covered by each coil.

Each amplifier coil is provided with a link winding to couple to an antenna tuner (see

World Radio History

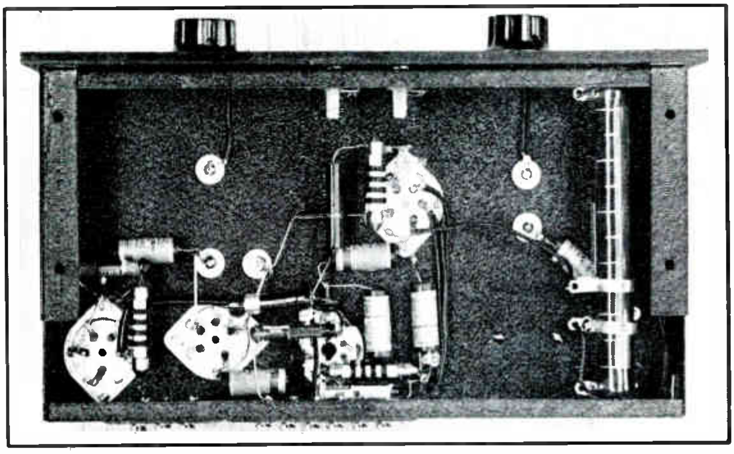


FIG. 843 — BOTTOM VIEW — 6L6-807 TRANSMITTER

Tuning condensers are mounted on button-type insulators with spacers on top to make condenser shafts come at same height. The grid choke and leak may be seen in the lower left corner and the oscillator screen voltage divider between coil and 6L6 sockets. The cathode circuit choke and condenser underneath it are below the 6L6 socket. The 807 grid leak and condenser are to the left of the 807 socket. The main voltage divider is at the extreme right end.

Chapter 13) or to a following amplifier with link input. The coupling to the antenna tuner should be adjusted to bring the amplifier plate current to 100 ma. at resonance. Power output under these conditions should run between 25 and 35 watts.

If the 807 stage has a tendency to self-oscillate when used as a straight amplifier with the load coupled, a 25-ohm resistor R_7 connected as shown in the diagram should eliminate it.

GENERAL UTILITY TRANSMITTER-EXCITER CAPABLE OF 75-WATT OUTPUT

The two-stage 6L6 transmitter previously described (Fig. 839) may be used to drive a medium-power final amplifier. The two are combined in the transmitter shown in the photographs of Figs. 844 and 846. Output may be obtained on three bands with a single 1.7-, 3.5- or 7-Mc. crystal. A variety of tubes may be used in the final amplifier. With the 809, RK11, RK12 or HY57, an output power of approximately 50 watts is obtainable as a c.w. transmitter or exciter, or approximately 35 watts as a plate-modulated amplifier. With higher voltages such tubes as the T40, TZ40 or HY40 will deliver 70 to 75 watts for c.w. or driver work and a carrier power of 45 watts for plate-modulated 'phone.

Construction

Most of the constructional details are obtainable from the photographs and captions. The reader is referred to Chapter 6 for suggestions on preparing the chassis for mounting apparatus. In mounting the panel, the lower edge is dropped one-half inch below the lower edge of the chassis to provide additional depth for the two variable condensers. The supporting side brackets are also dropped the same distance.

The link control is brought out to the panel by means of a ¼″ shaft coupled to the link shaft with a reducing coupling.

Coils for the oscillator and buffer-doubler are wound on one-inch diameter forms fastened inside National PB10 shielded units with 5-pin bases. Where the winding length specified permits, the number of turns specified should be spaced out to occupy the specified length. The tap on the buffer-doubler coil should be made as accurately as possible at the center so that it will not be necessary to reneutralize the buffer-doubler in changing bands. It may be necessary to shift the tap slightly to find the correct point. Dimensions given in the table should be followed as rigidly as possible. This applies particularly to the buffer-doubler coil L_2 since any appreciable deviation will make it impossible to tune to both of the bands for which the coil is designed. In the final amplifier, Barker and Williamson type BVL coils are used. The 3.5- and 7-Mc. coils must be pruned as indicated in Table I. The BVL-80 coil, used in conjunction with the padding condenser C_{10}, will do for the 1.75-Mc. band without alteration. Therefore, in purchasing the set, the 1.75-Mc. coil should be omitted, substituting a second BVL-80. Proper inductance values as well as optional dimensions are given in the table. The circuit diagram is shown in Fig. 845.

Parts are arranged so that the little r.f. wiring required may be made with short pieces of stiff wire. All power wiring, except that carrying high voltage for the final amplifier, is done with push-back wire. Wire with heavier insulation, such as ignition cable, is preferable for high-voltage wiring. The meter jacks may be wired before the panel is fastened to the chassis, leaving sufficient length to permit mounting

World Radio History

when the panel and chassis are assembled. Care should be taken to connect the jacks so that the meter will read in the proper direction when plugged into any of the four jacks. If the tip of the plug is connected to the positive side of the meter, the jack spring which makes contact with the plug tip should be connected to the positive high-voltage supply terminal in the case of the plate-circuit jacks and to the negative biasing terminal in the case of the grid-circuit jack.

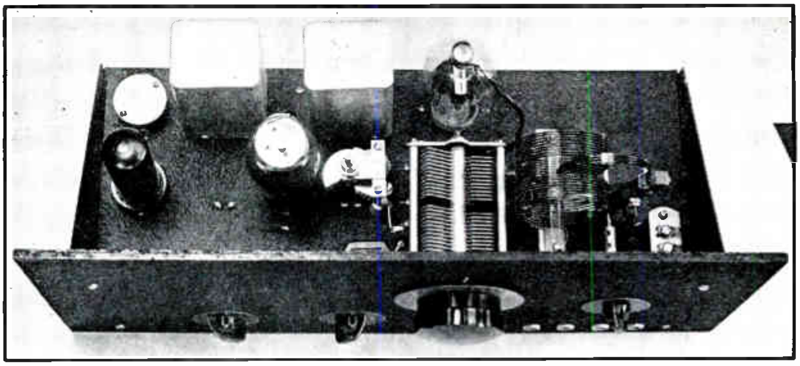


FIG. 844 — 75-WATT OUTPUT TRANSMITTER-EXCITER

The unit is designed to fit a standard rack. Chassis dimensions — 7″ × 17″ × 2½″; panel — 8¾″ × 19″ × ¼″ masonite. The tank condenser and final-amplifier neutralizing condenser to the left are mounted on short stand-off insulators. The mica blocking condenser is mounted on the chassis near the left front corner of the tank condenser. Control shaft of the 6L6 neutralizing condenser protrudes above the chassis through ½″ clearance hole between the two coil shields. Adjustment of the variable link output coupling may be made with control to right of final-amplifier dial.

Power-Supply Requirements

Power-supply requirements will depend upon the tube to be used in the final amplifier.

A single 6.3-volt filament transformer will suffice if the Type 809, RK11-12 or HY57 is selected. It should have a current rating of five amperes. If any of the other tubes mentioned above is selected, a separate 7.5-volt filament transformer will be required.

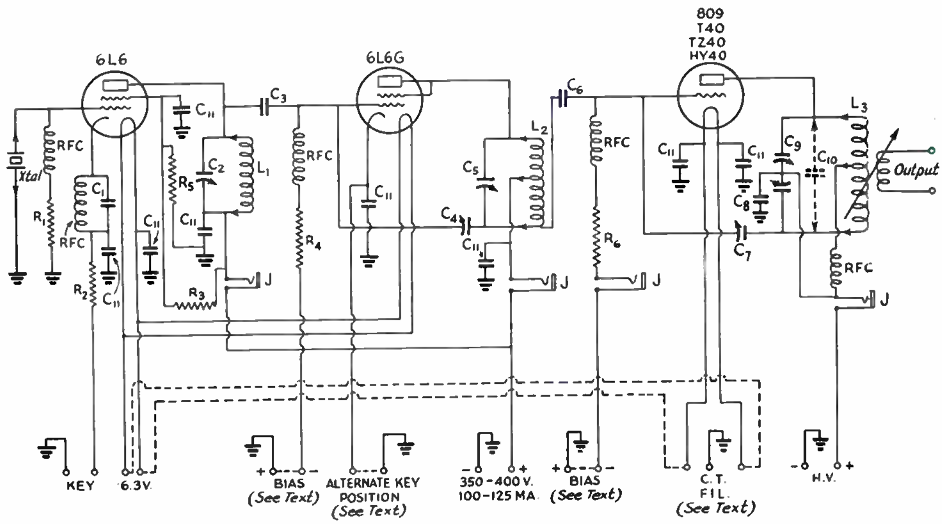


FIG. 845 — CIRCUIT DIAGRAM OF 75-WATT TRANSMITTER

C_1 — 100-μμfd. mica.
C_2 — 140-μμfd. midget (Cardwell ZU140AS) with mounting bracket.
C_3 — 100-μμfd. mica.
C_4 — 12-μμfd. (National UM-50) alternate plates removed.
C_5 — 140-μμfd. midget (Cardwell ZU140AS) with mounting bracket.
C_6 — 100-μμfd. mica.
C_7 — 25-μμfd. (National ST-25).
C_8 — 0.001-μfd. mica (Cornell-Dubilier 5000-volt d.c. working).
C_9 — 260 μμfd. per section (Cardwell MR260BD), spacing 0.03″.
C_{10} — 150-μμfd. fixed air padding condenser for 1.75-Mc. band (Cardwell EO150FS), 0.05″ spacing.
C_{11} — 0.01-μfd., 600-volt paper (non-inductive).
R_1 — 100,000 ohms, 1 watt.
R_2 — 400 ohms, 2 watts.
R_3 — 15,000 ohms, 10 watts.
R_4 — 50,000 ohms, 10 watts.
R_5 — 50,000 ohms, 2 watts.
R_6 — 1500 ohms, 2 watts for 809 RK12, TZ40, HY57; 5000 ohms, 10 watts for RK11 T40, HY40.
RFC — Radiofrequency choke — National R100.
J — Closed-circuit jack.
See Table I for coil dimensions.

World Radio History

A plate-voltage supply delivering 400 to 450 volts with a rating of about 150 ma. will be required for the oscillator and buffer-doubler. The 809, RK11-12 or HY57 will require a 750-volt supply rated at 150 ma. for c.w. operation or 600 volts at 125 ma. for 'phone operation. The larger tubes require 1000 volts at 150 ma. for c.w. work or 800 volts at 125 ma. for 'phone work. Rated plate currents for the smaller tubes are 100 ma. for telegraphy and 83 ma. for plate-modulated 'phone operation, and for the larger tubes, 115 ma. for telegraphy and 90 ma. for telephony. Some additional allowance must be made for bleeder current. The tank condenser specified was selected with the above ratings in mind. (See power-supply chart, Chapter 14, for details of suitable power supplies.) A source of 90 volts is required for biasing purposes. This may be obtained from a pair of 45-volt batteries or from a suitable bias power supply (see Chapter 14).

If a 6.3-volt tube is used in the final amplifier, the two sets of terminals may be connected in parallel as indicated by the dotted lines. The terminals for the alternate key position should be strapped together with a wire and the key connected in the oscillator circuit. The biasing voltage should be connected to the terminals indicated; a voltage of 90 is required for the 6L6G. If a pair of 45-volt batteries is used for this purpose, a tap may be taken off at 22.5 to 45 volts for the final amplifier. Care should be taken that the grid-leak resistance is proper for the tube used in the final amplifier as indicated under Fig. 845.

The oscillator and buffer-doubler stages are tuned up following the instructions for tuning the two-stage 6L6 transmitter. Proper crystal and coils should be selected which will permit operating the 6L6G as a straight amplifier, noting that each buffer-doubler coil covers two bands, and a milliammeter should be inserted in the grid biasing lead to the 6L6G until the 6L6G is neutralized as previously described (Fig. 839). During the process a dummy plug should be inserted in plate-circuit jack to remove plate voltage from the 6L6G.

With the key closed, the oscillator off-resonance plate current should be between 60 and 70 ma., dropping to somewhere between 25 and 40 ma. at resonance. When the 6L6G has been neutralized, the dummy plug may be removed and the meter transferred to the 6L6G plate-circuit jack. With the key closed, the off-resonance plate current should rise to 100 ma. or more. At resonance, it should fall to somewhere between 60 and 90 ma.

With the buffer-doubler tuned, the meter plug should be transferred to the third jack in the grid circuit of the final amplifier. When the key is again closed, the grid current should rise to 35 to 45 ma. Somewhat higher driving power will be obtained if a buffer-doubler coil which tunes to the desired frequency with a low value of capacity is chosen.

The next step is that of neutralizing the final amplifier and it is carried out in exactly the same manner as described for the buffer-doubler. When neutralized, the grid current should remain constant with tuning of the plate tank circuit. In preliminary tuning of the final amplifier with voltage applied, voltage should be reduced, if possible. A 200-watt lamp may be inserted in series with the primary of the high-voltage transformer or a 100-watt, 10,000-ohm resistor connected in series with the positive high-voltage lead to protect the tube against possible damage during preliminary tuning. With plate-voltage applied, the tank condenser should be rotated rapidly until the plate-current dip is found. Care should be taken that the correct dip in plate current is selected because some of

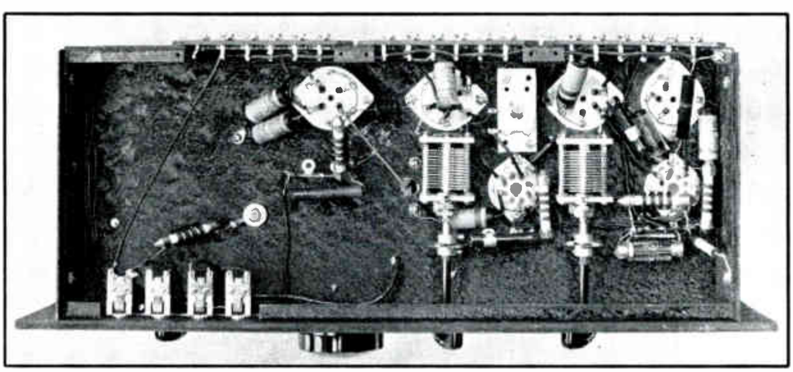


FIG. 846 — BOTTOM VIEW — 75-WATT TRANSMITTER

The oscillator and doubler tank condensers are insulated from the chassis by virtue of their isolantite end plates to which mounting brackets are fastened. The shafts are provided with insulating flexible couplings. Crystal and coil sockets are 5-prong type. The final-amplifier requires a 4-prong socket which is sunk about 1″ below the chassis so that the panel height may be limited. The chassis is cut out at the rear for the terminal strips and at the front so that the meter jacks (uninsulated) may be mounted directly upon the masonite panel. Insulated terminal strips used for supporting chokes and resistors may be seen at several points.

World Radio History

COIL TABLE I

Coil	*Turns*	*Wire*	*Diameter*	*Length*
No. 1	62	No. 26 d.s.c.	1″	1¼″
No. 2	42	No. 22 d.s.c.	1″	1¼″
No. 3	22	No. 22 d.s.c.	1″	1″
No. 4	10	No. 18 d.c.c.	1″	1″
No. 1D	58	No. 28 d.s.c.	1″	1″*
No. 2D	32	No. 22 d.s.c.	1″	1¼″*
No. 3D	14	No. 18 d.c.c.	1″	1″*
No. 4D	9	No. 14 bare	1″	1″*†

* Tapped at center.
† Self-supporting.

Coil No. 1A — B & W BVL-80, no alteration
Inductance — 30 microhenrys
Optional coil — 15 turns, 5″ diam., No. 14 double-spaced
Coil No. 2A — B & W BVL-80, remove 4 turns from each end
Inductance — 17 microhenrys
Optional coil — 21 turns No. 14, 2½″ diam., 3″ long
Coil No. 3A — B & W BVL-40, remove 3 turns from each end
Inductance — 8.5 microhenrys
Optional coil — 13 turns No. 14, 2½″ diam., 1⅞″ long
Coil No. 4A — B & W BVL-20, no alteration
Inductance — 3.1 microhenrys
Optional coil — 9 turns No. 14, 2½″ diam., 2½″ long
Coil No. 5A — B & W BVL-10, no alteration
Inductance — 1 microhenry
Optional coil — 4 turns No. 14, 2½″ diam., 1⅛″ long

COIL INDEX — TABLE II

Crystal Freq.	*Output Freq.*	L_1	L_2	L_3	C_5
1.75 Mc.	1.75 Mc.	No. 1	No. 1D	No. 1A	High
1.75 Mc.	3.5 Mc.	No. 2	No. 1D	No. 2A	Low
1.75 Mc.	3.5 Mc.	No. 2	No. 2D	No. 2A	High
1.75 Mc.	7 Mc.	No. 2	No. 2D	No. 3A	Low
1.75 Mc.	7 Mc.	No. 2	No. 3D	No. 3A	High
3.5 Mc.	3.5 Mc.	No. 2	No. 1D	No. 2A	Low
3.5 Mc.	3.5 Mc.	No. 2	No. 2D	No. 2A	High
3.5 Mc.	7 Mc.	No. 2	No. 2D	No. 3A	Low
3.5 Mc.	7 Mc.	No. 2	No. 3D	No. 3A	High
3.5 Mc.	7 Mc.	No. 3	No. 2D	No. 3A	Low
3.5 Mc.	7 Mc.	No. 3	No. 3D	No. 3A	High
3.5 Mc.	14 Mc.	No. 3	No. 3D	No. 4A	Low
3.5 Mc.	14 Mc.	No. 3	No. 4D	No. 4A	High
7 Mc.	7 Mc.	No. 3	No. 2D	No. 3A	Low
7 Mc.	7 Mc.	No. 3	No. 3D	No. 3A	High
7 Mc.	14 Mc.	No. 3	No. 3D	No. 4A	Low
7 Mc.	14 Mc.	No. 3	No. 4D	No. 4A	High
7 Mc.	14 Mc.	No. 4	No. 3D	No. 4A	Low
7 Mc.	14 Mc.	No. 4	No. 4D	No. 4A	High
7 Mc.	28 Mc.	No. 4	No. 4D	No. 5A	Low

the tank coils will tune to two bands. Approximately correct settings for the tank condenser with a 100-degree dial are: 1.75 Mc.—90, 3.5 Mc.—90, 7 Mc.—45, 14 Mc.—20, 28 Mc.—10. To maintain an optimum L-C ratio at 1.7 Mc., the 150-$\mu\mu$fd. air padding condenser C_{10} must be connected in parallel with the tank condenser as shown in Fig. 845. Full plate voltage may now be applied. The minimum plate current for any of the above mentioned tubes should be approximately 15 to 35 ma. depending upon the frequency. If desired, the power output may be checked roughly by coupling a 110-volt lamp to the final tank coil either by means of the link winding or by several turns of heavily insulated wire wrapped around the tank coil. The lamp should have a power rating approximately equal to the power output expected. Grid current to the final amplifier will decrease somewhat when plate voltage is applied and again when the load is coupled. It should not fall below 25 ma. for any of the tubes suggested.

The output link is provided for coupling by link line to a suitable antenna tuning unit (see Chapter 13) or to a following amplifier with link input. When the antenna has been tuned to resonance, coupling may be adjusted to load the amplifier to rated plate current by adjustment of the variable link. In a case where home-made coils are used without variable link, the number of turns to be used in the link winding to provide the correct loading must be determined experimentally.

Information on modulating the final amplifier for 'phone work will be found in Chapter 10.

A TWO-BEAM-TUBE TRANSMITTER

Figs. 847, 848 and 850 give various views of a two-tube exciter or transmitter which will cover three bands with one crystal. It is necessary to change only one coil when going from one band to the other. A 6L6 Tri-tet oscillator drives an RK47 or 814 beam tetrode as a straight amplifier on the two lower-frequency bands and as a doubler on the highest frequency. With rated input to the amplifier, the output is between 125 and 150 watts with straight amplification, and about 75 watts doubling.

Fig. 849 gives the circuit diagram. The 6L6 plate circuit is proportioned so that the crystal fundamental and second harmonic both can be covered with a single coil at L_2; C_2 is simply swung to give resonance at either.

Helpful suggestions on preparing the chassis will be found in Chapter 6.

Resistor R_5 is a grid leak used only when doubling in the final; it is shorted by switch S when the tube is a straight amplifier.

The amplifier tube is set in a socket suspended below the chassis. A shield can with the top cut off surrounds the lower part of the tube to provide additional shielding. The switch shaft of the multiple crystal holder is connected to a panel control by means of a flexible-cable coupling so that any of the crystals can be selected from the front. The holder fits a standard five-prong socket and can be pulled out in an instant should it be necessary to use an extra crystal provided with the customary mounting. The 6L6 plate coil is air-wound, cemented on celluloid strips and mounted inside a shielded plug-in coil box. The shield is grounded through one of the five pins on the coil base.

Two power-supply units will be required,

World Radio History

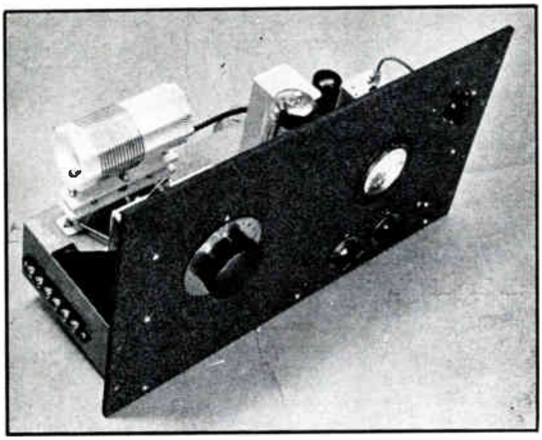


FIG. 847 — THE TWO-BEAM-TUBE TRANSMITTER OR EXCITER FOR 6L6-RK47 OR 814 TUBES

Output power of 150 watts is obtainable at 3.5 and 7 Mc., 100 to 125 watts at 14 Mc. and 75 watts at 28 Mc. The masonite panel is of standard rack dimensions: 10½" x 19" x ¼" and the chassis 7" x 17" x 3". Crystal switch in upper right corner, grid-leak switch below.

one delivering 400 v., 75 to 150 ma. and the other 1250 volts, 150 ma. Reference should be made to the power-supply chart of Chapter 14 for details. A filament transformer delivering 10 v. at 4.15 amps or more is also required.

Since either type tube has sufficient screening, no neutralizing is necessary. Aside from this, the tuning process is the same as described for previous transmitters.

For minimum crystal current it is essential that the dimensions of L_1 be duplicated and that C_1 be set as near minimum capacity as is consistent with the excitation required. Crystals of ordinary activity will work well with C_1 set right at minimum, and this control in nearly all cases may be left alone. The setting for crystal-fundamental output will be found near maximum capacity on C_2, and for second-harmonic output near minimum capacity. The 6L6 plate current at resonance will be about 60 milliamperes in either case, using 400 v. In tuning the final amplifier, it is always advisable to lower plate-voltage until plate-circuit resonance, indicated by plate-current dip, is found. Lacking other means, a 200-watt or larger lamp may be connected in series with the primary winding of the plate transformer.

In the amplifier stage, with R_5 shorted out, the unloaded minimum plate current should be between 15 and 25 ma., depending upon the frequency and L-C ratio. Doubling to 28 Mc., with R_5 in the circuit, the minimum plate current should be about 60 ma.; the tank can be loaded until the tube takes 120 ma. without color showing on the plate. At 150 ma. the plate gets pink, but the output is higher. On bands where the final stage is a straight amplifier there is no color on the plate at the rated plate current of 150 ma. Optimum grid current is 10 milliamperes.

The fixed bias, approximately 70 volts, may be secured from batteries or from a power pack (see Chapter 14). This value is for Class-C operation, and is greater than cutoff so that no plate current flows when excitation is absent.

No output-coupling arrangement is indicated in the diagram, this being left to the preferences of the constructor. There is ample room on the forms for a link. (See Chapter 13 for information on a suitable antenna coupler.)

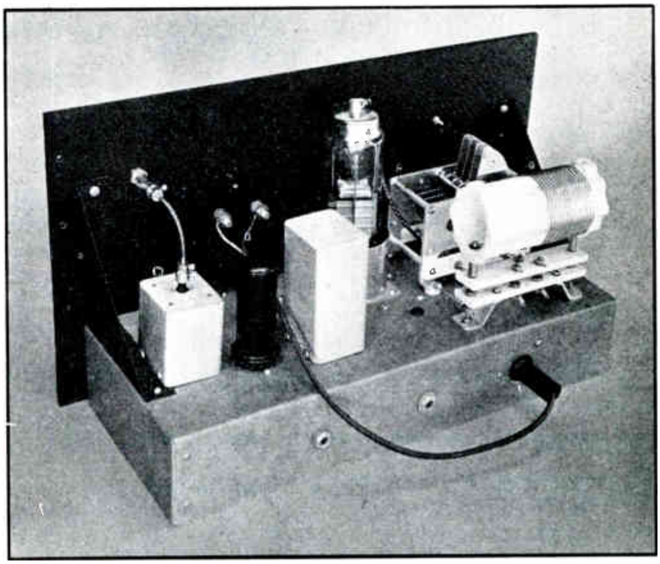


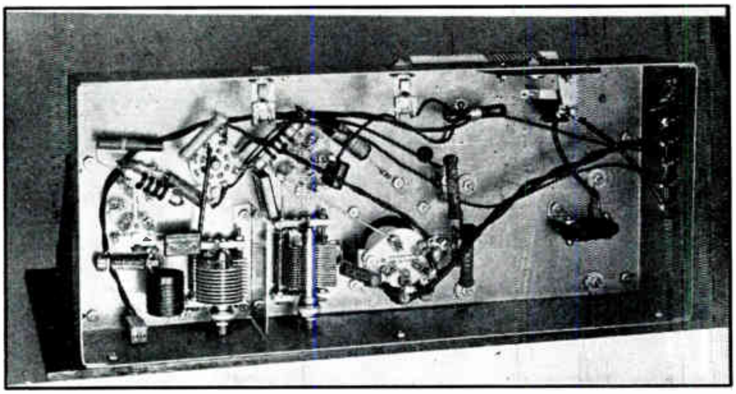
FIG. 848 — REAR VIEW — TWO-BEAM-TUBE TRANSMITTER-EXCITER

The plug-in multiple crystal holder with internal switch seen at the left (National) holds four crystals and plugs into a standard 5-prong socket. Oscillator plate coil is in shielded plug-in unit to right of 6L6. Meter jacks for the oscillator plate circuit, final-amplifier grid and plate circuits are mounted on the rear edge of the chassis; the two at low-voltage are of the insulated type and the high-voltage one provides greater insulation by a piece of bakelite mounted so that the jack projects through a hole of ample size in the chassis. Heavily insulated cord should be used to connect the meter to the plug.

World Radio History

FIG. 850 — BOTTOM VIEW

The cathode-circuit coil may be seen to the left of its tuning condenser. C_3 is insulated from the chassis by four button-type insulators and the shaft provided with an insulating flexible shaft coupling. The 5-prong amplifier-tube socket is lowered an inch or so below the chassis on brackets. A small baffle shield is placed between the two small variable condensers.



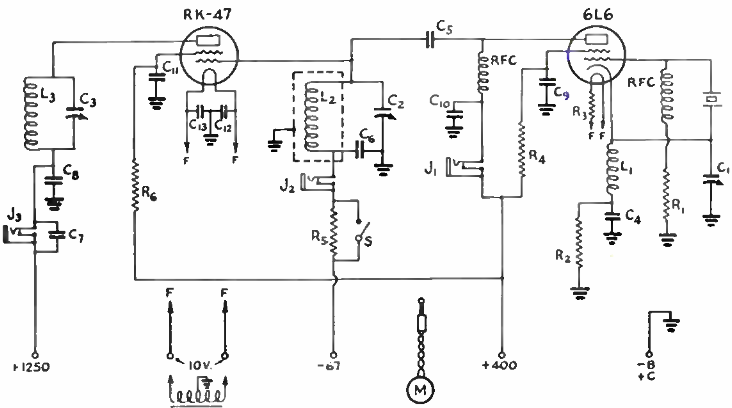


FIG. 849 — CIRCUIT DIAGRAM OF THE TWO-BEAM-TUBE TRANSMITTER

C_1 — 100-μμfd. variable (National ST-100).
C_2 — 250-μμfd. variable (National STH-250).
C_3 — 50-μμfd. transmitting type, airgap 0.171″ (National TMA 50A).
C_4 — 0.005-μfd. mica, receiving type (Dubilier).
C_5 — 500-μμfd. mica, 1000-volt (Aerovox Type 4).
C_6, C_7 — 0.002-μfd. mica, receiving type (Aerovox).
C_8 — 0.002-μfd. mica, 5000-volt (Sangamo).
C_9–C_{13}, inc. — 0.01 paper, 600-volt (Aerovox and Sprague).
R_1 — 100,000 ohms, 2-watt (IRC).
R_2 — 400 ohms, 2-watt (IRC).
R_3 — 5-ohm adjustable wire-wound (Electrad).
R_4 — 25,000 ohms, 10-watt (IRC Type AB).
R_5 — 15,000 ohms, 10-watt (Ohmite).
R_6 — 4000 ohms, 10-watt (IRC Type AB).
J_1, J_2, J_3 — Closed-circuit jacks (Yaxley).
RFC — Receiving-type chokes (National R-100).
M — 0-200 d.c. milliammeter (Weston 301).
L_1 — For 7-Mc. crystal, 8 turns No. 22 on 1-inch form, spaced to make length 1 inch. For 3.5-Mc. crystal, 15 turns same diameter and length.
L_2 — 7 to 14 Mc.: 17 turns No. 14, outside diameter 1 inch, spaced to make length 2 inches. 3.5 to 7 Mc.: 35 turns No. 16 d.c.c. on 1-inch form. (Mounted in National Type PB-10 5-prong coil base and shield.)
L_3 — 3.5 Mc.: 36 turns No. 14, diameter 2½ inches, length 3¾ inches. 7 Mc.: 14 turns No. 14, diameter 2½ inches, length 2 inches. 14 Mc.: 6 turns No. 14, diameter 2½ inches, length ⅞ inch. 28 Mc.: 3 turns No. 14, diameter 2½ inches, length 2⅝ inches.

All except 3.5-Mc. coil wound on National XR-10A forms with PB-15 plug bases to fit XB-15 jack base. The 7- and 14-Mc. coils are wound in consecutive grooves; the 28-Mc. coil in every sixth groove.

R_3 should be adjusted to drop the 6L6 filament voltage to 6.3 volts from the 10-volt source.

The 6L6 shell and RK-47 beam-forming plates are connected directly to ground. The 6L6G is not recommended for this circuit, as the crystal current runs considerably higher than with the 6L6.

Filament supply required: 10 volts at 4.15 amp. The 400-volt plate supply should deliver 100 ma., the 1250-volt supply 150 ma. **(See Chapter 14.)**

A SINGLE-TUBE 200-WATT AMPLIFIER

The single-tube amplifier shown in the photograph of Fig. 851 was designed for the popular medium-power class tubes such as the 808, RK35-37-51-52, T55, 35T and HK54-154 types operating at 1500 volts and up to 150 ma. It is provided with fixed-link input for coupling to a driver and variable-link output for coupling to a following amplifier with link input or to an antenna through a suitable antenna coupler (see Chapter 13). The tank condenser specified is sufficient to provide nearly optimum capacity at all frequencies down to 3.5 Mc. when the ratio of plate volts to plate-current milliamperes is not less than 10 to 1. At 1.7 Mc. an air padding condenser should be connected as shown in the circuit diagram of Fig. 852. The blocking condenser C_5 is essential to prevent break-down of the tank condenser, otherwise a much larger tank condenser would

World Radio History

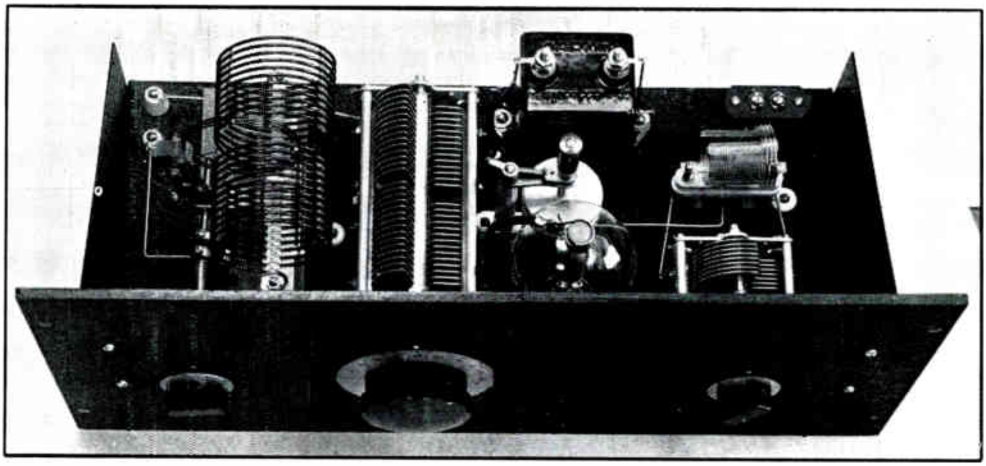


FIG. 851 — 200-WATT INPUT AMPLIFIER

This single-tube amplifier was designed for tubes operating at a plate voltage of 1250 to 1500 volts such as RK-35-37-51-52, 808, T55, 35T and HK54-154. Components are assembled on a 8″ × 17″ × 2″ chassis with a 8¾″ × 19″ masonite panel. The tank condensers are mounted on short stand-off insulators. Each shaft is provided with an insulating flexible coupling. The plate blocking condenser is essential.

be required. Short-circuiting turns to reduce coil inductance is suggested to avoid spoiling the coil for other purposes where the full inductance may be required.

The type 808 shown in the photograph as well as the RK35-37 and the HK54-154 have the grid terminal at the side of the tube so that the socket may be sub-mounted on the chassis. The other types mentioned above have the grid terminal at the base so that the socket should be mounted above the base when using these latter types.

The r.f. chokes and by-pass condensers are mounted beneath the chassis where plenty of room will be found. Both tuning condensers must be insulated from the chassis. While a shaft coupling with bakelite insulation is satisfactory for the grid-condenser control, it is important to provide one with insulation for high voltages for the plate-condenser shaft. A control for varying the output-link coupling is brought out to the front of the panel. Since the shaft provided with the Barker and Williamson unit has a 3/16″ diameter shaft, a reducing coupling will be required to couple it to a ¼″ shaft. The high-voltage line is brought up through the chassis through a button-type insulator. Terminals are provided at the left for the output, at the right for exciter input and at the rear for power-supply connections. Chapter 6 contains suggestions for cutting and drilling the chassis.

Power-Supply Requirements

The plate-voltage supply should deliver 1500 volts at 150 ma. or more. (See power-supply chart in Chapter 14.) Filament-supply requirements vary with the type of tube selected. The 808 requires 7.5 volts, 4 amperes. Provision must also be made for biasing the grid; this requirement also depends upon the tube chosen. For c.w. operation with the 808, it is most simply provided by a 45-volt battery and 5000-ohm, 10-watt grid-leak resistance in series across the biasing terminals, although a suitable power supply may be used as described in Chapter 14. With other types, sufficient fixed bias should be provided to cut off plate current without excitation (roughly the plate voltage divided by the amplification factor of the tube which is given in the tube tables, Chapter 5) and supplying the remainder of the biasing voltage specified in the tube tables by a grid leak whose resistance when multiplied by the grid current in amperes will give the required additional voltage.

Driving power also varies with the type of tube. It should be easily possible to drive any of the tubes for which the amplifier is designed by the 6L6-808 exciter of Fig. 842 or the band-switching exciter of Fig. 866. The exciter should be capable of delivering not less than 20 to 25 watts at all frequencies.

Proper tuning of an amplifier has been discussed in detail in the design section of this chapter. Briefly, taking the 808 as an example, the first step after connecting the exciter and power supply, is that of neutralizing. With plate voltage off and excitation applied, a milliammeter in series with the grid-bias circuit should read at least 35 ma. when the grid circuit of the amplifier and the plate circuit of the exciter are tuned to resonance and the coupling properly adjusted. Referring to the

World Radio History

diagram of Fig. 852, it will be noted that the grid is shown connected at an intermediate point on the grid-tank coil. This connection was found necessary to provide a proper impedance match between the grid and the output circuit of the 6L6-807 exciter. Connection of the grid at the top of the tank circuit would not permit loading of the 807 driver. The tap was placed at the 15th, 9th, 6th and 5th turn from the ground end in order from the largest to the smallest grid coil.

With the grid circuit adjusted for maximum grid current consistent with rated driver plate current, tuning the plate circuit will cause a dip in grid current at resonance. The neutralizing condenser should then be adjusted until all signs of the grid-current dip have disappeared and the stage is neutralized. Plate voltage, reduced by inserting a 200-watt or larger bulb in series with the primary winding of the plate transformer, may now be applied and the plate circuit tuned to resonance

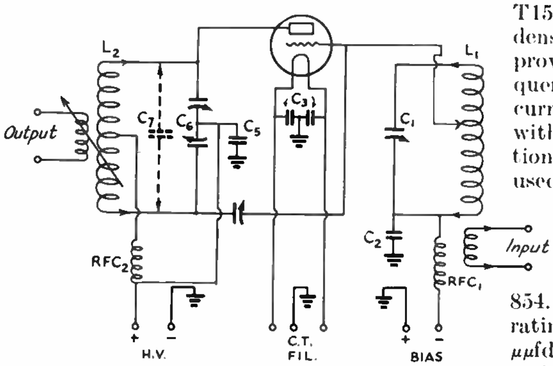


FIG. 852 — CIRCUIT DIAGRAM OF 200-WATT AMPLIFIER

C_1 — 150 μμfds., .03″ airgap (Cardwell MR150BS).
C_2 — 0.001-μfd. mica, by-pass.
C_3 — 0.01 μfd., 600-volt paper, by-pass.
Neutralizing condenser (National NC800).
C_5 — 0.002 μfd., 7000 volts, blocking. (Cornell-Dubilier 22C86).
C_6 — 180 μμfds. per section, .05″ airgap (Cardwell MO180BD).
C_7 — 80 μμfds. air padder for 1.75 Mc. (Cardwell JD80-OS) .1″ airgap.
RFC_1 — R.F. Choke (National R100).
RFC_2 — R.F. Choke (National R154U).
L_1 — National AR series. (See text for explanation of tap.)

Note: Substitute coils may be made by referring to the charts of Figs. 828 and 829, using 160 μμfds. for lowest frequency to be covered by each coil.

L_2 — 1.7 Mc. — B & W TVL-160 with turns short-circuited at each end so circuit resonates with C_7 and C_6 at maximum capacity. (See text regarding padding condenser.)
3.5 Mc. — B & W TVL-80 with 7 turns short-circuited at each end.
7, 14 and 28 Mc. — B & W TVL-40, TVL-20 and TVL-10.

Note: Substitute coils may be made by referring to the chart of Fig. 829 and basing dimensions upon capacity values of 180, 90, 45, 25 and 25 μμfds., respectively, for 1.7, 3.5, 14 and 28 Mc.

indicated by dip in plate current. It is always advisable to reduce amplifier plate voltage in tuning up not only to prevent damage to the tube but also to prevent tank-condenser break-down if the amplifier does not happen to be loaded.

The antenna may now be coupled through an antenna coupler (See Chapter 13) and the coupling adjusted to bring the plate current up to the rated value (125 ma. for the 808). With the load applied, the grid current should not drop below 25 ma.

Information on grid and plate modulation of this amplifier will be found in Chapter 10.

A SINGLE-TUBE HIGH-POWER AMPLIFIER

The single-tube high-power amplifier shown in the photographs of Figs. 853 and 855 was designed for tubes such as the types RK63-36-38, 806, HK354-254, 250TH-TL, 100TH-TL, T155-200 and HF200-300. A plate tank condenser was chosen with a capacity sufficient to provide optimum capacity at the lower frequencies when the ratio of plate volts to plate-current milliamperes is 12 to 1 or higher and with a plate-spacing sufficient for c.w. operation up to 750 watts input at 3000 volts when used in conjunction with the blocking condenser specified. For 1.7-Mc. operation, an air capacity of 75 μμfds. should be added in parallel with the tank condenser as shown in the circuit diagram of Fig. 854. This condenser should have a peak-voltage rating of not less than 7000. 50-μμfd. and 25-μμfd. Eimac vacuum units in parallel should be satisfactory. As mentioned previously, short-circuiting turns to reduce coil inductance is suggested to avoid spoiling the coils for other purposes where the full inductance may be required. If turns are removed, the number must be determined experimentally. The condenser should be set at approximately the capacities mentioned under the coil table.

The input circuit is arranged for fixed-link coupling to the driver and the output tank coil is fitted with a varible link winding for coupling to a low-impedance transmission line to antenna or a suitable antenna coupler (see Chapter 13).

A control for the variable link is brought out to the panel by means of a ¼″ extension shaft coupled to the $\frac{3}{16}$″ shaft provided for the link by means of a reducing coupling.

Power Supply and Excitation

Power-supply requirements will depend upon the tube selected and the desires of the builder. The tube tables of Chapter 5 should be consulted for maximum ratings. In this instance, the RK63 was selected and the decision

World Radio History

made to operate it at 3000 volts, 250 ma. for c.w. operation. The plate-voltage supply therefore is required to deliver this power. (See power-supply chart, Chapter 14.) The filament transformer is required to deliver 5 volts at 10 amperes. A source of biasing voltage is also required. It is common practice to provide sufficient fixed bias to cut off plate current and to obtain the remaining voltage required for recommended operating bias from a grid leak of suitable resistance. Following this practice, a fixed bias of 90 volts and a grid-leak resistance of 2500 ohms, 25 watts will be required. (If other tubes are used or other operating conditions imposed, see comment in regard to biasing in reference to Fig. 852.) Since grid-current flow will be rather heavy, batteries of the heavy-duty type should be selected if this form of fixed bias is to be used. It is preferable to use a biasing power pack such as one of those described in Chapter 14. The resistance introduced in the grid circuit by the voltage-divider or bleeder resistance of an unregulated supply should be 4000 ohms.

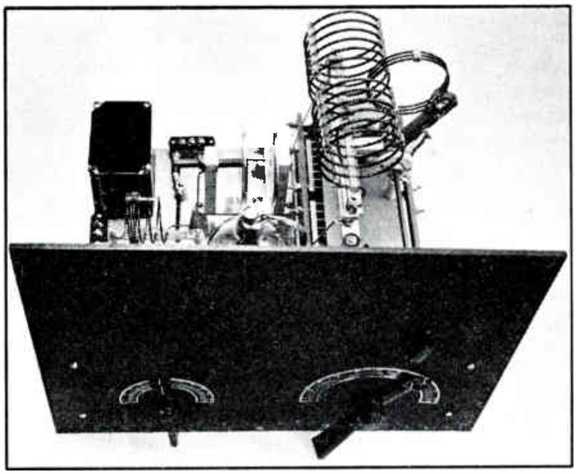


FIG. 853 — THE HIGH-POWER SINGLE-TUBE AMPLIFIER

The apparatus is mounted on a 15″ × 17″ × ½″ maple board half of which is covered with a sheet of thin metal. The masonite panel dimensions are 15¾″ × 19″ × ¼″. The grid tank condenser is mounted on 1¼″ stand-offs, bringing the terminals up near the grid terminal of the tube. The plate tank is mounted upside-down on metal brackets cut from standard chassis brackets. These brackets must be mounted upon the unshielded portion of the baseboard to provide insulation from ground. The B & W coil mounting is fastened to the bottom of the tank condenser.

Excitation requirements will also vary with the type of tube used and the operating conditions. An exciter delivering 70 watts on all bands should be satisfactory for driving the amplifier with any of the previously mentioned tubes under the maximum operating conditions set forth. The 75-watt-output exciter of Fig. 845 with the TZ40 operating at 1000 volts should be entirely adequate for efficient c.w. operation.

Tuning

With power supplies connected and the appropriate coils in the amplifier but with plate voltage off, excitation should be applied and the exciter output circuit and amplifier grid circuit tuned for maximum grid current which should run not less than 70 ma. under the circumstances described. The coupling between exciter and amplifier should be adjusted so that the exciter tube is loaded to normal plate current. It is possible that the grid link may require adjustment to obtain proper loading of the exciter.

The plate tank circuit should next be tuned to resonance as indicated by a dip in grid current. The neutralizing condenser should now be adjusted with an insulated screwdriver, or insulated rod sharpened to an edge, until all indication of dip in grid current disappears. The amplifier is now neutralized and ready for application of plate voltage. Voltage should be reduced for preliminary tuning; as a matter of fact this is always good practice in tuning an amplifier above the very low-power class since it not only prolongs tube life but also prevents possible tank-condenser break-down when the amplifier is unloaded. Resonance in the plate circuit is indicated by a dip in plate current. Coupling and tuning the antenna will cause an increase in plate current. The variable link should be adjusted to load the amplifier to the desired plate current with the antenna and tank circuits tuned to resonance. When plate voltage and load are applied, the grid current will fall off to a certain degree. It should not fall below 50 ma. under the conditions described. Plate and grid modulation of this amplifier are discussed in Chapter 10.

PUSH-PULL AMPLIFIERS

For ease of handling, the push-pull amplifier is to be preferred to a single tube, especially at 7 Mc. and higher frequencies. It may be taken as a general rule that, in transmitters for high frequencies, it is more desirable to use, for example, two tubes of 100 watts output rating rather than one tube rated at 200 watts output. Not only is the circuit more satisfactory to operate, particularly from the neutralizing standpoint, but the fact that even harmonics are practically cancelled in the push-pull amplifier reduces the possibility of harmonic radiation.

World Radio History

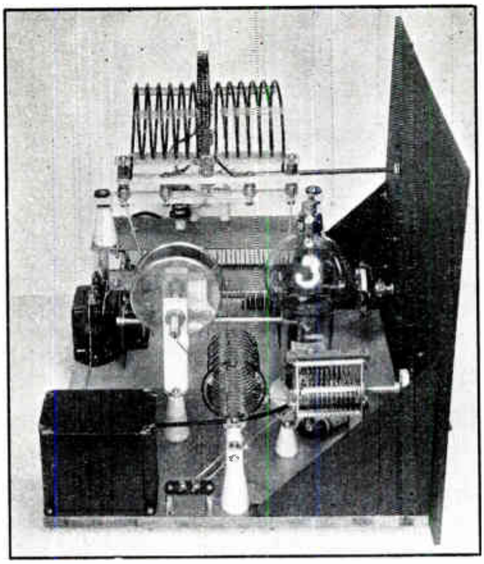


FIG. 855 — SIDE VIEW — SINGLE-TUBE HIGH-POWER AMPLIFIER

The blocking condenser in back of the plate tank condenser is essential. The filament transformer is included in the assembly to eliminate voltage drop in the leads. It is important that each tank-condenser shaft be equipped with a suitably insulated coupling. The tube shown in use is the RK63.

A MEDIUM-POWER PUSH-PULL AMPLIFIER

THE push-pull amplifier shown in the photograph of Fig. 856 is designed primarily for c.w. operation with such tubes as the 35T, RK35-37-51-52, 808, T40-55 and HK54-154 at 1250 volts. With slight alterations, it may be adapted for plate-modulated 'phone operation (see Chapter 10) or c.w. operation at higher plate voltages.

Most of the details of construction may be obtained from an inspection of the photograph.

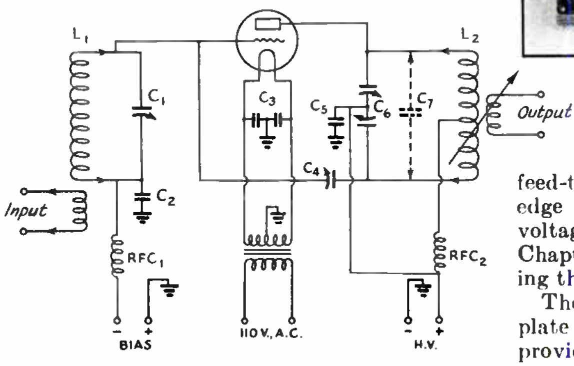


FIG. 854 — CIRCUIT DIAGRAM OF THE HIGH-POWER SINGLE-TUBE AMPLIFIER

C_1 — 100 μμfds., .07″ spacing (Cardwell MT100GS).
C_2 — 0.001-μfd. mica, 600-volt, grid by-pass.
C_3 — 0.01 μfd., 600-volt paper, filament by-pass.
C_4 — Neutralizing condenser (Hammarlund N-20).
C_5 — 0.002 μfd., 12,500-volt (Cornell-Dubilier 22A86).
C_6 — 150 μμfds. per section, 0.17″ airgap (Cardwell TJ150UD).
C_7 — 75 μμfds. Eimac. (See text.)
RFC_1 — R.F. Choke (National R100).
RFC_2 — R.F. Choke (National R154U).
L_1 — Barker & Williamson BXL series with following alterations: 1.7 Mc. — Trim coil to tune to resonance at condenser maximum; 3.5 Mc. — short-circuit 9 turns; 14 Mc. — short-circuit 1 turn if circuit will not tune to resonance; 28 Mc. — short-circuit 1 turn.

Note: Substitute coils may be made by referring to the graphs of Figs. 828 and 829 basing dimensions upon capacities of 100, 75, 50, 45 and 35 μμfds., respectively, for 1.7, 3.5, 7, 14 and 28 Mc.

L_2 — Barker & Williamson HDVL series with following alterations: 1.7 Mc. — Trim coil to tune to resonance at maximum of C_6 with C_7 in parallel; 3.5 Mc. — short-circuit 2 turns each end; 7 Mc. — short-circuit one turn each end; 14 Mc. — short-circuit one turn each end if circuit will not tune to resonance.

Note: Substitute coils may be made by referring to the graphs of Figs. 828 and 829, basing dimensions upon capacities of 170, 85, 40, 25 and 25 μμfds., respectively, for 1.7, 3.5, 7, 14 and 28 Mc.

The plate-circuit r.f. choke, grid leak, by-pass condensers and power wiring are underneath the chassis. A ceramic feed-through insulator mounted on the rear edge of the chassis is provided for the high-voltage terminal. Reference should be made to Chapter 6 for suggestions on cutting and drilling the chassis.

The circuit diagram is shown in Fig. 857. The plate tank condenser has sufficient capacity to provide nearly optimum *L-C* ratios at frequencies down to 3.5 Mc. when the ratio of plate volts to plate current milliamperes is not less than 5 to 1. Plate spacing is sufficient for 300 watts input at a maximum of 1250 volts. If it is desired to operate at higher plate voltages, the blocking condenser specified for Fig. 852 should be connected as shown in that diagram. It may be mounted beneath the chassis. When such a connection is used, the tank condenser must be insulated from the chassis and it is of extreme importance to provide the shaft of the condenser with a suitably insulated shaft coupling to remove high voltage from the control.

The coils L_3 and L_4 are ultra-high-frequency chokes used to prevent parasitic oscillations, which are very apt to occur in push-pull amplifiers, especially those using tubes which drive easily as amplifiers. They do not detract from the efficiency at the normal working frequency.

The coupling link for the grid tank coil consists of three or four turns of cotton-covered wire wound to about one inch diameter. This coil is placed inside the coil form at the center of the grid winding, and the leads come

World Radio History

through holes in the form to the plug base. The coupling between link and grid coil can easily be varied by bending the link with respect to the tank coil. The link on the plate tank coil, L_2 consists of a turn or two of high-voltage wire wound over the center of the plate coil.

Power Supply and Excitation

Power supply requirements will depend upon the type of tube used and the voltage at which it is desired to operate the amplifier. As mentioned previously, the plate voltage should be limited to 1250 volts if no blocking condenser is used. At this plate voltage, the plate current should be limited to about 250 ma. for the *L-C* ratio to remain near optimum value. With the blocking condenser in use, the input may be increased to 1500 volts at 300 ma., the maximum ratings for most of the tubes for which the amplifier is suitable. Suitable power supplies are described in the power-supply chart in Chapter 14.

Filament requirements may be obtained from the tables of Chapter 5. The 35T's shown in the photograph require a transformer delivering 5 volts at 8 amperes.

Fixed bias sufficient for plate-current cut-off with the 35T's at 1500 volts may be obtained from a pair of heavy-duty 45-volt batteries and a grid leak of 1000 ohms will supply the additional bias required for operation, or bias may be obtained from a bias supply such as described in Chapter 14. The resistance introduced in the grid circuit by the bias-supply voltage-divider or bleeder resistance should be 2500 ohms. Bias-supply requirements for other tubes may be obtained by following the suggestions given in connection with Fig. 852 and, previously, in the design section of this chapter.

For operation under the conditions described, the exciters of Figs. 842 and 866 or that of Fig. 845 with a type 809 or similar tube in output stage will furnish adequate excitation.

Tuning

Neutralizing and tuning of a push-pull amplifier is essentially the same as that of a single-tube stage. With power supplies connected, plate voltage off and excitation applied, the exciter output and amplifier grid circuits should be tuned and the coupling adjusted for maximum grid current consistent with rated exciter plate current. Grid current under the conditions described should run about 60 ma. Inability to load properly the exciter stage may mean that an adjustment of link windings is necessary.

When proper excitation has been obtained, the neutralizing condensers should be adjusted to eliminate all trace of dip in grid current when the plate tank circuit is tuned through resonance with plate voltage off, always keeping the neutralizing condensers at equal plate spacing.

With the amplifier neutralized, plate voltage, reduced by the method recommended for amplifiers which have already been described, may be applied and the plate circuit tuned to resonance as indicated by the dip in plate cur-

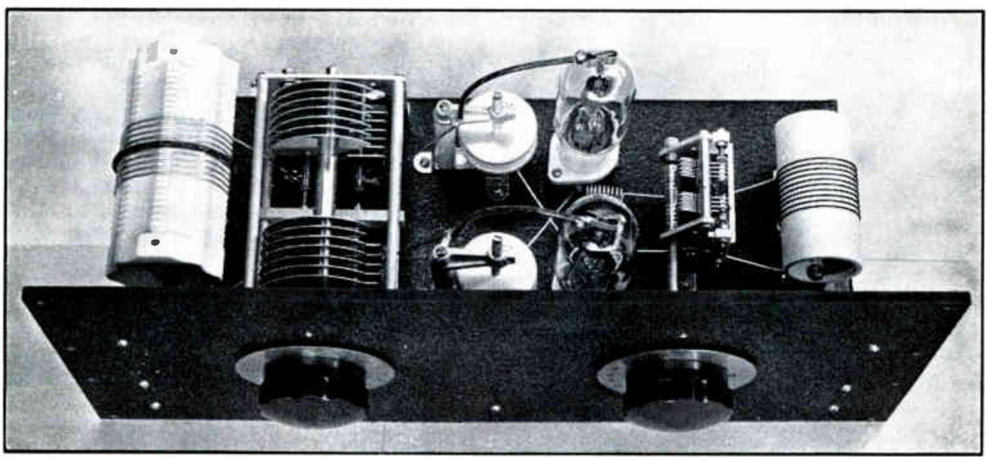


FIG. 856 — THE MEDIUM-POWER PUSH-PULL AMPLIFIER

This amplifier is designed primarily for c.w. operation with tubes such as the '35T, 'RK35-37-51-52, 808, T55-40 and HK54-154 at a maximum plate voltage of 1250. By the use of the blocking condenser described in the text it may be made suitable for plate modulation at this voltage or for c.w. operation at 1500 volts. Panel dimensions — $8\frac{3}{4}''$ x 19''; chassis 8'' x 17'' x $2\frac{1}{2}''$. One of the two parasitic chokes described in the text may be seen between the two tubes.

World Radio History

rent. With full plate voltage and the load coupled by means of a low-impedance line to an antenna tuner (see Chapter 13), the grid current should not fall below 40 to 50 ma. A suitable plate modulator is described in Chapter 10.

A 750-WATT PUSH-PULL AMPLIFIER

THE push-pull amplifier shown in the photographs of Figs. 858 and 860 is suitable for use with a pair of low-capacity tubes such as the types 100TH, RK36-38, HF200 or HK254. The tank condenser has sufficient capacity to provide approximately optimum capacity on all bands up to 3.5 Mc. when the amplifier is operated with a ratio of plate volts to plate-current milliamperes of not less than 8 to 1. At 1.7 Mc., a padding condenser of 50 $\mu\mu$fds. rated at not less than 7500 volts, such as one of the Eimac vacuum units should be connected across the coil specified. The tank-condenser airgap is sufficient to withstand c.w. operation with 750 watts input at 2500 volts. Voltage should be reduced or a blocking condenser (see Fig. 854, C_5) should be used if the stage is to be plate-modulated. If this connection is used, it is of utmost importance that the tank condenser be well insulated from the panel and that a suitably insulated coupling be used between the condenser shaft and the control.

Most of the details of construction are evident from the photographs. Reference should be made to Chapter 6 for assistance in construction. The r.f. chokes, by-pass condensers, grid leak and power wiring are beneath the chassis. The tube sockets are sub-mounted making it unnecessary to bring the filament wiring up through the chassis. The supporting strip at the rear of the tank condenser serves as a ground strap of low resistance.

The layout of the amplifier is such as to keep all leads symmetrical. The tubes are arranged so that each plate terminal comes opposite the condenser stator to which it is to be connected. The positions of the neutralizing condensers are also reversed, one being placed behind one tube and the other in front of the second tube.

The grid coils are wound on National XR13 forms with the associated plugs and base. The link coils are wound to fit inside the forms rather than on the outside of the windings, since there is more room inside and the leads can be brought out inconspicuously.

The circuit diagram is shown in Fig. 859. The condenser C_3 is necessary to prevent low-frequency parasitic oscillations caused by resonance in grid and plate r.f.-choke circuits. It should be mounted to give a fairly short connection between the center-tap of the grid coil and ground. The high-voltage lead to the center of the plate tank coil is fed through the

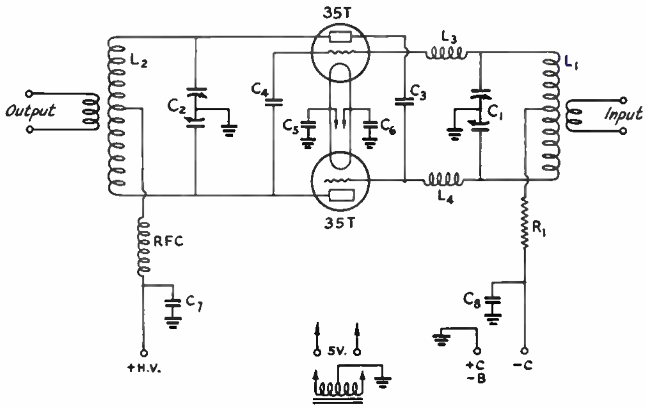


FIG. 857 — CIRCUIT DIAGRAM OF THE MEDIUM-POWER PUSH-PULL AMPLIFIER

C_1 — 100 $\mu\mu$fd. per section, .026″ spacing (National TMS-100D).

C_2 — 100 $\mu\mu$fd. per section, .077″ spacing (National TMC-100D).

C_3, C_4 — Neutralizing condensers, 2-6 $\mu\mu$fd. (National NC-800).

C_5, C_6 — .01-μfd. paper tubular, 400-volt (Aerovox).

RFC — 1.1-mh. transmitting choke (Coto-Coil Cl-21).

C_7 — .001-μfd. mica, 2500-volt (Cornell-Dubilier).

C_8 — .002-μfd. paper tubular, 600-volt (Aerovox).

R_1 — Grid leak. (See text.)

L_1 — 1.7 Mc. — 90 turns No. 22 d.s.c., dia. 1¾ in.
3.5 Mc. — 44 turns No. 18 enamelled, 16 turns per inch, dia. 1¾ in.
7 Mc. — 20 turns No. 18 enamelled, 8 turns per inch, dia. 1¾ in.
14 Mc. — 10 turns No. 18 enamelled, 8 turns per inch, dia. 1¾ in.
28 Mc. — 4 turns No. 18 enamelled, 4 turns per inch, dia. 1¾ in.

All wound on National XR-13 forms. Links 3 or more turns, bunch-wound, inside coil form.

L_2 — 1.7 Mc.* — 50 turns No. 18 d.c.c., dia. 2½ in., length 3½ in.
3.5 Mc. — 35 turns No. 14, dia. 2½ in., length 3½ in.
7 Mc. — 18 turns No. 14, dia. 2½ in., 7 turns per in.
14 Mc. — 10 turns No. 14, dia. 2½ in., 7 turns per in.
28 Mc. — 6 turns No. 14, dia. 2½ in., 3.5 turns per in.

All except 1.7- and 3.5-Mc. coils wound on National XR-10A forms. 1.7- and 3.5-Mc. coils may be wound on tubing or on celluloid strips as described in Chapter Six. Links one or two turns as required, wound with high-voltage wire around center of coil.

L_3, L_4 — Parasitic chokes, 8 turns No. 14, ½-in. dia.

* An air padding condenser of 50 $\mu\mu$fds. with airgap not less than .17″ must be used in parallel with the coil at this frequency (Cardwell JCO-45-OS fixed or a 50-$\mu\mu$fd. variable).

World Radio History

chassis by means of a feed-through type insulator.

Power Supply and Excitation

Power-supply requirements will vary somewhat with the type of tube and the input at which it is desired to operate the amplifier. In this instance, a pair of 100TH's, was operated at 2500 volts, 300 ma. or an input of 750 watts. Details of a suitable plate-power supply may be taken from the power-supply table in Chapter 14. These tubes require a filament transformer delivering 5 to 5.1 volts at 13 amperes. Voltage should be checked at the tube sockets.

Appropriate biasing voltage may be obtained from a pair of heavy-duty 45-volt batteries used in conjunction with a grid leak resistance of 1500 ohms, 25 watts, but preferably from one of the bias power-supply units described in Chapter 14. The resistance introduced in the grid circuit by the bias-supply voltage-divider or bleeder resistance should be 2500 ohms.

Excitation requirements will also vary somewhat with tubes and operating conditions. Sufficient excitation for any of the above mentioned tubes, operating within the conditions outlined, may be obtained from the exciter shown in Fig. 845 with the TZ40 tube in the output stage.

This amplifier is neutralized and tuned exactly following the process described in connection with the push-pull amplifier of Fig. 856. The driver output and amplifier input links are adjusted to give maximum grid current to the amplifier consistent with maximum rated plate current for the driver with the driver output and amplifier input tank circuits tuned to resonance. In neutralizing, the neutralizing condensers should be kept at the same plate spacing while adjusting them to eliminate all traces of dip in grid current as the plate tank circuit is tuned through resonance with plate voltage off. When plate voltage is first applied in

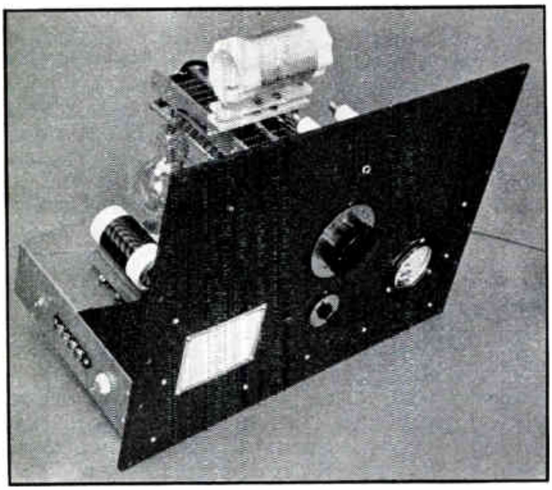


FIG. 858 — THE 750-WATT PUSH-PULL AMPLIFIER WITH 100TH'S

It is also suitable for types RK36-38 and HK254. The chassis measures 10″ x 17″ x 3″ and the panel 17½″ x 19″.

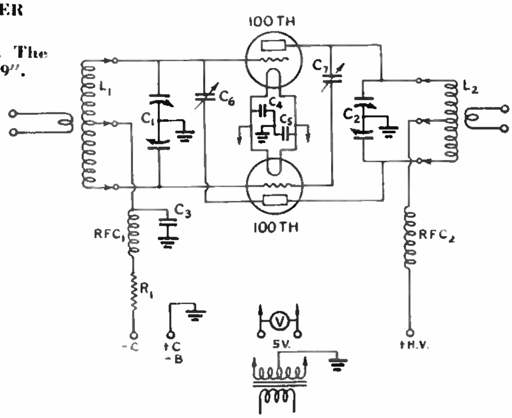


FIG. 859 — CIRCUIT DIAGRAM OF THE 750-WATT PUSH-PULL AMPLIFIER

C_1 — Split-stator transmitting condenser, 100 μμfds. per section, 0.07″ airgap (Cardwell MR100BD).
C_2 — Split-stator transmitting condenser, 75 μμfds. per section, 0.2″ airgap (Cardwell XC-75-XD).
C_3 — 250 μμfds. mica condenser, 500-volt.
C_4, C_5 — 0.01-μfd. paper.
C_6, C_7 — Neutralizing condensers (National NC-800).
R_1 — See text.
RFC_1 — Receiving-type r.f. choke (National R100).
RFC_2 — Transmitting-type r.f. choke (National R154U).
L_1 — 1.7 Mc. — 85 turns No. 24 d.c.c., close-wound; link 5 turns.
3.5 Mc. — 52 turns No. 18 enamelled, close-wound; link 3 turns.
7 Mc. — 30 turns No. 14 enamelled, close-wound; link 2 turns.
14 Mc. — 12 turns No. 14 enamelled, length 1⅜″; link 2 turns.
28 Mc. — 6 turns No. 14 enamelled, length 1⅜″ link 2 turns.
All grid coils wound on National XR-13 1¾″ diam. forms.
L_2 — 1.7 Mc.* — 30 turns, diameter 5″, length 4½″ (No. 12).
3.5 Mc. — 22 turns, diameter 5″, length 3″ (No. 12).
7 Mc. — 22 turns, diameter 2½″, length 3⅝″ (No. 12).
14 Mc. — 8 turns, diameter 2½″, length 1⅛″ (No. 12).
28 Mc. — 6 turns ¼″ copper tubing, diameter 2½″, length 4″.
1.7- and 3.5-Mc. coils wound on National XR-14A forms; 7- and 14-Mc. coils on National XR-10A forms; 28-Mc. coil self-supporting.
V — A.c. voltmeter, 0–10 volts.
*** Used with 50-μμfd. padder. (See text.)**

tuning the amplifier, it should always be reduced as already mentioned frequently in this chapter. The grid current should not fall below 75 ma. with the amplifier fully loaded.

A suitable plate modulator for this amplifier is described in Chapter 10.

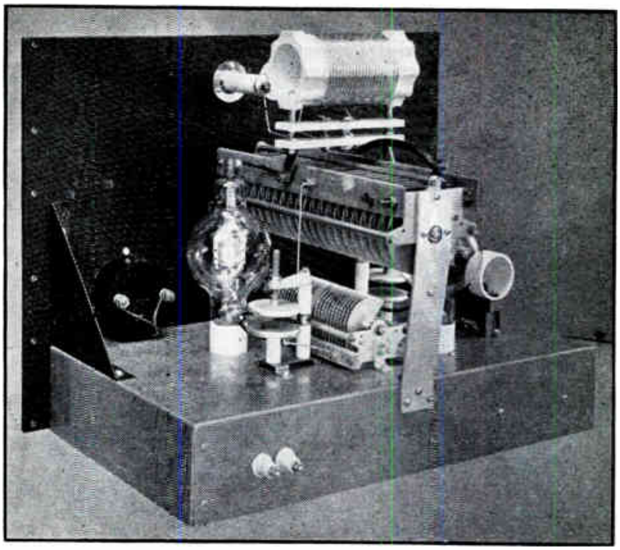


FIG. 860 — REAR VIEW — 750-WATT PUSH-PULL AMPLIFIER

The plate tank coil is supported partly by the panel and partly by a heavy aluminum strip fastened to the chassis at the back. The jack-base for the plate coils (National XB-15) is mounted cross-wise on the condenser by means of angle brackets. These brackets also form the connections between the condenser stators and the ends of the tank coil. The grid coil is mounted at right angles to the plate coil.

A 1-KW. PUSH-PULL AMPLIFIER OF CONSERVATIVE DESIGN

The push-pull amplifier shown in the photographs of Figs. 861, 862 and 864 was designed for c.w. or 'phone operation at the full legal limit of 1 kw. with tubes and associated equipment operating well within their maximum ratings. Suitable tubes are types such as the 806, 250TH, RK63, T155, HF300 or the HK354's shown in the photographs.

Most of the constructional details are evident from the photographs and their captions. Every effort should be made to keep the wiring on each side of the circuit symmetrical. This applies particularly to the length of leads between the condenser stators and the tube terminals and the leads connecting the neutralizing condensers. With the plate tank condenser mounted upside-down, the mounting strip for the coil mounting may be fastened to the condenser mounting feet. A control for varying the link coupling of the output circuit is brought out to the panel. Since the shaft provided with the coil unit is 3/16″ diameter, a reducing coupling is used to couple it to a 1/4″ shaft. The insulated shaft coupling for the plate tank condenser is of utmost importance to remove danger of high-voltage shock. It should have sufficient insulation to withstand voltages of the order of 7500 or 10,000 volts.

Mounting the grid-circuit components underneath the baseboard with its metal covering provides shielding between grid and plate circuits.

The filament transformer is included in the unit to eliminate voltage drop in secondary wiring of appreciable length. This is important where heavy filament currents are involved.

The circuit diagram is shown in Fig. 863. The tank condenser specified in the list of components is the one shown in the photographs. It was chosen with 2000-volt operation without the blocking condenser in mind. With the blocking condenser in use, an appreciable saving in space can be made by the substitution of a smaller tank condenser, although the larger condenser gives a greater factor of safety under conditions of light loading. The Johnson type 100DD90 has sufficient plate spacing (0.250″) for c.w. or 'phone operation up to 1 kw. input at 3000 volts. With this condenser, it is possible that the 14- and 28-Mc. coils will not need the alterations mentioned in the table of components. Short-circuiting turns to reduce coil inductance is suggested to avoid spoiling the coil for other purposes which may require the full inductance of the coil. If turns are removed, the number must be determined experimentally with the tank condenser set at maximum for 3.5 Mc., approximately half-capacity for 7 Mc. and near minimum capacity for 14 and 28 Mc.

The tank condenser specified is sufficient to provide optimum capacity at frequencies down to 3.5 Mc. with tubes operated at either 3000 volts 330 ma. or 2500 volts, 400 ma. At 1.7 Mc. a padding condenser of 50 $\mu\mu$fds. will be required in parallel with the tank coil specified. This condenser should have a voltage rating of not less than 10,000 volts. One of the Eimac vacuum-type units should be satisfactory.

Power-Supply and Excitation Requirements

Full 1-kw. input may be obtained at 3000 volts, 330 ma. or 2500 volts, 400 ma. Proper

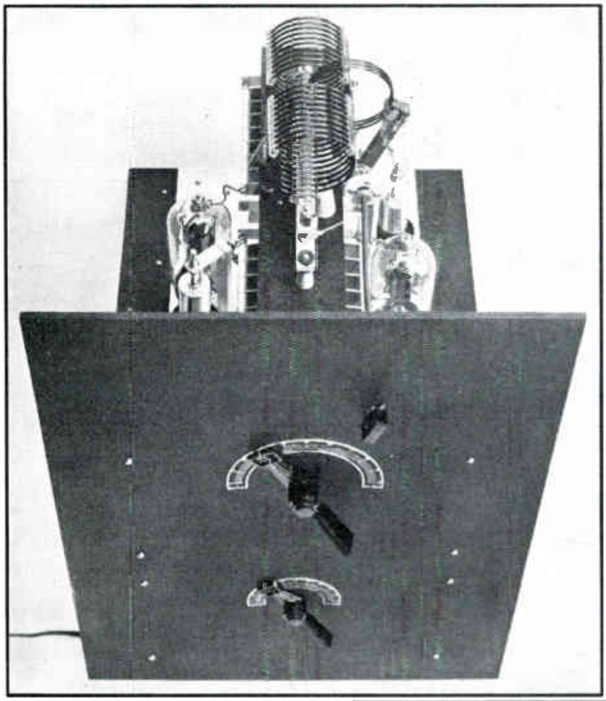
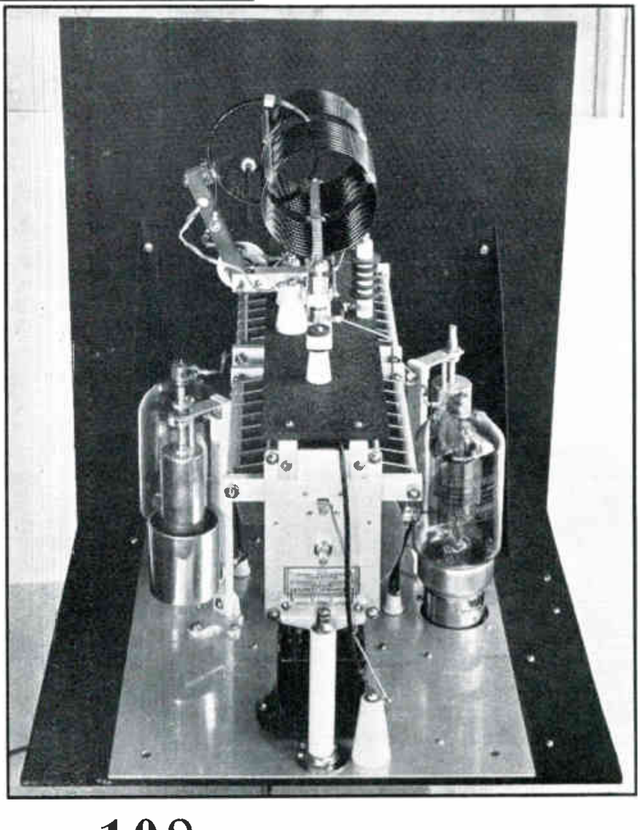


FIG. 861 — A 1-KW. PUSH-PULL AMPLIFIER OF CONSERVATIVE DESIGN USING TYPE HK354E'S

Designed for tubes operating at plate voltages of 2500 to 3000 such as types 806, 250TH, RK63, T155, HF300, T200 etc. The panel is a sheet of 1/4″ masonite measuring 28″ × 19″. It is fastened to the baseboard of similar material by four 9″ triangular chassis brackets, two below and two above the baseboard. The baseboard measures 17″ × 21″ and is covered with a thin sheet of metal.

FIG. 862 — REAR VIEW

The plate tank condenser is mounted upside-down on heavy 4½″ stand-off insulators. The tank-coil mounting is mounted upon a strip of 1/4″ masonite 3½″ × 16¾″ fastened to the bottom of the tank condenser. The stand-off insulators supplied with the unit are replaced with others 1″ high to reduce lead length. The blocking condenser C_4 is mounted underneath the tank condenser near the rear. When this condenser is used it is of the utmost importance to use a heavily insulated coupling between tank-condenser shaft and the control.



components for suitable plate supplies may be determined from the power-supply table in Chapter 14. The 354E's shown in the photographs require a filament transformer delivering 5 volts at 20 amperes. Filament requirements for other tubes may be determined from the tube tables of Chapter 5.

The 354E's require a fixed bias of 90 to 100 volts for plate-current cut-off at 3000 volts. Since the grid current runs quite high, it is preferable to obtain this biasing voltage from a biasing power supply such as one of those described in Chapter 14. The resistance introduced in the grid circuit by the bias-supply voltage divider or bleeder should be about 4000 ohms.

For c.w. operation a driver delivering 70 to 75 watts will provide sufficient excitation. The exciter shown in Fig. 845 with the T40 in the output stage should be adequate. Requirements for grid or plate modulation of this amplifier are discussed in Chapter 10.

Tuning

The process of neutralizing and tuning of the push-pull amplifier of Fig. 857 applies equally to this amplifier. With plate voltage off, the coupling between amplifier grid and exciter plate circuits should be adjusted to give maximum amplifier grid current when the two circuits are tuned to resonance. Some alteration in link turns may be necessary if it is found impossible to load the exciter output tube satisfactorily. The coupling should be adjusted to load the driver tube to rated plate current. With this coupling, it should be possible to obtain amplifier grid current of 100 ma. or more.

The plate tank circuit is tuned to resonance as indicated by the dip in grid current and the neutralizing condensers adjusted until this dip disappears as the plate circuit is tuned through resonance. The two neutralizing condensers should be kept at equal capacity settings during the process.

With the amplifier neutralized, plate voltage, reduced by the method described previously, may be applied and the plate circuit tuned to resonance as indicated by the dip in plate current. When the amplifier has been tuned to resonance and partially loaded, full plate voltage may be applied and the loading increased to bring the input up to the maximum limit. Variable-link coupling is provided for coupling to a low-impedance line feeding the antenna or a suitable antenna coupler (see Chapter 13). With the amplifier loaded, the grid current should not fall below 75 ma.

BAND-SWITCHING

Thus far, in the equipment described in this chapter, plug-in coils have been employed as a means of transferring operation from one band to another. In the exciter units, where efficiency may often be of less importance than convenience, some of the circuits are designed to cover two bands with a single coil by the use of a large tuning condenser. This method is not suitable for higher-power amplifiers because of the losses involved in the high-*C* circuit which results at the lower of the two frequencies covered by this method.

Several systems have been worked out whereby an inductance change instead of a capacity change is employed in shifting operation from one band to another. In one system, switches are employed to short-circuit turns of a low-frequency coil to render it suitable for higher frequencies. This method is very convenient and involves no appreciable losses in covering three bands. In a second method, separate appropriate tank coils are provided for each band while a system of switches is used to switch connections between the tank condenser and one or another of the coils. A third method, used in exciters, employs a system of switches to cut frequency-doubling stages in or out of the circuit as desired. Two typical practical examples of band-switching units will be described.

A 40-WATT OUTPUT EXCITER WITH STAGE SWITCHING

The exciter or low-power transmitter pictured in Figs. 865 and 867 is designed for flexi-

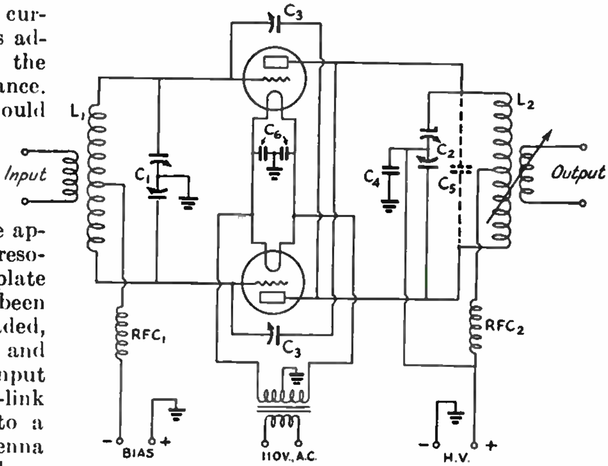


FIG. 863 — CIRCUIT DIAGRAM OF THE PUSH-PULL 1-KW. AMPLIFIER

C_1 — 200 μμfds. per section, 0.07″ airgap or greater (National TMA-200D).
C_2 — 100 μμfds. per section (Johnson 100CD110, 0.350″ airgap). (See text.)
C_3 — Neutralizing condenser (Johnson N375).
C_4 — 0.002 μfd., 12,500-volt mica (Cornell-Dubilier 22A86), blocking condenser.
C_5 — 50 μμfds. Eimac vacuum type padder for 1.7 Mc. (See text.)
C_6 — 0.01 μfd., 600-volt paper, filament by-pass.
RFC1 — Grid-circuit r.f. choke (National R100).
RFC2 — Plate-circuit r.f. choke (National R154U).
L_1 — Barker & Williamson BXL series with center links, altered as follows: BXL-160 — Cut to tune to resonance at condenser maximum; BXL-80 — short-circuit 3 turns each end; BXL-40 — short-circuit 1 turn each end; BXL-20 — no alteration; BXL-10 — short-circuit 1 turn at one end.

Note: Substitute coils may be made by referring to graphs of Figs. 828 and 829, basing dimensions upon capacities of 100, 75, 40, 30 and 30 μμfds. respectively for 1.7, 3.5, 7, 14 and 28 Mc.

L_2 — Barker and Williamson HDVL series with following alterations: HDVL-20 — short-circuit 1 turn each end; HDVL-10 — short-circuit ½ turn each end.

Note: Substitute coils may be made by referring to graphs of Figs. 829, basing dimensions upon capacities of 100, 50, 25, 25 and 25 μμfds. respectively for 1.7, 3.5, 7, 14 and 28 Mc.

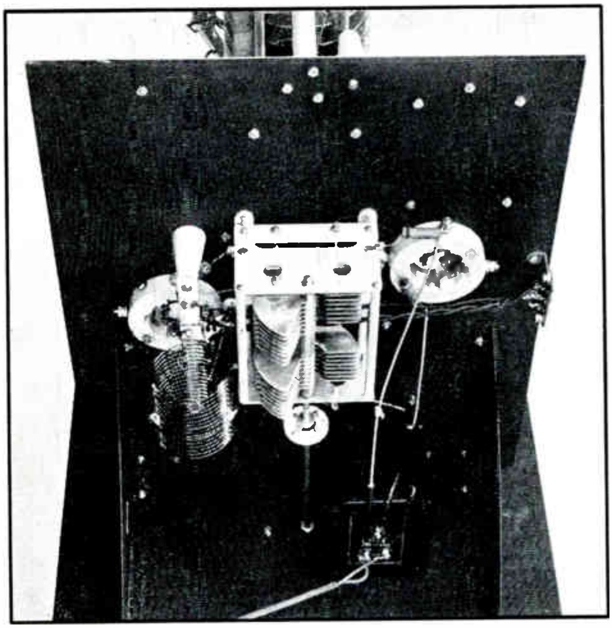


FIG. 864 — BOTTOM VIEW — 1-KW. PUSH-PULL AMPLIFIER

The rotors of the grid tank condenser are grounded. The grid tank-coil mounting straddles one of the tube sockets which are sub-mounted in the baseboard. The grid choke coil is placed underneath the coil mounting. Leads from grid tank circuit to tube grid terminals are passed through base via feed-through insulators.

bility in being adaptable to all bands from 1.75 to 28 Mc., with crystals cut for different bands, and also for quick band changing over three or four bands. It consists of a 6V6G tetrode oscillator followed by two triode doubler stages in one tube, a 6N7G; by means of a switch, the output of any of the three stages can be connected to the grid of the final tube, an 807 screen-grid beam tetrode. A second two-gang switch changes tank coils in the 807 plate circuit. The circuit diagram is given in Fig. 866.

The oscillator, first and second doubler plate coils, L_1, L_2 and L_3 respectively, need not be changed for crystals ground for a given band. The switching circuit is so arranged that the grids of unused stages are automatically disconnected from the preceding stage and grounded so that excitation is not applied to the idle tubes.

In the 807 plate circuit, the tank condenser, C_4, has sufficient capacity range to permit covering two bands with a single coil. The lower-frequency band will be found toward maximum capacity and the higher-frequency toward minimum in each case. The 807 may be used as a doubler, if desired, for four-band operation from a single crystal; the output and plate efficiency are only slightly reduced from straight-amplifier operation.

Capacity coupling between stages is used throughout. The plates of the first three stages are parallel-fed so that the plate tuning condensers can be mounted directly on the metal chassis. The 6V6G oscillator, 6N7G doubler-doubler and the 807 screen all operate at the same voltage; with the voltage divider specified the actual voltage at this point is slightly less than 300 volts, with 600 applied. The 6V6G screen runs at a little over 100 volts. A jack is provided for reading plate current to each tube. Series feed is used in the 807 plate circuit, the tank condenser being insulated from the chassis with "button" insulators. Condenser C_{15} provides a little feedback additional to that within the tube itself so that crystals will be certain to oscillate.

The above-chassis layout is shown in top-view photograph. Along the back, from left to right, are the crystal, 6V6G, and 6N7G. Directly in front of them are the three low-level plate coils, L_1, L_2 and L_3. These are wound on ordinary receiving forms, and plug into sockets mounted above the chassis on the metal pillars furnished with the sockets. Next in line comes the 807, with part of a tube shield around its lower half for additional shielding, and finally the 807 tank circuit with its pair of coils.

The chassis is of electralloy, measuring 7 by 17 by 3 inches.

Below chassis, the three tuning condensers, C_1, C_2 and C_3, are mounted directly underneath their associated coils, and are fastened directly to the under-side of the chassis. The "hot" leads from the coils come down through grommetted holes in the chassis; grounds to the coils are made direct to the chassis, on top.

In the oscillator section, at the left, the grid choke is just to the right of the crystal socket; the grid leak, R_1, connects between the low-potential end of the choke and ground. The plate choke is mounted horizontally between two insulating lugs, and occupies a position midway between C_1 and C_2. The plate blocking condenser, C_5, is mounted on its terminal wires between the hot end of the choke and the stator plates of C_1.

In the doubler circuit, each plate choke goes directly to a meter jack. The plate blocking condensers, C_6 and C_7, mount between the plate terminals on the tube socket and a pair of lugs on an isolantite terminal strip which is mounted on a small metal pillar so that it is

World Radio History

about an inch away from the chassis. From these points, connections go to the tank circuits, and also through the grid coupling condensers, C_9 and C_{10}, to the switch. The left-hand lug on the strip is a junction point for the first grid coupling condenser, C_8, and the lead to the switch.

The grid chokes for the 6N7G are mounted vertically at the right side of the switch, the lower terminals going to an insulated double lug. The grid leaks, R_2 and R_3, go from the strip to ground.

The socket for the 807 is the last on the right. Just below it is the grid choke. The screen by-pass and heater by-pass are clearly visible in the photograph. The 807 grid leak, R_4, and the oscillator screen voltage divider, R_6 and R_7, are mounted on a lug strip parallel with the rear of the chassis. The large resistor is R_5.

The two-gang switch for shifting the output coils may be seen at the right. A baffle shield is placed to the left of the switch to reduce coupling between the switch and grid-circuit components.

The oscillator feedback condenser, R_{15}, is made by cutting two ⅜-inch square plates, with mounting tabs on one side, from thin copper. The tabs are soldered to the grid and plate terminals on the tube socket and the plates arranged to face each other with about a quarter-inch separation. The adjustment is not critical; use the greatest spacing which will permit the oscillator to "start" regularly.

All grounds are made directly to the chassis.

Power leads are brought to a terminal strip on the edge of the chassis — at the left-hand side in the bottom view. The output link is connected to a two-terminal strip on the rear edge.

Reference should be made to Chapter 6 for suggestions on cutting and drilling the chassis.

The doubler switch is a standard item having three gangs, each with six contacts. Since only three contacts per gang are needed for the doubler stages, alternate contacts should be removed to give greater spacing and reduce capacity effects. Only two sets of contacts are required in the amplifier switch. In the doubler switch the gang nearest the panel connects to the first 6N7G grid; that nearest the back on the set connects to the 807 grid. Leads between the amplifier coils and switch contacts are passed through clearance holes in the chassis fitted with rubber grommets.

To operate the exciter, coils for consecutively higher-frequency bands are plugged in at L_1, L_2 and L_3; only five are necessary for operation with any crystals from 1.75 to 7 Mc. and for output from 1.75 to 28 Mc. For example, with 3.5-Mc. crystals, the 3.5-, 7- and 14-Mc. coils would be plugged in at L_1, L_2 and L_3 respectively. For 1.75-Mc. crystals, the 1.75-, 3.5- and 7-Mc. coils would be used, and so on.

To tune, first open the plate circuit of the 807 by turning the coil switch to an open position. With the doubler switch in the lower position in Fig. 866 (all tubes in use) and the meter plug in J_1, turn C_1 until the oscillation dip occurs. The plate current should drop from about 40 ma. to approximately 20 ma. Move the meter plug to J_2 and adjust C_2 to resonance (minimum plate current), then move the plug to J_3 and repeat. In both cases the off-resonance plate current should be around 50 or 60 ma. and in-resonance about 20 to 25 ma. The last adjustment should be made quickly and the plate power then shut off, to avoid overheating the 807 screen. With the appropriate coil switched in at L_4, the meter plug may then be inserted in J_4, plate voltage applied and C_4 adjusted to resonance. Un-

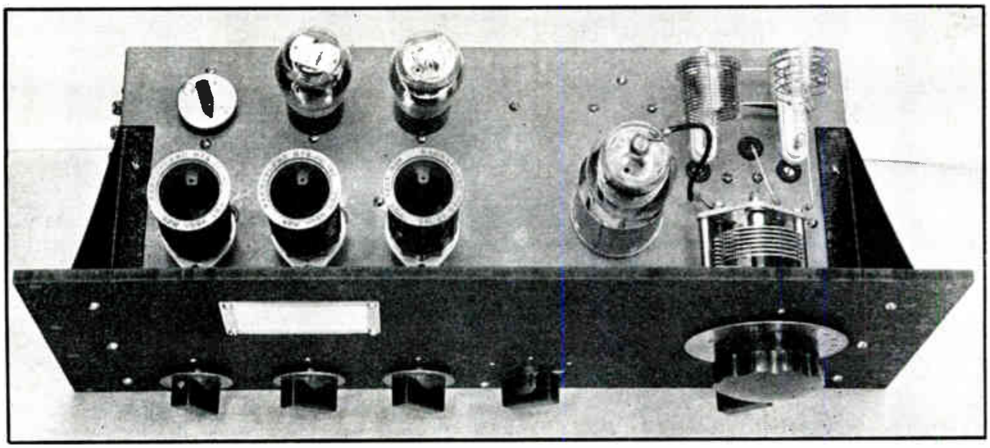


FIG. 865 — A 40-WATT OUTPUT EXCITER FOR WORKING FOUR BANDS WITH ONE CRYSTAL
Five bands may be covered through the use of plug-in coils.

World Radio History

loaded minimum plate current on the 807 will range between 10 and 15 milliamperes, depending upon the frequency and the coil in use. Each coil covers two bands, so that if the 807 is excited on the frequency to which the plate circuit is resonant with near-maximum capacity, the condenser can simply be swung to the other end of the scale for doubling. Minimum plate currents when doubling run higher than when amplifying straight through, but should not exceed 25 or 30 ma. even on 28 Mc. The tube can be loaded to about 100 milliamperes on every band.

Fixed bias is used on the 807 to hold the plate current to a safe value in case excitation is lost, and to stabilize the tube. Bias of the order of 50 volts, which brings the plate current without excitation down to about 40 or 50 ma., is sufficient; the 100 volts indicated on the diagram is approximately cut-off. The grid leak R_4, improves efficiency when the tube is used as a doubler.

Slight retuning may be necessary when switching from one band to another, since the input capacities of the triodes and 807 differ. Metering is not necessary for this purpose; simply adjust for maximum final output. When changing frequency within a band, retuning will not be necessary unless the two frequencies are fairly widely separated.

With maximum rated input to the 807 (60 watts) the output is approximately 40 watts on all bands.

Reference should be made to the power-supply chart in Chapter 14 for details of a suitable power supply. Link windings are provided on each output coil for coupling to a low-impedance transmission line feeding a following amplifier or antenna coupler with link input (see Chapter 13).

A MEDIUM-POWER BAND-SWITCHING PUSH-PULL AMPLIFIER

ILLUSTRATING the short-circuiting method of band-changing is the T55 push-pull amplifier shown in Figs. 868 and 870. The circuit is shown in Fig. 869. The tank coils are selected to tune to the 3.5-Mc. band with the proper amount of capacity and two-gang, three-position switches in grid and plate circuits short-circuit portions of each coil for the 7- and 14-Mc. bands. Both input and output links are variable so that proper adjustment of coupling for each band may be made.

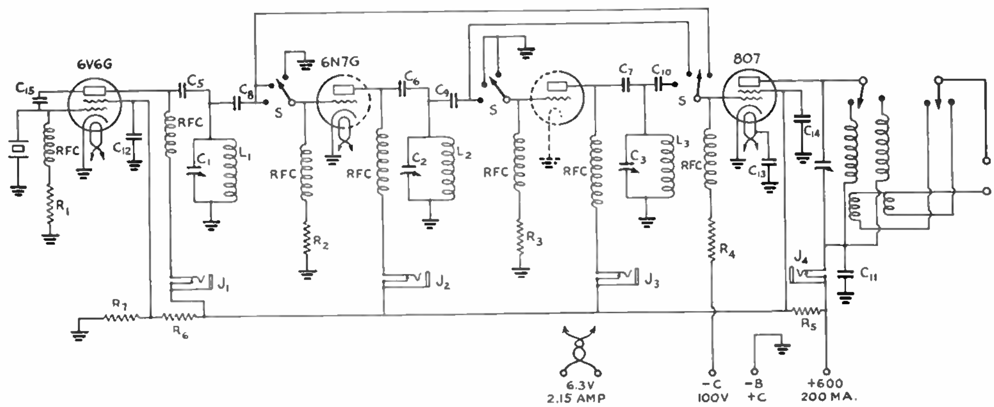


FIG. 866 — CIRCUIT DIAGRAM OF THE 40-WATT EXCITER

To avoid complicating the diagram, the two sections of the 6N7G double triode are shown separately.

C_1, C_2, C_3 — 100-μμfd. variable, receiving type (National ST-100).
C_4 — 150-μμfd. variable, low-power transmitting type (National TMS-150).
C_5, C_6, C_7 — 0.001-μfd. mica, 500-volt (Aerovox 1467).
C_8, C_9, C_{10} — 100-μμfd. mica, 500-volt (Aerovox 1468).
C_{11} — 0.0025-μfd. oil-filled tubular condenser, 2000-volt (Mallory OT-458).
C_{12}, C_{13}, C_{14} — 0.01-μfd. paper, 600-volt (Aerovox 684).
C_{15} — Oscillator feedback condenser (see text).
R_1, R_2, R_3 — 25,000 ohms, 1-watt (I.R.C.).
R_4 — 50,000 ohms, 1-watt (I.R.C.).
R_5 — 3500 ohms, 50-watt (Ohmite).
R_6 — 10,000 ohms, 10-watt (I.R.C.).
R_7 — 10,000 ohms, 2-watt (I.R.C.).
RFC — Sectional-wound chokes (National R-100).
J_1, J_2, J_3, J_4 — Closed-circuit jacks (Yaxley).
S — Three-gang switch (Yaxley 1336). See text.
S_1 — Yaxley-162C.
L_1, L_2, L_3 — 1.75 Mc.: 50 turns No. 22 d.s.c., close wound.
3.5 Mc.: 26 turns No. 18 enamelled, length 1½ inches.
7 Mc.: 17 turns No. 18 enamelled, length 1½ inches.
14 Mc.: 8 turns No. 18 enamelled, length 1½ inches.
28 Mc.: 4 turns No. 18 enamelled, length 1½ inches.

All wound on Hammarlund SWF-4 coil forms (diameter 1½ inches). On all except the 1.75-Mc. coil the turns are spaced evenly to fill the specified length.

L_4 — National AR series with end links. Remove 2 turns from each coil except the one covering 14–28 Mc. Remove 3 turns from this coil.

World Radio History

Construction

The chassis is fastened to the panel so that the top surface comes at the center line of the panel. The plate tank condenser is mounted upside-down on supports cut from standard crackle-finish chassis brackets fastened to the end plates of the condenser so that the shaft comes 3⅜″ above the surface of the chassis. The two Ohmite switches are mounted on metal angle brackets which, in turn, are mounted on 1″ stand-off insulators. The angle brackets are of such height that the switch shaft will come at the same height above the chassis as the variable link shaft. The two switches are coupled together with a length of bakelite rod ⅜″ diameter with reducing couplings at each end to fit the ¼″ switch shafts. A control for the link variation is brought out to the front of the panel by means of a ¼″ extension shaft coupled to the link shaft with a reducing coupling. The tubes and neutralizing condensers are placed symmetrically in respect to the stator sections of the tank condenser. The distance between the tubes is determined by the distance between mounting holes in the BVL jack strip underneath, since this strip must be mounted using the holes in the centers of the National 4-prong CIR tube sockets. The distance between the tubes and the plate tank condenser is such that the grid-coil mounting is in a position which will bring the variable link shaft at the same distance from the center of the panel as the plate link shaft so that the controls will be symmetrical. Plate leads from the tank condenser are covered with ¼″ spaghetti and crossed over so that the neutralizing condenser leads need not be crossed.

Underneath, the grid tank condenser is mounted on stand-off insulators and spacers to bring the distance of its shaft below the chassis the same as that between the top of the chassis and the shaft of the plate tank condenser. Both tank condensers are mounted with the shafts along a line drawn through the center of the chassis. The grid-circuit switch is mounted on a bracket which brings the shaft of the switch level with the shaft of the variable link. A control is brought out for the grid link as well as the plate link.

As mentioned previously, the jack strip for the grid coil is mounted on short stand-off insulators and spacers in the holes which appear in the National CIR-type sockets. These holes provide the only available method of mounting the jack strip if the controls on the panel are to make a symmetrical design. The tube sockets themselves are spaced about ¾″ below the surface of the chassis and the distance of the jack strip below the chassis to make the link shaft come at the correct level may be adjusted by varying the thickness of these spacers.

The taps on the coils are made before the coil is placed in position. They are made by scraping the enamel from the wire at the appropriate turn near the bottom of the turn and bending the "hole" end of a long soldering lug firmly about the turn and soldering it fast. Care should be taken to prevent short-circuiting of turns by the lug. The turns adjacent to the lug may be pressed slightly to one side if necessary. The coil may then be plugged into the jack strip so that the length of lead between the tap lug and the appropriate switch points may be estimated. The leads are then cut from No. 14 wire and soldered to the lugs.

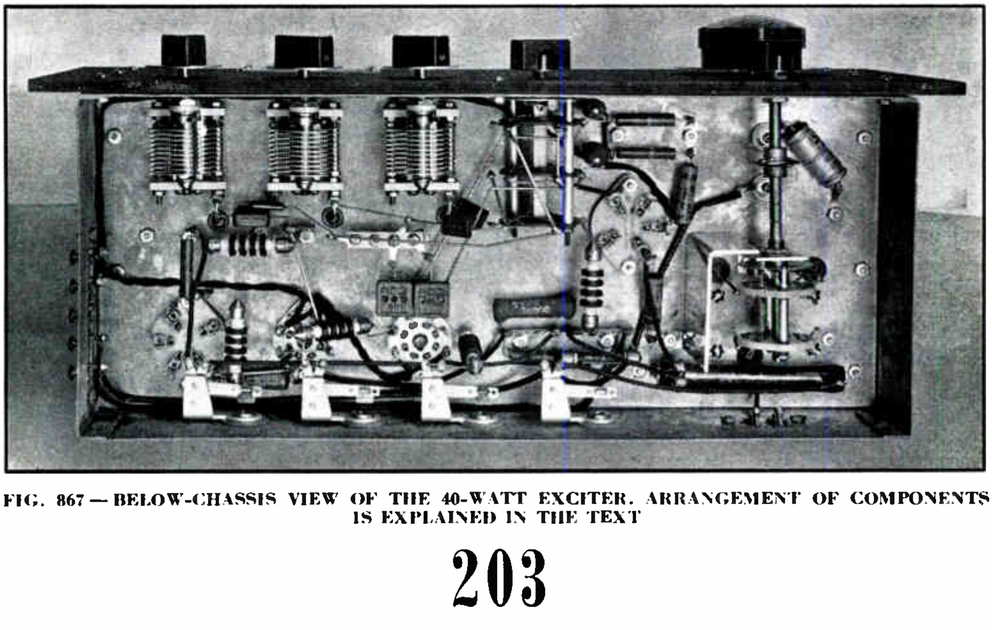


FIG. 867 — BELOW-CHASSIS VIEW OF THE 40-WATT EXCITER. ARRANGEMENT OF COMPONENTS IS EXPLAINED IN THE TEXT

World Radio History

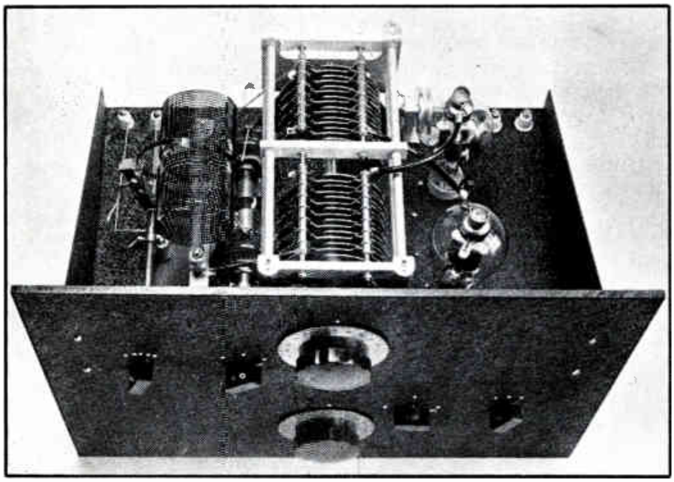


FIG. 868 — THE BAND-SWITCHING PUSH-PULL AMPLIFIER WITH T55'S

The unit is constructed in two sections with the plate-circuit apparatus on top of the chassis and the grid-circuit components beneath. The chassis measures 11" x 17" x 2" and the panel 14" x 19" x 1/4". The neutralizing condenser for the tube in the foreground is hidden by the panel. It is placed so as to be symmetrical with the other neutralizing condenser.

rather than the neutralizing-condenser leads.

The plate tank-condenser capacity is suitable for the frequencies covered for tubes operating at 1500 volts, 300 ma. for the pair and plate spacing is sufficient for plate modulation at 1250 volts.

Specifications for a suitable plate power supply will be found in the power-supply chart in Chapter 14. The T55's require a filament transformer delivering 7.5 volts at 5.5 amperes. Biasing voltage may be obtained from a pair of 45-volt batteries in series with a grid leak of 2500 ohms, 25 watts connected across the biasing terminals or from a biasing supply similar to one of those described in Chapter 14. An unregulated supply should have a resistance

The coil is again plugged in and the loose ends of the tap leads cut and fastened to the switch. The 14-Mc. switch points should come nearest the coil so that these leads will be shortest. Ample space is left at the left side of the chassis (Fig. 870) for mounting the filament transformer.

A terminal strip is placed at the rear edge of the chassis. A medium-size feed-through insulator forms the positive high-voltage terminal and another similar insulator is used to bring the positive high voltage lead up through the chassis to the center of the plate tank coil.

If desired, brackets may be fastened to the rear end of the chassis so that the unit may be placed upon a table rather than in a standard rack for which it is designed. Suggestions for cutting and drilling the chassis will be found in Chapter 6.

Any of the tubes such as the types 35T, RK35-37-51-52, 808, HK54-154, etc., operating at 1500 volts will be suitable for use in this amplifier. If a type with the grid terminal at the side instead of the base is used, the leads from the tank circuit to the grids will be passed through the chassis

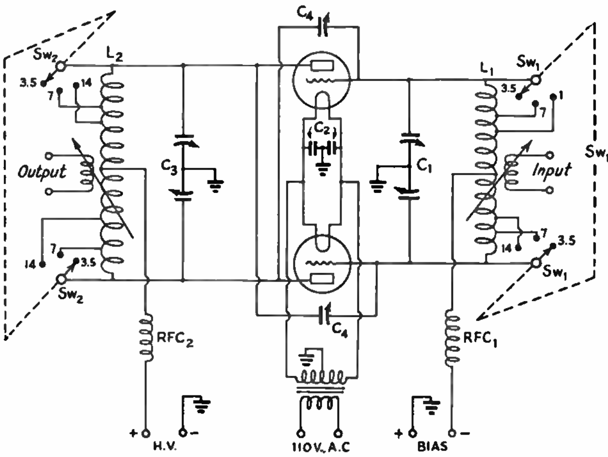


FIG. 869 — CIRCUIT DIAGRAM OF THE T55 PUSH-PULL BAND-SWITCHING AMPLIFIER

C_1 — 100 μμfds. per section, 0.025" or greater airgap (National TMS100D).
C_2 — 0.01 μfd., 660-volt paper.
C_3 — 100 μμfds. per section, 0.170" airgap (National TMA100DA).
C_4 — Neutralizing condensers (Hammarlund N-10).
RFC_1 — Grid-circuit r.f. choke (National R100).
RFC_2 — Plate-circuit r.f. choke (National R154U).
SW_1 — Two-gang, three-position switch (Mallory 162-C).
SW_2 — Two Ohmite type BC3 — three-position switches ganged together.
L_1 — Barker and Williamson BVL-160, taps at 7 and 13 turns from each end.
L_2 — Barker and Williamson TVL-80, taps at 11th and 16th turn from each end.

of 4000 ohms between the grid tap and ground. The band-switching exciter of Fig. 866 should furnish adequate excitation.

This amplifier is neutralized and tuned exactly in the same manner suggested for the push-pull amplifiers previously described. The variable link in the grid circuit provides an adjustment of input coupling. The output link provides adjustment of coupling to a low-impedance transmission line or to a suitable antenna coupler (see Chapter 13). For c.w. operation, a grid current of 40 to 50 ma. with the amplifier loaded should indicate adequate excitation. Plate and grid modulation of this amplifier are discusssed in Chapter 10.

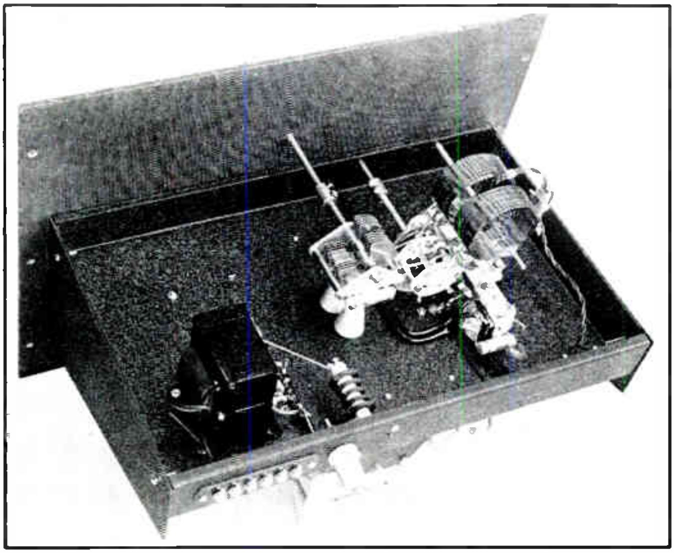


FIG. 870 — BOTTOM VIEW — T55 BAND-SWITCHING EXCITER

Note particularly the method used in mounting the grid-coil jack strip. (See text.) The grid-circuit r.f. choke is underneath the grid tank coil. Leads from neutralizing condensers to tube grid terminals are passed through clearance holes in the chassis.

GANG TUNING

It is possible and practicable to gang the tuning controls of a multistage transmitter designed to accomplish this. Thus, the number of tuning adjustments can be reduced to two or three which include one adjustment for setting the frequency and one for tuning the antenna. A practical example of design of this type is shown in the photograph of Fig. 871 and the circuit diagram of Fig. 872.

Complete and continuous frequency coverage requires the use of a self-controlled oscillator such as the electron-coupled oscillator used in this instance. The oscillator is impedance-capacity coupled to the grid of a low-power buffer amplifier for the purpose of isolation against reaction upon the oscillator from the following stages. The buffer has sufficient output to drive an 807 beam-type buffer-doubler which, in turn, drives the RK51 final amplifier.

It will be noticed that the circuit is strictly conventional and that the only additional equipment required is the row of midget condensers ganged together with flexible shaft couplings. These may be seen in the photograph, running through the approximate center of the chassis. The National type PW dial, or something similar, is essential since the load of several condensers is too great for an ordinary friction dial. Only condensers of certain manufacturers are at present equipped with tail shafts so that they may be ganged and these only in the midget types. Condensers of these types with fairly good plate spacing are obtainable. The spacing does not have to be as great as might first be expected because the tuning condensers are connected across only a portion of the total r.f. voltage developed across the tank coil. The condenser in the final stage, where the voltages are highest, need not have a tail shaft since it is the last unit of the gang.

The transmitter is assembled on a half-inch wood base 12″ x 25″. This base is covered with a thin sheet of metal and is mounted on a pair of 1″ x 2″ strips running the length of the base to provide space underneath for low potential equipment.

Starting at the left-hand end of the transmitter, the oscillator coil is contained in the shield can directly in front of the main tuning dial with the oscillator tube, grid condenser and leak, padding and tuning condensers immediately alongside. Both oscillator and buffer coils plug into National CIR type sockets mounted on substantial stand-off insulators.

The metal tube in the rear is the 6J7 buffer. A vertical baffle shield separates the buffer plate coil and condensers from those of the 807 stage. Complete shielding of the 807 is of the utmost importance if oscillation is to be avoided. The plate lead must be shielded from the input leads inside the tube. This is accomplished by means of a two-section cylindrical shield made up from parts of two National type T58 receiving tube shields. One section

World Radio History

extends downward from the surface of the C1R socket to the base, while the other extends upward from the socket surface to a level equal to that of the lower ceramic supporting disk inside the tube. The plate coil for the 807 is wound on a National XR13 form.

All condensers except the split-stator condenser are mounted on small Johnson stand-off insulators. The rotors of the split-stator condenser are grounded so it may be mounted directly on the metal base. The neutralizing condenser may be seen directly in front of the RK51. The plate tank coils in the final amplifier are of the Barker and Williamson TVL series. At the time of construction, the TVL-80 coil was not available, so the TVL-160 was cut down to the dimensions given in the list of coil specifications. If the TVL-80 is used, the position of the band-spread taps may be determined experimentally as described later.

Care should be used in obtaining the best shaft alignment possible in mounting the ganged condensers. Flexible shaft couplings with fiber insulation will be satisfactory for low-power stages, but one with ceramic insulation should be used between tuning condensers of the last two stages.

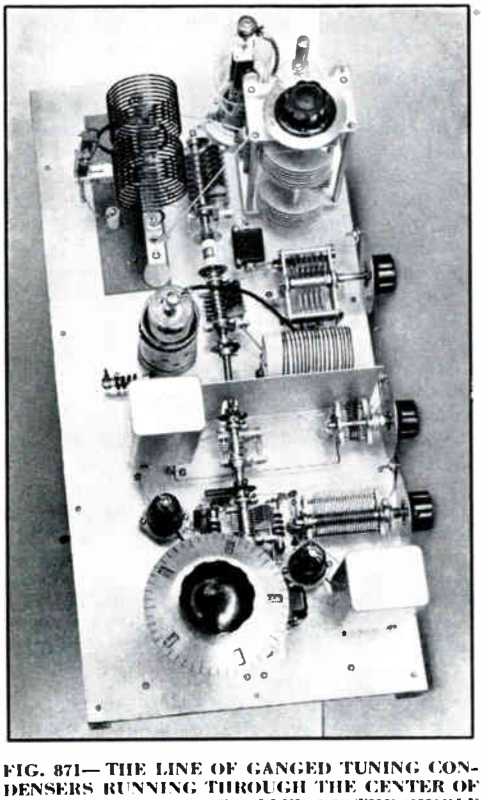


FIG. 871— THE LINE OF GANGED TUNING CONDENSERS RUNNING THROUGH THE CENTER OF THE CHASSIS IS CONTROLLED BY THE SINGLE PW DIAL

Band-setting condensers are along the front edge.

All low-potential wiring is carried beneath the base with wire suitable for the purpose. Mounting screws protruding through the baseboard make handy ground connections. Be sure, however, that any screws so used make good connection to the metal sheet.

Ganging Adjustments

Returning to the oscillator circuit, plug-in coils are provided for the 3.5- and 7-Mc. bands. Since only one doubler stage is provided in this particular transmitter, the oscillator is operated at 3.5 Mc. for the 3.5- and 7-Mc. bands and at 7 Mc. for the 14- and 28-Mc. bands, doubling frequency in the output stage for the latter. The 3.5-Mc. oscillator coil is wound to tune to the high-frequency end of the band with the high-C padder C_1 set near maximum capacity. With the 100-$\mu\mu$fd. tuning condenser C_5 connected across the entire coil, the oscillator will just about cover the band. If it does not cover the band, a turn or two should be added to the coil and the capacity of C_1 reduced to tune to the high-frequency end of the band. This will increase the frequency range of the tuning condenser. With the oscillator running as it should and covering the desired frequency range, we next turn our attention to the buffer plate coil. Here, again, we make the coil of such a size that the padder C_2 will tune the circuit to the high-frequency end of the band with a reasonable amount of capacity, say 40 to 50 $\mu\mu$fd. for this band. We then place the tuning tap C_6 at the point specified in the coil table. With the coil in place and the 807 in the socket with heater running, the oscillator is tuned to the high-frequency end of the band. The padder, C_2, is then tuned for resonance as indicated by the dip in plate current. The frequency control dial is then rotated to bring the circuits to the low-frequency end of the band. Now C_2 should be adjusted very carefully to determine if the buffer plate circuit is still at resonance. If it is not, it should be carefully noted whether an increase in capacity or decrease in capacity is necessary to bring it back to resonance. If the padder capacity must be increased, it indicates that the tuning or bandspread condenser is not tuning fast enough and, therefore, it must be connected across a greater portion of the coil. On the other hand, if the padder capacity must be decreased to bring the circuit to resonance, the tuning condenser is tuning too rapidly and, therefore, the tap must be adjusted so that it is connected across a smaller portion of the coil. Each adjustment of the tap will have some effect upon the minimum capacity of the circuit so that each time an adjustment is made it will be necessary to return

World Radio History

the tuning to the high-frequency end of the band and retune for this end of the band before again checking the low-frequency end.

The same process is repeated in each circuit, making certain that the tube of the following stage is always in the circuit with filament lighted but with plate voltage off. A stage requiring it should be neutralized before any attempt at tracking is made. Once the circuits have been lined up accurately, it should be possible to twirl the frequency-control dial from one end to the other with no noticeable change in either plate or grid currents, and it should be possible to dispense with all meters except possibly that in the final amplifier. A lamp-bulb dummy load coupled to the final amplifier should show substantially constant output over the entire band.

The same process is followed in adjusting L_3 and L_4 for the 7-Mc. band. This band being narrower in frequency, will cover only 100 or so dial divisions. This is entirely sufficient for convenient adjustment. In order to maintain tracking, however, the 807 and final circuits must be adjusted to cover the full range of the oscillator harmonic of 7000 to 8000 kc. If it is desired to spread this band out over the entire dial, it will be necessary to use a separate 3.5-Mc. oscillator coil with C_5 connected at a tap which will provide tuning over the range of 3500 to 3650 kc.

The 7-Mc. oscillator coil for 14- and 28-Mc. output is designed to cover the range of 7000 to 7500 kc. so that its fourth harmonic will cover the wider band from 28 to 30 Mc. Therefore, the 14-Mc. band will also cover only a portion of the dial scale unless an additional oscillator coil covering 7000 to 7200 kc. is used. The

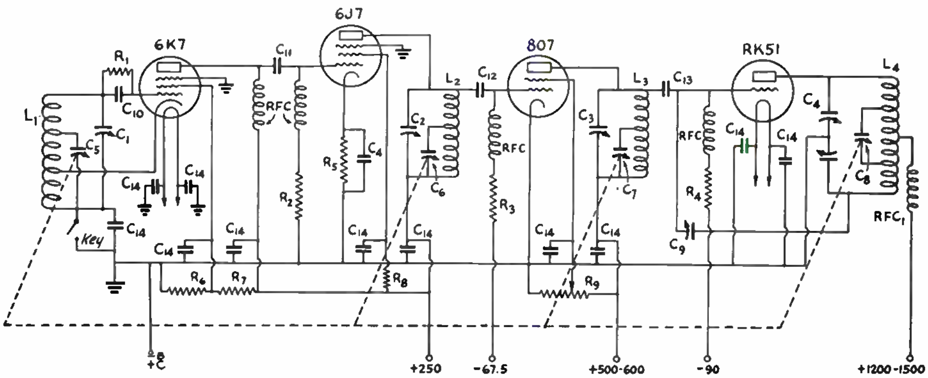


FIG. 872 — CIRCUIT DIAGRAM OF THE GANG-TUNED TRANSMITTER

C_1 — 320-μμfd. max. oscillator padder (Hammarlund MC-325M).
C_2 — 50-μμfd. max. buffer padder (Hammarlund MC50M).
C_3 — 50-μμfd. max. doubler padder (Cardwell MT50GS).
C_4 — 100-μμfd. per section final padder (National TMC100D).
C_5 — 100-μμfd. max. oscillator tuner (Hammarlund MC-100M).
C_6 — 35-μμfd. max. buffer tuner (Hammarlund MC35M).
C_7 — 35-μμfd. max. doubler tuner (Hammarlund MC35MX).
C_8 — 35-μμfd. max. final tuner (Bud No. 566).
C_9 — Neutralizing condenser (National NC800).
C_{10} — 250-μμfd. mica, oscillator grid condenser.
C_{11} — 250-μμfd. mica buffer coupling condenser.
C_{12} — 250-μμfd. mica, 1000-volt rating, doubler coupling condenser.
C_{13} — 100-μμfd. mica, 2500-volt rating, final coupling condenser.
C_{14} — 0.01-μfd., 600-volt paper r.f. by-pass.
R_1 — 0.1 meg., ½-watt, oscillator grid leak.
R_2 — 50,000-ohm, ½-watt, buffer grid leak.
R_3 — 50,000-ohm, 1-watt, doubler grid leak.
R_4 — 5000-ohm, 10-watt, final grid leak.
R_5 — 500-ohm, ½-watt, buffer cathode biasing resistance.
R_6 — 50,000-ohm, 2-watt, oscillator screen voltage divider.
R_7 — 25,000-ohm, 2-watt, oscillator screen voltage divider.
R_8 — 40,000-ohm, 1-watt buffer screen voltage dropping resistor.
R_9 — 25,000-ohm, 75-watt with slider, doubler screen voltage divider.
RFC — National R100.
RFC1 — National R154.

L_1 — 3.5 and 7-MC. output — 17 t. No. 24, 1″ dia., 1″ long, tapped at 5th turn from ground, no bandspread tap.
14 and 28-MC. output — 9 t. No. 22, 1″ dia., 1″ long, tapped at 2¾ turns from ground for cathode and 6 turns from ground for bandspread.
L_2 — 3.5 and 7-Mc. output — 38 t. No. 24 d.c.c., 1″ diam. 1⅛″ long, tapped at 33rd turn from ground.
14 and 28-Mc. output — 20 t. No. 24 d.c.c., 1″ diam., ¾″ long, tapped at 11th turn from ground.
L_3 — 3.5-Mc. output — 28 t. 1¾″ diameter, 1½″ long, tapped at 24th turn from ground.
7-Mc. output — 17 t. 1¾″ diam., 2¼″ long, tapped at 13th turn from ground end.
14 and 28-Mc. output — 8 t., 1¾ diam., 2½″ long, tapped at 3¼ turns from ground end.
L_4 — 3.5 Mc. — 34 t., 2½″ diam., 3⅛″ long, tapped at 10¾ turns each side of center (B & W TVL-160 with turns removed. See text).
7 Mc. — 22 t., 2½″ diam., 4″ long, tapped at 6 turns each side of center.
14 Mc. — 12 t., 2½″ diam., 4″ long, tapped at 2 turns each side of center.
28 Mc. — 6 turns, 2½″ diam., 5″ long, tapped at approximately 6/10 turn each side of center.

World Radio History

combination of two and three bands with one oscillator and one buffer coil eliminates the necessity for changing these coils so frequently, of course. As progress is made toward the higher-frequency bands, the positions of the tuning taps will become more critical, but it should require only a few trials to determine the proper points for the taps.

Once the proper settings of the padding condensers have been determined for each band, the dial readings should be tabulated so that no time will be lost in changing bands. It is possible, of course, to prune the coils closely so that no adjustment of the padder condensers will be necessary when changing bands. This involves much cutting and trying, however, and besides it is usually considered desirable to use less circuit capacity for the higher frequencies and more for the lower frequencies.

Variable link output is provided for coupling to an antenna tuner. With the coupling properly adjusted, it should be possible to set the frequency with the main control dial and then tune the antenna to resonance indicated by maximum increase in amplifier plate current. The coupling should be adjusted so that the antenna circuit may be tuned through resonance without exceeding the plate-current rating of the final-amplifier tube.

HARMONIC SUPPRESSION

Unless certain precautions are taken a transmitter may feed energy to the antenna system at harmonics of the fundamental frequency as well as at the fundamental frequency. If the antenna system is suitable for these harmonic frequencies, the amount of power radiated at these frequencies may be appreciable. This is a matter to be considered seriously, especially if the harmonic frequency falls outside any of the bands assigned to amateurs.

The harmonics which are most often radiated are the second from transmitters employing single-tube output stages and the third from those employing push-pull output stages, although the fifth and higher harmonic frequencies have been known to cause trouble. Harmonic output is apt to be particularly high from output amplifiers using less than optimum values of tank-condenser capacity, being driven with high excitation and feeding long-wire antennas which readily radiate harmonics.

While forms of coupling which will not permit feeding harmonics of appreciable amplitude to the antenna may be employed, it is generally advisable, as the first step, to increase the tank-circuit capacity to optimum value (see design section, this chapter) not only for the purpose of reducing harmonic output but also to improve output at the desired frequency. The units described in this chapter have been designed around tank-condensers of optimum capacity.

It will also be noticed that the units described are provided with link output coupling since this type of coupling discriminates against frequencies higher than the fundamental frequency to which the tank circuits at each end of the low-impedance transmission line are tuned. When large antenna coupling coils are used, sufficient capacity between tank and coupling coils may exist to transfer readily harmonic output to the antenna system. In this case, the capacity coupling may be eliminated by the use of an electrostatic shield between the tank coil and the antenna coupling coil. Practical application of electrostatic shielding will be found in Chapter 6.

NOTE ON TANK CONDENSER CAPACITIES

As mentioned frequently in the descriptions of transmitter units in this chapter, the tank condensers specified have maximum capacities which will give optimum *L-C* ratios at 3.5 Mc. It should be pointed out that, in cases where the minimum frequency to be used is higher than this frequency, the size of the tank condenser may be reduced. If the minimum frequency at which operation is desired is 7 Mc. instead of 3.5 Mc., the maximum capacity of the tank condenser may be reduced to half the value specified under the circuit diagram, or to one-quarter of the value specified if 14 Mc. is the minimum frequency to be used. The plate spacing should remain the same as specified in each case.

World Radio History

CHAPTER NINE

KEYING THE TRANSMITTER

And Elimination of Interference with Broadcast Reception

A RADIO TRANSMITTER is not in itself capable of transmitting intelligence — the output must be varied or "modulated" in some way. Radiotelephony employs continuous variation of the amplitude of the carrier in accordance with the voice frequencies, while radiotelegraphy uses complete modulation of the carrier to form dots and dashes, corresponding to the characters of the International Morse code. Both forms of modulation have their problems which must be given due consideration, from the simple business of impressing the modulation to the more serious matter of minimizing the possible interference caused by the variation in the transmitter's output. This chapter will deal with the problems of radiotelegraphy.

Satisfactory keying, from the standpoint of code-character formation, results if the keying method employed reduces the power output to zero when the key is "open" and permits full power to reach the antenna when the key is "closed." Furthermore, it should do this without causing keying transients or "clicks," which cause interference with other amateur stations and with local broadcast reception; and it should not affect the stability of the transmitter.

Back-Wave

From various causes some energy may get through to the antenna during keying spaces. The effect then is as though the dots and dashes were simply louder portions of a continuous carrier; in some cases, in fact, the "back-wave," or signal heard during the keying spaces, may seem to be almost as loud as the keyed signal. Under these conditions the keying is hard to read. A pronounced back-wave often results when the amplifier stage feeding the antenna is keyed; it may be present because of incomplete neutralization of the final stage, allowing some energy to get to the antenna through the grid-plate capacity of the tube, or because of magnetic pickup between antenna coupling coils and one of the low-power stages. In such cases it can be remedied by proper neutralization or by rearranging the tank circuits to eliminate unwanted coupling. Shielding also will help.

A back-wave also may be radiated if the keying system does not reduce the input to the keyed stage to zero during keying spaces. This trouble will not occur in keying systems which cut off the plate voltage when the key is open, but may be present in grid-blocking systems if the blocking voltage is not great enough and, in power supply primary-keyed systems, if only the final stage power supply primary is keyed. In grid-block systems, if the plate current does not go to zero when the key is open, more blocking voltage is required. In the upper circuit of Fig. 905, the tube will not be blocked completely if there is any leakage between grid and cathode of the tube. This leakage may take place in the tube itself or its base, in the socket, through poor insulating material on which any of the parts may be mounted, in the key, or in the leads running to the key. If the leakage resistance is even as high as a few megohms a small plate current may flow, producing an evident back-wave.

Choosing the Stage to Key

Radiation of a back-wave often can be prevented by keying a stage preceding the final amplifier. In such a case there will naturally be less likelihood of energy getting through to the antenna, since it would have to go through two or more stages instead of one.

If one of the early stages in the transmitter is keyed, the following stages must be provided with fixed bias sufficient to cut off plate current, or at least to limit the current to a safe value. Complete cut-off is preferable, since the possibility of back-wave radiation is reduced when no plate current at all is drawn by the tubes following the keyed stage. If sufficient bias for cut-off is not available, the plate current should at least be reduced to a value such that the d.c. input does not exceed the rated plate dissipation of the tube.

The stability of the transmitter can be adversely affected by keying if the keyed stage directly follows the oscillator. Practically all oscillators, including crystal-controlled types,

World Radio History

will exhibit some frequency change with changes in load. In a multi-stage transmitter the load on the oscillator is of course the input circuit of the following tube; since the resistance represented by this load changes when the tube is keyed, there will be a corresponding change in oscillator frequency. For this reason it is good practice to have a buffer stage between the oscillator and the keyed stage. Electron-coupled or Tri-tet oscillators are less subject to this difficulty than straight self-controlled or crystal oscillators because of the buffering action of the separate output circuit used in these oscillators.

If the oscillator itself is keyed for break-in work, chirpy keying will nearly always result, especially on the higher-frequency bands. On 14 Mc. and above, therefore, it is very advisable to forgo oscillator keying (and break-in) for the distinctly better keying that will result from keying a buffer and/or final stage. A back-wave is also more apparent on the 14- and 28-Mc. bands, for even a very weak signal will travel great distances with but little attenuation. It is well always to check any new keying system by listening to your signal on someone else's receiver at least a mile or so away, or on a well-shielded battery-operated monitor (so that power-line fluctuations with keying do not affect the monitor).

Plate Keying

A stage keyed in the power supply ahead of the filter is often advantageous, because the filter acts as a *lag* circuit, giving a desirable form to the keying characteristic. However, if much filter is used it will be found that the lag becomes too great for high-speed keying. For this reason, keying through the filter of the power supply should always be done only after consideration of the amount of filter.

A simple method of plate keying, adaptable mainly in small portable transmitters where the voltage is not high, is that shown in Fig. 901. The condenser C_1 should be varied to give just enough lag to overcome any tendency towards clicks. It is not advisable to use this system with high voltages unless a keying relay is employed.

Keying can also be accomplished in the center-tap of the plate transformer, but it is not advisable because it has no advantages

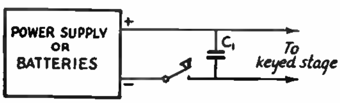


FIG. 901 — SIMPLE NEGATIVE-LEAD KEYING, APPLICABLE TO LOW-VOLTAGE STAGES

The condenser C_1 should be the minimum that will prevent any clicks. Between 0.25 and 1.0 μfd. will be about right.

over other systems and requires a well-insulated keying relay in all cases.

Primary Keying

Keying the primary of one or more plate transformers will result in excellent keying with no clicks or thumps on the signal, and only a small local click due to the spark at the key. This click is easily reduced by means of an r.f. filter (see Fig. 915). However, if adequate filter is used on the power supply the keying will be too "soft" and the lag too great,

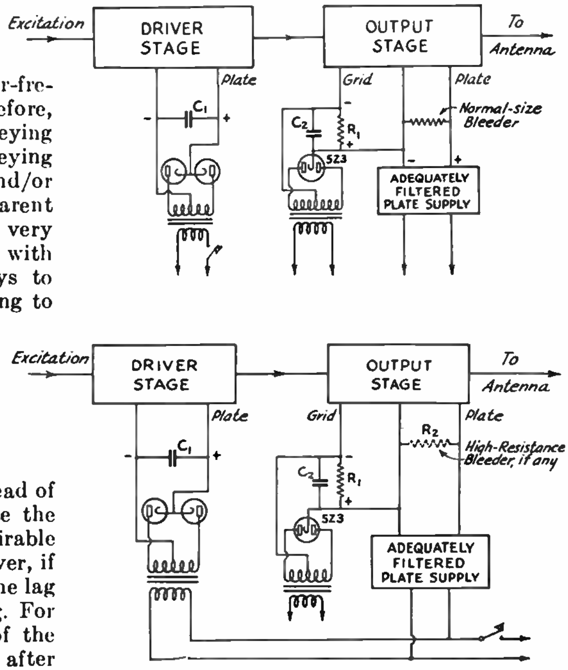


FIG. 902 — PRIMARY KEYING METHODS

The upper diagram shows only the driver stage keyed; the lower diagram shows keying of both driver and final stages. C_1 can usually be on the order of 1 μfd.; higher values will introduce "tails." C_2 should have a voltage rating capable of withstanding the bias developed across R_1, and should have a capacity of 4 μfd. or more. R_1 is the usual size of grid leak resistor for the tube or tubes used in the final stage, with a slightly greater-than-normal rating to withstand the extra current introduced by the bias supply.

and for this reason primary keying should be done in a driver stage, and *never* in the output stage. A driver stage, if it is *fully exciting* the driven stage, can have the filter reduced to a point where the keying will not be too soft and yet the excitation will not introduce much ripple on the signal.

Two methods of primary keying are shown in Fig. 902. Each method requires a bias pack capable of delivering cut-off bias for the final stage. The first shows keying of only the driver

World Radio History

stage, the second shows keying of both the driver and output stage. In the second method, since the final stage is biased to cut-off, the filter condensers of the final stage power supply will remain charged between characters, and care should be taken to see that these condensers are discharged when the station is shut down or coils are being changed. A high-resistance bleeder (R_2) of ¼-megohm or so will discharge the condensers to a low point after a period of time without impairing the keying. Keying with the two methods is equally effective.

Controlled Rectifier Keying

The advantages of primary keying, with the additional advantage of not having to break a heavy current with the key or keying relay, can be obtained with the controlled rectifier tubes recently made available to amateurs. These tubes can be obtained with either grid-control [1] or external magnetic control.[2] They can be used for power-supply keying in the same fashion as primary keying (Fig. 902) with the modification that where a primary was shown keyed, the rectifier tubes are keyed.

Representative grid-control keying circuits

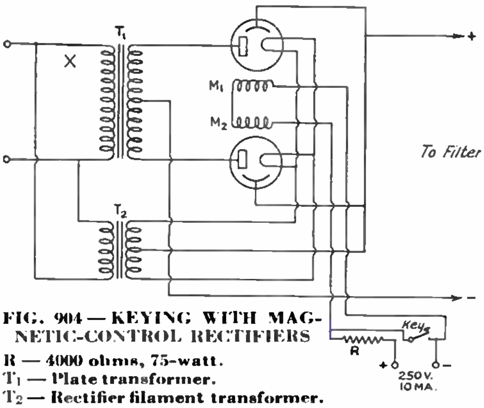


FIG. 904 — KEYING WITH MAGNETIC-CONTROL RECTIFIERS

R — 4000 ohms, 75-watt.
T_1 — Plate transformer.
T_2 — Rectifier filament transformer.
X — Switch to allow preheating filaments.
M_1, M_2 — Magnet coils, wound on U-shaped cores the ends of which are placed on either side of the tube. 5000 turns of No. 34 or 36 wire on a half-inch square silicon steel laminated core, approximately 1½″ long on each side of the U (Raytheon U3372).

are shown in Fig. 903, and a magnetic-control diagram is shown in Fig. 904.

Controlled-rectifier tubes cannot be used as keyer tubes in d.c. circuits but only in a.c. applications. Unlike the normal triode vacuum tube, the grid loses control of the current once the current has started flowing, and the only way the grid can regain control is to have the plate voltage reduced to zero. This happens during the negative half of an a.c. cycle, and makes it possible to use the tubes.

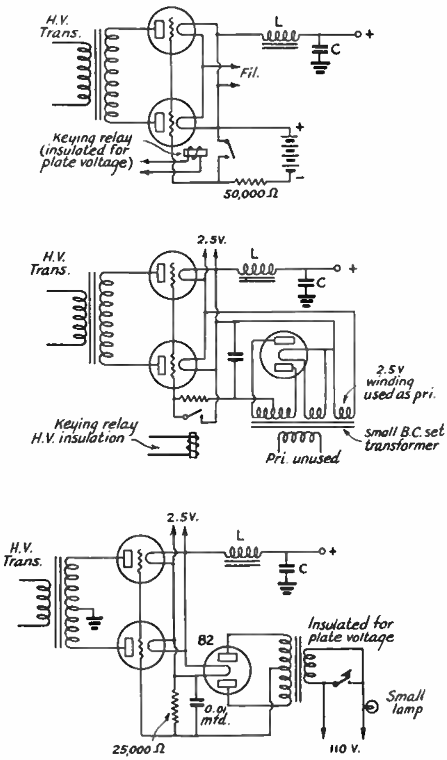


FIG. 903 — KEYING WITH GRID-CONTROL RECTIFIERS

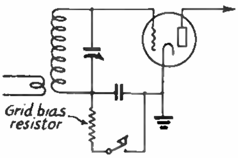
The two upper systems require high-voltage-insulated relays for keying. These can be made easily from old trickle-charger automatic switches, with the contacts placed on bakelite outriggers. The contacts can be small because the current is negligible. The lower diagram shows a system requiring no relay but necessitating a well-insulated transformer. The voltage from the keying transformer should be 300 or more volts each side of center tap.

Grid Keying

Grid keying methods operate on the principle of controlling plate current flow through application of proper bias values with the key opened and closed. Two representative arrangements are shown in Fig. 905. The upper drawing shows the key inserted in series with the grid leak or grid return circuit. With the key closed, the amplifier or oscillator operates normally; with the key open, there is no d.c. path between grid and filament, consequently the electrons drawn to the grid by the exciting voltage remain trapped on the grid causing it to assume a highly negative charge. If there is no leakage in the grid-filament circuit the negative charge will be sufficient to cut off completely the flow of plate current and therefore the power output. The system works best with high-μ tubes: it may be found impossible to completely cut off low-μ tubes.

World Radio History

Another method of accomplishing the same result, in this case through supplying additional fixed bias of sufficient value to cut off plate current flow despite excitation, is shown in the lower drawing of Fig. 905. Grid-leak bias for normal operation is shown, although a battery or other bias source could be substituted for the leak. With the key closed, the lower end of the leak is connected to the filament center tap. When the key is opened, additional bias from the blocking-voltage source is connected in series with the leak through the resistor R. The chief function of R is to limit the flow of current when the key is closed, since without R the key would be a direct short circuit. The value of R is not critical but should be quite high — at least 5000 ohms for every 45 volts — to limit the current to a safe value. The additional bias voltage required to cut off plate current (or "block" the grid) will depend upon the amplification factor of the tube and the amplitude of the excitation voltage; it must at least be equal to the peak positive grid swing plus the bias required to cut off plate current without excitation. Since it is difficult to measure or calculate the grid swing, the operating value of keying bias had best be determined experimentally. If the amplifier or oscillator is operating Class-C, the keying bias required probably will be two or three times the normal operating bias (twice cut-off). For example, if the Class-C operating bias is 200 volts the total bias required to block the grid probably will be 400 or 500 volts. Smaller bias would serve for an amplifier with less excitation.



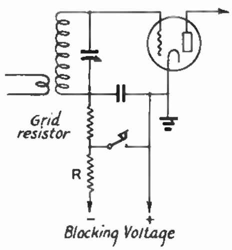


FIG. 905 — METHODS OF BLOCKED-GRID KEYING

Grid-block keying systems are best adapted to stages using high amplification-factor tubes working without too much excitation, otherwise the value of voltage required to completely cut off the output becomes too large.

Center-Tap Keying

A combination of both grid and plate circuit keying is shown in Fig. 906. This method, known as center-tap keying, has attained wide popularity. In center-tap keying, one side of the key is connected to the midpoint of the filament center-tap resistor or to the center-tap of the filament transformer; the grid and plate returns connect to the other side of the key. In this way both grid and plate returns are opened when the key is open.

Center-tap keying combines some of the good and bad features of both grid and plate keying.

Suppressor-Grid Keying

Multi-element tubes (screen-grid, pentode, and beam-power) can all be keyed by the foregoing methods, since they operate on d.c. circuits common to all types of tubes. However, the multi-element tubes allow further methods.

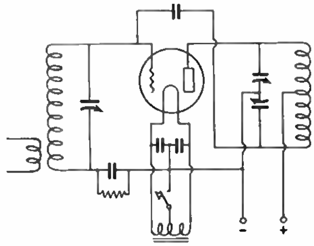


FIG. 906 — CENTER-TAP KEYING

With heater-type tubes, the key would be placed in the cathode lead rather than in the filament center-tap lead as shown.

Keying the suppressor grid of a pentode-type tube usually will be found to be quite satisfactory. The plate current can be completely cut off by placing a small negative voltage on the suppressor grid — 100 to 200 volts is adequate in most cases. Merely inserting the key in the suppressor lead is not sufficient to cut off the power output, so it is necessary to arrange the keying circuit to put negative bias on the suppressor grid when the key is open. Fig. 907 illustrates one method, using a separate power pack which supplies keying bias, that has been used in a number of stations with excellent results. With the key open, the suppressor receives negative bias through the 50,000-ohm resistor, the value of bias being adjusted to cut off plate current. When the key is closed, the suppressor bias is brought to zero through return to the cathode. The 50,000-ohm resistor prevents short-circuiting the bias supply. The combination of R_1 and C_1 forms a lag circuit for the elimination of clicks. The resistor and condenser can have practically any value, so long as their product (ohms times microfarads) is around 5000. It is not wise to have the value of resistance too high, however. From 5000 to 10,000 ohms is about right. The power pack can also be used to supply bias voltage for the following stages.

Screen-Grid Keying

In screen-grid tubes, whether of the tetrode or pentode type, the screen potential has a very marked effect on the plate current, and therefore the output of the tube. Screen-grid tubes often can be keyed by inserting the key in the positive screen lead, especially when the screen voltage is obtained from a supply separate from that furnishing the plate power. If the screen voltage is obtained from the plate supply through a dropping resistor, this method of keying is unsafe with high-voltage tubes unless a keying relay is used, because the potential on one side of the key rises to the full plate potential when the screen current is cut off. Opening the screen circuit does not always reduce the output to zero, however, so screen keying is seldom used, although it has some application in oscillator keying, as will be described later.

Keyer Tubes

Vacuum-tube lag-circuit keying arrangements are shown in Fig. 908. They may be used in the plate, screen-grid, or center-tap circuits of any amplifier which is to be keyed. When the key is open, high negative bias is placed on the grid of the keyer tube so that the plate current is completely cut off. When the key is closed the grid of the keyer tube is connected to its filament and the tube acts like a resistance of low value, thus permitting plate current to flow in the keyed stage.

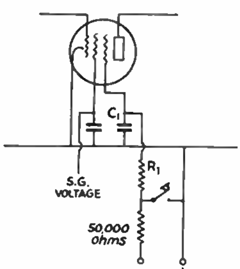


FIGURE 907 — SUPPRESSOR-GRID KEYING

The condenser C_1 can be the usual 0.01-μfd. by-pass shunted by a larger condenser to give the proper time-constant.

The time-constant of the resistance and capacity in the grid circuit of the keyer tube provides the slow build-up of power output which prevents clicks. Since the key is in a low-voltage low-current circuit, the transients set up in the key circuit itself are of small intensity. The keyer tube has some resistance even though the grid is connected to the filament when the key is closed, so the plate voltage on the keyed stage will be lower than with other keying systems. To overcome this, several tubes may be connected in parallel. Tubes of the 45 type are excellent for low-power transmitters because their plate resistance is low. One 45 should be used for each 50 ma. of plate current required by the tube being keyed. The filament transformer for the keyer tubes

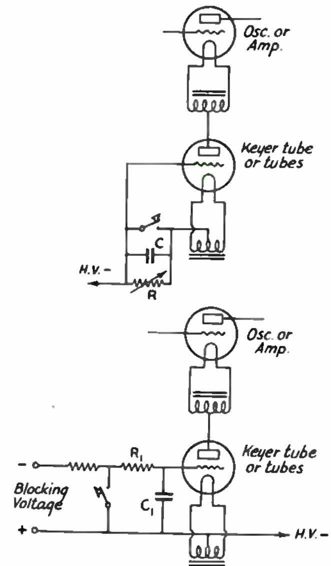


FIG. 908 — VACUUM-TUBE KEYING

The series method is simple but does not completely cut off the current flow. It may be used in some applications where the following stage is heavily biased. C may be between 0.25 and 1.0 μfd. Resistor R should be adjusted to cause the plate current to drop to a minimum when the key is open. A variable resistor of 50,000 ohms should give enough range.

The system with external bias is very effective. R_1 and C_1 give the variable time-constant, and should be proportioned as described under suppressor-grid keying.

need not be center-tapped: in fact, the tubes may be connected in series if desired.

Tube keying is used in a large number of commercial high-speed transmitters and is well worth investigating by the serious amateur interested in good keying.

Sources of Bias

If a multi-stage transmitter is keyed in one of the low-power stages, it is necessary to bias the following stages so that they will not draw plate current with the key up. A simple a.c. power supply is ordinarily used for this purpose, although batteries can be substituted. The grid leak resistor will be placed across the output of the bias supply and, in cases where large amounts of grid current are drawn at fairly low voltages (low resistance grid leak), the bias supply must run at fairly heavy current. For example, if the final amplifier is to

World Radio History

run with 400 volts bias at 100 ma., a grid leak of about 4000 ohms will be used. But if the cut-off bias is 200 volts, the grid resistor will draw 50 ma. from the bias supply. This relatively heavy drain must always be considered when building a bias supply. Also, the grid leak resistor must be heavy enough to stand the current and the filter condensers must have a high-enough voltage rating to stand the full bias voltage.

If the bias supply is to be used only for keying, as in the case of grid-block or suppressor-grid keying, a very small b.c. transformer may be used, its only requirement being that it furnish sufficient voltage.

It is possible to obtain keying bias without extra cost from the power supply used for low-power stages in multi-stage transmitters, when the keyed stage has its own separate supply. This can be done as illustrated in Fig. 909. The plate power supply for the exciter tubes is utilized as a keying bias supply for the keyed amplifier. Since this entails connecting the positive terminal of the low-voltage supply to the negative terminal of the high-voltage supply, the filament circuits of the tubes working from the two supplies cannot be connected together. In Fig. 909, the condenser C serves to put all cathodes at the same r.f. potential without direct connection between them. Resistor R limits the current when the key is closed, as already explained. A value of 50,000 ohms will suffice for a low-voltage supply of 400 volts or so. It should have a rating of about 5 watts.

Keying for Break-In Operation

Break-in operation requires that there be no local signal from the exciter stages when the key is up, and therefore oscillator keying followed by biased stages is dictated, except in the few instances where it is possible to locate the transmitter a mile or more from the receiving location. Any of the keying systems described can be used to key a crystal or electron-coupled oscillator but care must be taken to see that the stability of the signal is not affected.

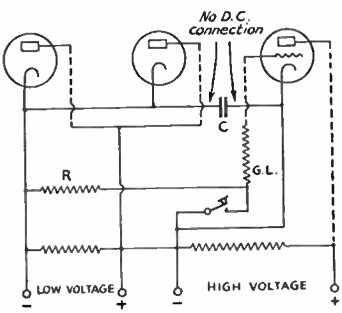


FIG. 909 — UTILIZING THE LOW-VOLTAGE POWER SUPPLY FOR BLOCKING BIAS IN BLOCKED-GRID KEYING

Experience has shown that the use of a voltage divider instead of a simple series resistor for the screen of the oscillator tube helps materially in eliminating chirps. Cathode keying of the oscillator is simple and usually effective. Two methods of keying in the cathode circuit are shown in Fig. 910, and screen-grid keying is shown in Fig. 911. The suppressor-grid of a Tri-tet oscillator may be keyed, as in Fig. 907,

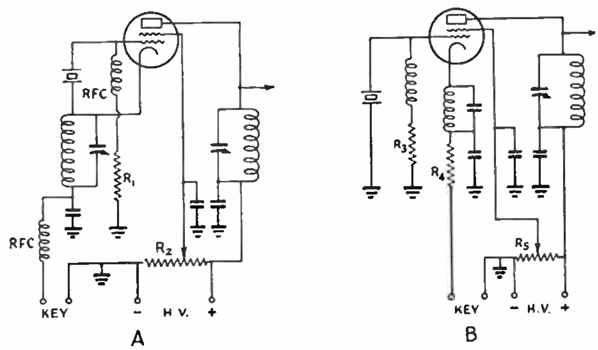


FIG. 910 — CATHODE KEYING FOR TRI-TET OSCILLATOR

Typical values for 6L6: R_1 — 50,000 ohms; R_2 — 20,000 ohms. B — Cathode keying for grid-plate oscillator. Typical values for 6L6: R_3 — 50,000 ohms; R_4 — 400 ohms; R_5 — 20,000 ohms.

but the crystal will oscillate weakly all of the time, as in the case of screen-grid keying, resulting in a signal in the receiver on the crystal frequency even with the key in the "open" position. For this reason, screen-grid and suppressor-grid oscillator keying are not recommended for net-frequency operation unless the transmitter is well-removed from the receiving location.

Crystal keying may also be used to advantage, and two typical circuits are shown in Fig. 912. The grid-block system for keying a complete transmitter, shown in Fig. 913, has the merit that all stages are blocked when the key is up and a low-current bias supply can be used.

If it is found difficult to key an oscillator without a chirp, loosening the loading on the oscillator may cure it. If it is a pentode-type oscillator, the capacity of the tuning condenser should be decreased slightly instead of running the tube at its maximum output point. Decreasing the capacity of the cathode condenser will help in the case of a Tri-tet oscillator.

If an electron-coupled oscillator chirps under keying, it may be that the grid-circuit tank utilizes too low-C a circuit, and taking turns

World Radio History

off the coil and increasing the condenser size will help. Detuning the plate circuit will also contribute to the stability, as will careful proportioning of the screen and plate voltages. A major cause of poor e.c.o. stability is incomplete shielding from the high-powered portion of the transmitter, and it is advisable to remove the e.c.o. from the transmitter proper and place it in a well-shielded box on the operating table if any chirp persists.

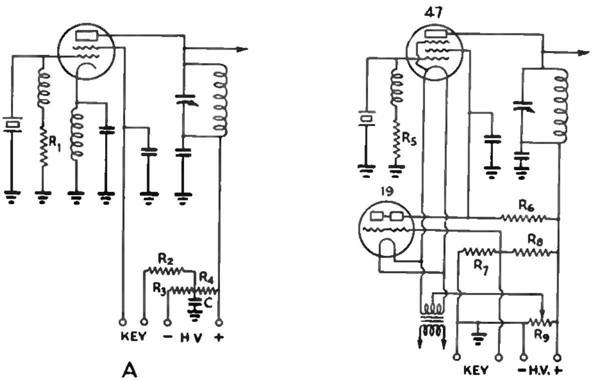
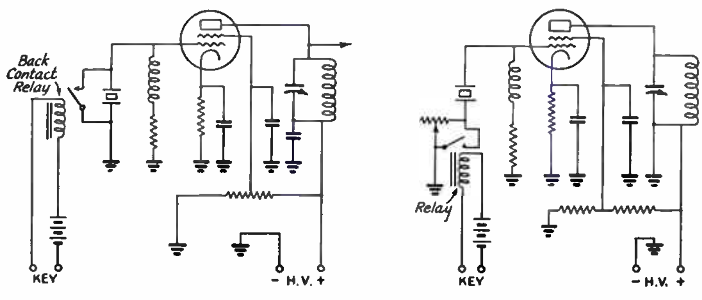


FIG. 911 — TWO SYSTEMS FOR SCREEN KEYING OF TETRODES OR PENTODES

A — For 89 or 802: R_1 — 7500 ohms; R_2 — 5000 ohms; R_3 — 30,000 ohms, 20 watts; R_4 — 40,000 ohms, 20 watts. B — R_5 — 10,000 ohms; R_6 — 75,000 ohms; R_7 — 10,000 ohms; R_8 — 100,000 ohms; R_9 — Usual plate supply bleeder.



A B

FIG. 912 — CRYSTAL KEYING CIRCUITS

Keying Transients or Clicks

When power is applied or removed from a circuit very suddenly, as is the case when a transmitter is keyed, the energy thus instantaneously released surges back and forth in the circuit until equilibrium is reached. This is called "shock excitation." A familiar mechanical analogy is the vibration of a tuning fork or a bell when tapped with a small hammer or mallet. Shock-excited oscillations are highly damped in most circuits and therefore have no sharply-defined natural period. In other words, such an electric oscillation, if radiated, can be detected in receivers tuned to frequencies widely different from that on which the actual transmitting is being done. Since the duration of the oscillation is short, it is heard as a "click" or "thump" in the affected receiver. The click on closing the key usually is much more pronounced than on opening, although under certain conditions the reverse may be true.

Because the amount of energy involved is small and is distributed over a wide band of frequencies, the interference-producing effects of keying transients usually are confined to an area quite close to the transmitter except on frequencies within a few kilocycles of the transmitting frequency. In other words, key clicks are likely to be observed on only those broadcast receivers located within a hundred yards or so of the transmitter, but may cause interference to amateur stations hundreds of miles away working in the same portion of the same band.

Obviously it is to the interests of the amateur himself to prevent key clicks, not only because of a possible unfavorable reaction on the part of nearby broadcast listeners but also to prevent unnecessary interference in the amateur bands.

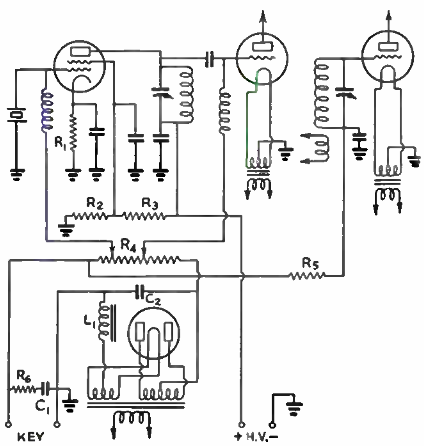


FIG. 913 — BLOCKED-GRID KEYING SYSTEM FOR BREAK-IN

R_1, R_2, R_3 — Usual values; R_4 — 20,000 ohms, 50 watts; R_5 — Final stage grid leak.

World Radio History

Prevention of Key Clicks

There are two general methods of attack in preventing keying transients. The first is by feeding the power to the transmitter at a comparatively slow rate on closing the key and shutting it off gradually instead of suddenly on opening the key. The second is by the use of radio-frequency filters which absorb the transient before it can get to a part of the circuit from which radiation is possible. Both methods have been very successful.

In the first method, an inductance of a few henrys is inserted in the circuit, usually in series with the key. As explained in Chapter Three, an inductance coil possesses the property of opposing a sudden change of current in a circuit. Regardless of the method of keying used, insertion of inductance in series with the key will have the effect of causing the plate current to build up to its final value at a comparatively slow rate, since some current, no matter how small, always flows in the key circuit.

The energy stored in the electromagnetic field of the inductance when the key is closed is suddenly returned to the circuit when the key is opened. If the current in the circuit is appreciable, the inductive discharge will cause an arc or spark to form at the key contacts at the moment of opening. The spark not only causes undue wear on the contacts but also is a secondary cause of key clicks, since the key circuit acts somewhat like a miniature spark transmitter. An effective remedy for this condition is to shunt a condenser (usually from 0.25 to 1 μfd.) across the key to absorb the spark. The energy stored in the inductance is released through the condenser instead of at the key contacts and thus tends to prevent the sudden cessation of power on opening the key.

In most keying circuits there is an appreciable voltage across the key contacts when open, hence the condenser in the key-click filter will receive a charge. On closing the key the charge is dissipated in the key contacts, again causing a spark, unless a resistor of suitable value is put in series with condenser and key to absorb most of the energy. The value of the resistor will depend, as is apparent from the foregoing discussion, upon the capacity of the condenser and the voltage appearing across it when the key is open. Because of the variable nature of these factors it is difficult to give definite specifications. However, a resistor of from 50 to a few hundred ohms usually will be found to absorb the spark satisfactorily.

Lag Circuits

Three representative lag circuits are shown in Fig. 914. The one shown at *B* is a more complex version of the one shown at *A*, and can be tried in hard-to-cure cases. That at *C* is a novel system that has worked well in several cases.

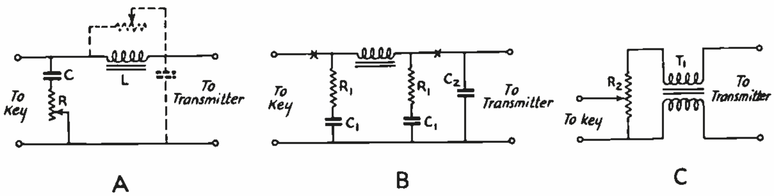


FIG. 914 — LAG CIRCUITS FOR ELIMINATING THUMPS AND CLICKS

The primary of a bell-ringing transformer will usually serve at L in low-powered transmitters.

C — 0.25 to 1.0 μfd.
C_1 — 0.5 μfd.
C_2 — 0.006 μfd.
R — 50–200 ohms.
R_1 — 100 ohms.
R_2 — 500–25,000 ohms.
T_1 — Bell-ringing transformer.

Radio-frequency chokes may be necessary at "x" in B.

Lag circuits should be used in keying when it is found that the signal itself has a thump or click on it, as reported by other amateurs. A click in local b.c. receivers may often be caused by only the spark at the key and can be cured by a simple r.f. filter.

R.F. Filters

With an r.f. key filter the transient oscillations set up at the key are prevented from reaching the transmitter and being radiated. To be most effective, this type of filter must be installed right at the key, since connecting leads of even a few feet between key and filter are long enough to permit radiation of clicks and consequent interference to nearby receivers. In fact, the same thing is true of the lag circuits previously described — even though they perform their intended function of preventing the sudden application and cessation of power, transients in the keying circuit itself may be radiated to cause interference. Short leads usually will prevent such a condition, although in some cases it may be necessary to install an r.f. key filter as well.

An r.f. key filter usually consists of a pair of r.f. choke coils having an inductance of ten millihenrys or so, connected in series with each of the key contacts and shunted by a con-

World Radio History

denser as shown in Fig. 915. The condenser ordinarily will have a capacity of 0.1 to 0.5 μfd. The combination acts like a low-pass filter, preventing transients at broadcast or higher frequencies from getting to the transmitter itself and being radiated. As with the lag circuit, some experimenting with different inductance and capacity values probably will be required for effective elimination of clicks in individual transmitters.

Parasitics and Key Clicks

If it is found that the use of standard key click filters has little or no effect upon clicks, an investigation should be made to determine if parasitic oscillations are taking place in any of the transmitter circuits. In any case, it should be possible to adjust the bias of any amplifier so that some plate current is drawn without the amplifier going into oscillation. If oscillations do take place, steps should be taken to prevent it because the chances are good that self-oscillations may have a tendency to start each time the key is closed resulting in bad key clicks even though the oscillation is immediately killed off by excitation.

Other Considerations in Key Click Prevention

It is reasonable to expect that less trouble will be encountered in eliminating key clicks if the power supply for the keyed stages has good voltage regulation (see Chapter Fourteen). If the voltage regulation is poor, the plate voltage with the key open may be 50% to 100% higher than with the key closed; hence, at the instant of closing the key there is an impact at much higher than normal voltage. This intensifies the key click. If the power supply regulation is good — that is, if the plate voltage is substantially the same whether zero or full plate current is being drawn — the tendency towards clicks is lessened.

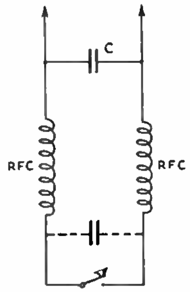


FIG. 915 — AN R.F. FILTER FOR THE ABSORPTION OF KEYING TRANSIENTS

It is ordinarily used without a condenser directly across the key. However, an improvement sometimes results when a condenser of about .002 μfd. is connected as shown by the dotted lines.

Key clicks are less likely to be radiated if the antenna or feeder system is inductively coupled to the transmitter rather than directly or capacitively coupled. If the feeders are tapped on the final tank coil or are conductively or capacitively coupled through a low-pass filter, comparatively little impedance is offered to transients covering the broadcast band. A considerable improvement in key click reduction often can be secured simply by changing a non-inductively coupled system to one in which the transmitted energy must be air-transferred at some point before reaching the antenna. Care should be taken to prevent stray capacitive coupling.

Not all key-click interference with broadcast reception is radiated from the antenna. It may be radiated from the transmitter itself or from connecting wires. Shielding of transmitter and wiring often will result in a considerable improvement in this respect, although it is not always necessary.

It is always desirable and in some cases may be necessary to run the 110-volt leads to the transmitter in BX cable, grounding the outer shield. Shielding of the keying leads also may be helpful, especially if a long line is run between the transmitter and the key. Whenever shielded wire is used the shield should be connected to a good ground, otherwise the shielding is likely to be ineffective.

To prevent keying transients from being carried over house wiring and power lines from the transmitter to nearby receivers, a filter may be installed in the 110-volt line which feeds the power transformers. Such a filter is shown in Fig. 916. It consists of a pair of radio-frequency choke coils, one in each leg of the line, and a pair of condensers in series across the line with their mid-connection grounded. These filters are commercially available in most radio stores, but can easily be assembled in the home workshop.

The wire of which the chokes are wound must be heavy enough to carry the current taken by the power-supply system. No. 14 or No. 16 will be sufficient in most cases. Mailing tubes or pieces of broomstick make good winding forms for these chokes. Between 100 and 300 turns will be required. The condensers may be 0.1-μfd. units rated at 200 volts or more.

Power transformers with electrostatic shields between the primary and secondary windings are helpful in preventing interference from being carried by the supply lines, provided the shield is connected to a good ground, and often will make extra chokes and condensers unnecessary.

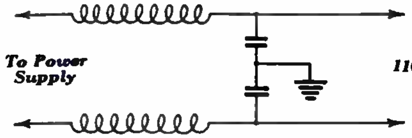


FIG. 916 — R.F. FILTER FOR THE POWER LINE

World Radio History

Keying transients are less likely to get through to the antenna if the keying is done in a stage preceding the final amplifier. The tank circuits following the keyed stage give a band-pass effect which tends to reduce the amplitude of the transient.

Keying Methods from the Standpoint of Click Prevention

Generally speaking, it is easier to prevent clicks if the keying method used is one in which the keyed current is small, although there may be occasional exceptions to this rule. First choice, then, naturally would fall to those methods which key a control or suppressor grid rather than the plate circuit, since grid current is usually small compared to the plate current for the same tube. This has an economic advantage as well, since the chokes comprising the key-click filter are less expensive the smaller the current they have to carry.

Center-tap keying, Fig. 906, usually is less troublesome in producing clicks than simple plate or negative high-voltage keying. However, the current interrupted by the key is comparatively large. The fact that the grid circuit is keyed along with the plate tends to lessen keying impacts.

There is little to choose between the grid-keying methods shown, although suppressor-grid keying may have some slight advantage over control-grid keying in the case of pentodes. The keyed current is usually very small. The chief objection to grid-keying methods is the necessity for providing additional keying bias.

Blanketing

Keying transients or clicks are not the only source of interference to nearby broadcast reception, although probably the most prevalent and the type requiring the most careful attention. A second type of interference, called "blanketing" because it causes the program to disappear or come in at reduced strength whenever the key is closed, also is common. It is simply a proximity effect, the affected receiver picking up enough of the radiated energy to cause overloading of one or more of the receiver tubes with a consequent reduction in amplification. This type of interference can be minimized by moving the broadcast antenna away from the transmitting antenna or by changing its direction. The pick-up will be least if the two antennas are at right angles to each other.

In severe cases it may be necessary to install a wave-trap at the receiver to prevent blanketing. A wave-trap consists simply of a coil and condenser connected as shown in Fig. 917. The condenser may be an old one with about 250 or 350 $\mu\mu$fd. maximum capacity and need not be especially efficient. Most amateurs have "junk boxes" with several such condensers in them. The size of the coil will depend upon the frequency on which the transmitter is working. Representative values are given in the table.

Frequency of Interfering Signal	*Coil (3" dia.)*
1,715–2,000 kc.	20 turns
3,500–4,000 kc.	8–10 "
7,000–7,300 kc.	4–5 "
14,000–14,400 kc.	3 "

Bell wire (No. 18) or a size near to it may be used. When the trap is installed the transmitter should be started up and the condenser in the trap adjusted to the point where the interference is eliminated. This trap will not affect the operation of the broadcast receiver.

Blanketing may be and generally is accompanied by key clicks. The wave trap may help to eliminate the clicks but usually a key click filter will be needed as well. A key click filter alone cannot eliminate or even alleviate the blanketing effect.

Low-Pass Filters for Blanketing

The chief disadvantage of the wave-trap is that it has to be retuned if the transmitting

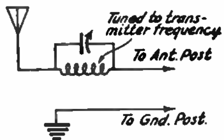


FIG. 917 — HOW A WAVE-TRAP CAN BE INSTALLED TO PREVENT CERTAIN TYPES OF INTERFERENCE

frequency is changed from one band to another, and sometimes also if the frequency change is only from one end to the other of the same band. In such cases a better arrangement is the low-pass filter, designed to reject all received frequencies except those below a certain critical frequency. If the critical frequency is chosen just below the lowest amateur frequency used, the transmitter can be shifted from one band to another without the necessity for readjustment of a wave trap. A typical low-pass filter is shown in Fig. 918. The constants given are for a cut-off frequency of 1600 kilocycles. The filter is designed for terminating impedances of 400 ohms.

Another type of filter which has a sharper cut-off than the one just described is shown in Fig. 919. This is of particular advantage for 'phone stations operating in the 1800- and 3900-kc. bands, since maximum attenuation is in the middle of those bands, the nominal cut-off being somewhat lower. The type A filter has greatest attenuation at 1930 kc., with cut-off beginning at 1670 kc. Type B has greatest attenuation at 3950 kc., with cut-off beginning at 2470 kc. The type A is recommended for work in several bands.

Superheterodyne Harmonics

A third type of interference is peculiar to superheterodyne broadcast receivers. A strong signal from the transmitter will be heard at three or four points on the dial, while over the rest of the tuning range there may be no sign of interference. The explanation lies in the fact that the transmitted signal is picked up by

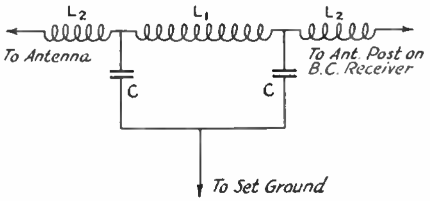


FIG. 918 — A LOW-PASS FILTER FOR REDUCTION OF INTERFERENCE WITH BROADCAST RECEPTION

It should be installed at the receiver. Constants are as follows: L_1, 54 turns of No. 24 d.s.c. on 1⅝-inch diameter form; L_2, 33 turns same; C, 500 μμfd. fixed. Cut-off frequency is approximately 1600 kc.

beating with harmonics of the superheterodyne oscillator and amplified by the i.f. stages in the receiver. If the receiver is properly shielded and the oscillator is isolated from the antenna circuit, the signal from the transmitter cannot get into the oscillator circuit to be mixed with its harmonics and this type of interference cannot occur. When it *does* occur the fault does not lie with the transmitter but with the broadcast receiver, and nothing can be done to the transmitter to prevent such interference. A wave-trap may help if the transmitter signal is brought into the receiver through the antenna, but in some cases the pick-up is direct because the receiver is inadequately shielded, and the interference is just as strong whether the antenna is connected to the receiver or not.

Often interference of this type with a nearby broadcast receiver can be eliminated by changing the operating frequency of the transmitter.[4]

Rectifier Noise

Mercury-vapor rectifiers often are the source of a peculiar and easily identifiable type of interference which takes the form of a raspy buzz with a characteristic 120-cycle tone (100 cycles on 50-cycle power lines and 50 cycles on 25-cycle lines) often broadly tunable in spots on the broadcast receiver dial. At the instant the mercury vapor ignites on each half cycle of the power frequency an oscillation is set up, the frequency depending upon the characteristics of the power supply apparatus. Unless suitable precautions are taken the oscillations will be radiated or will travel back over the power line and be detected in receivers connected to the line.

The line filter shown in Fig. 916 usually will suppress this type of noise. Sometimes the condensers alone will do it, no chokes being necessary. Transformers with electrostatic shields between primary and secondary are not likely to transmit the oscillations to the line. Other ways of curing this type of interference are shown in Fig. 920. They include shielding of the rectifier tubes, connecting a radio-frequency choke between each plate and the transformer winding, and shunting fixed condensers of about .002 μfd. capacity between the outside ends of the transformer winding and the center-tap. The condensers should be rated to stand at least 50% more voltage than the r.m.s. voltage delivered by half of the secondary winding.

Sometimes making the plate leads to the rectifiers extremely short will be sufficient to eliminate the interference.

Checking Your Keying

When a new transmitter is first put on the air, or when changes are made in the power supply or keying system, it is advisable to check the keying and note to make sure that everything is in order. Although it is possible to listen to one's own signal with a modern superheterodyne or a.c.-operated monitor, such methods will often lead to false impressions of the signal because the line voltage is almost certain to fluctuate with keying, resulting in a slight chirp in the monitor's frequency unless a stabilized power supply is used. A well-shielded battery-operated monitor can be used, or you can have the transmitter keyed

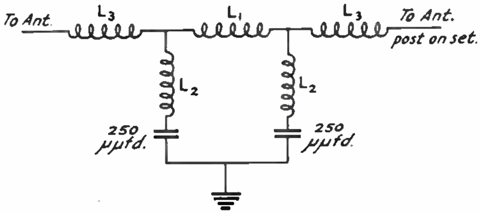


FIG. 919 — CIRCUIT DIAGRAM OF SHARP CUT-OFF LOW-PASS FILTER

Inductance in Microhenries

Type	L_1	L_2	L_3
A	38	28	19
B	40	6	20

Coil Specifications

Microhenries	Turns	
6	10	No. 28 d.s.c. wire
19	18	" " "
20	19	" " "
28	24	" " "
38	29	" " "
40	30	" " "

Coils wound on 1⅜"-diameter form.

World Radio History

by an amateur friend while you listen to your signal at his receiver some distance away. Signals that sound satisfactory right in the station (due to compensating effects of fluctuating line voltage) will often be found to have unpleasant characteristics when copied on a stable receiver some distance away. Don't take the other fellow's word for it. Make sure.

Remember that a poorly-keyed signal that chirps and clicks is an indication of your selfishness and carelessness. Don't have one!

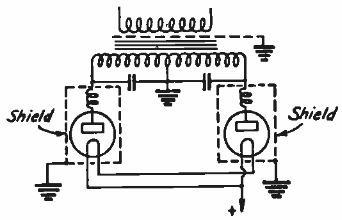


FIG. 920 — DEVICES FOR ELIMINATING NOISE FROM MERCURY-VAPOR RECTIFIER TUBES

The r.f. chokes in series with each plate should be placed inside the shields enclosing the rectifiers. The chokes should have an inductance of about 10 millihenrys each. Small honeycomb-type windings are suitable.

Checking for Interference with Broadcasting

One's own broadcast receiver, if of modern design, is a good "subject" for experimenting with key click filters and other interference-prevention methods. If interference can be eliminated in a receiver in the same house, operating from the same power line and with an antenna close to the transmitting antenna, the chances are good that there will be no general interference in the neighborhood. The amateur should ascertain, however, whether or not interference is caused in nearby broadcast receivers. If your neighbors appreciate that you are as much interested in preventing interference to their enjoyment of broadcast programs as they are, much more can be accomplished than by acrimonious disputes. It is better to settle the interference problem right at the beginning than to trust to luck with the possibility of an unfavorable reaction towards amateur radio in general and yourself in particular on the part of nearby broadcast listeners.

In searching for causes of interference, it is a good idea to have someone operate your transmitter while you listen on the affected receiver. Remove the antenna from the receiver, and if the interference disappears it is certain that it is coming into the set through the antenna, which simplifies the problem. The various types of interference prevention already described should work under these conditions. If the interference persists when the antenna is removed, however, it is probably getting into the receiver through the power lines. This happens occasionally with a.c. operated broadcast receivers.

House wiring may pick up r.f. either directly from the antenna or through the power-supply system of the transmitter. If the 110-volt line is found to be picking up energy directly from the antenna it is advisable to change the location of the antenna, if possible, or run it in a different direction, not only because of interference to broadcast reception but because energy so picked up is useless for radiation and decreases the effective range of the transmitter. This is particularly important when, as often happens, electric lamps in different parts of the house are found to glow when the key is pressed. The energy used in lighting the lamps is wasted.

If r.f. is found to be getting into the line through the power-supply equipment, a line filter such as is shown in Fig. 911 should be used, together with power leads in grounded BX.

Interference usually decreases as the transmitter frequency is raised. In many cases where bad interference is caused on the 1750- and 3500-kc. bands, changing to 7000 or 14,000 kc. will cure it.

Radiotelephone Interference

Key-click filters are naturally of no value on transmitters used exclusively for 'phone transmission, since clicks do not occur. A phenomenon similar to key clicks can take place if the transmitter suffers from frequency modulation or from over-modulation, because both these defects cause the radiation of side-bands often far removed from the band of frequencies normally required for the transmission of speech. These abnormal side-bands can and frequently do cause interference in the broadcast band, often just as a series of unintelligible noises when the transmitter is modulated. The obvious remedy is to use a radio frequency system in the transmitter whose frequency does not vary when modulation is taking place, and to adjust the transmitter so that over-modulation or "lop-sided" modulation does not occur. Chapter Ten covers this subject.

Blanketing and other forms of interference caused by r.f. pickup can be treated in exactly the same way as described previously. Wave-traps or low-pass filters in the receiving antenna lead-in and r.f. filters in the power lines will prove effective in eliminating this type of interference.

Bibliography

[1] *QST*, February, 1938, page 34. [2] *QST*, September, 1938, page 42. [3] *QST*, September, 1938, page 30. [4] *QST*, September, 1937, page 12.

CHAPTER TEN

RADIOTELEPHONY

Principles of Modulation — Design and Construction of Speech Amplifiers and Modulators

Radiotelephone transmission is accomplished by modulation of a radio-frequency "carrier" output. "Carrier" is a term normally applied to the radio-frequency output of a c.w. telegraph transmitter when the key is kept in a closed position. For telegraphy the desirable characteristics of this carrier include constancy of frequency and constancy of amplitude. For 'phone operation, on the other hand, the above two desirable characteristics simply form a basis for proper operation. To a carrier normally fulfilling these requirements is added audio-frequency power which is controlled, both in frequency and amplitude, by the operator's voice.

Chapter Eight covers the subject of obtaining carrier output of the sort necessary for high-quality 'phone transmission. Audio-frequency power may be used to control the output of the r.f. section of the transmitter in any of several successful modulator arrangements, and there are many combinations of microphone and speech amplifier to choose from for controlling the modulator used.

A complete 'phone transmitter is made up of r.f., audio-frequency, and power supply elements as shown in the block diagram of Fig. 1001. Different arrangements for oscillator, doubler, buffer and final r.f. amplifier are given in Chapter Eight; and power supplies which may be used with r.f. and audio stages are given in Chapter Fourteen. In order to construct a transmitter of this type it is first necessary to provide the radio-frequency section and adjust it for dependable operation with stable output. A modulator must then be constructed (if plate modulation as shown in Fig. 1001 is to be used, the modulator should be capable of delivering an audio output equal to half the power input to the final amplifier), a microphone must be obtained, and an amplifier must be added for building up the small output of the microphone to a power sufficient for driving the modulator.

This completes the apparatus for 'phone operation, but the final step — proper adjustment and coördination of the different sections — is a very important one. The output of the transmitter should be that earlier described for a good carrier when no sound actuates the microphone; the output of the modulator should be a magnified but accurate reproduction of the sound waves affecting the microphone; and the modulation of the transmitter output should correspond exactly to this modulator output.

Of the several possible methods of modulating a radio-frequency wave, only one system, that known as amplitude modulation, is of

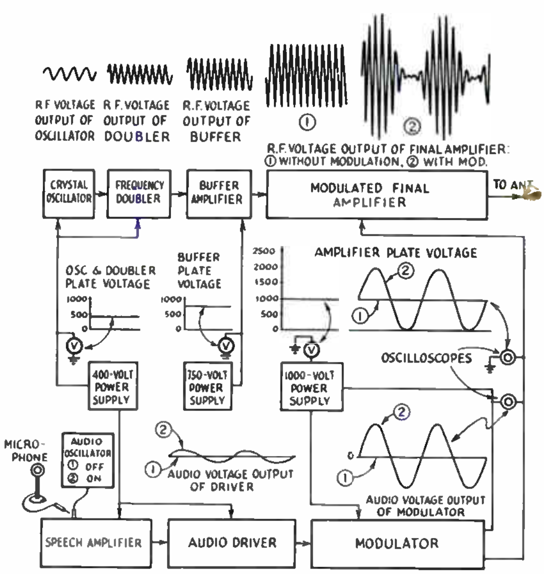


FIG. 1001 — WHAT HAPPENS IN THE SECTIONS OF A MODERN PLATE-MODULATED 'PHONE TRANSMITTER

The r.f. stages and power supplies alone form an excellent c.w. telegraph transmitter. The r.f. output wave of the unmodulated final amplifier, shown at (1), is the type of wave produced by a telegraph transmitter with the key closed. All curves labelled (1) apply to conditions with no audio input — i.e., with the test oscillator turned off. The curves labelled (2) apply with 100-per cent modulation with continuous sine-wave input.

World Radio History

practical importance for amateur 'phone transmitters. The discussion in this chapter is devoted wholly to this type of modulation.

PRINCIPLES OF MODULATION

AMPLITUDE modulation for voice transmission is the process by which the amplitude of the transmitted radio-frequency wave is varied in accordance with the sound waves actuating the microphone. The degree of modulation is described in terms of the amplitude variation of the transmitted wave, and is usually given as a decimal modulation factor or as a percentage. *The modulation factor, expressed in percentage, is 100 times the maximum departure (positive or negative) of the envelope of a modulated wave from its unmodulated value, divided by its unmodulated value.* If the modulation is *undistorted* or *linear*, the average amplitude of the modulated wave is the same as its unmodulated value, so long as the modulating signal also is symmetrical, because the increase in amplitude during half the modulation cycle is balanced by an equal decrease in amplitude during the next half cycle.

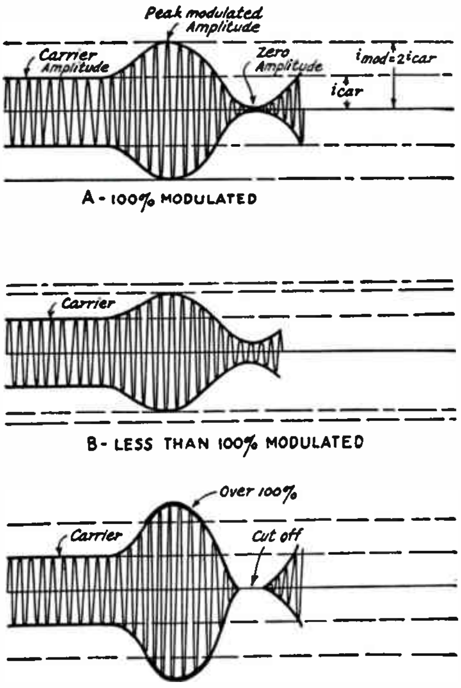


FIG. 1002 — GRAPHICAL REPRESENTATION OF THE AMPLITUDE MODULATED WAVE

C illustrates the condition of overmodulation, the negative peak of the envelope being cut off. The outline of the r.f. peaks is the envelope and should correspond to the wave shape of the modulating signal.

Fig. 1002 gives conventional sketches of amplitude modulation, with the relations for determining percentage modulation indicated. In form of an equation, the expression for percentage modulation is

$$\% \ M = \frac{i_{mod} - i_{car}}{i_{car}} \times 100$$

where i_{mod} is the maximum amplitude (the positive peak), or the minimum amplitude (the negative peak), and i_{car} is the unmodulated carrier amplitude. In the case of *overmodulation* as shown by *C*, the positive percentage is greater than 100. However, the negative percentage can never be greater than 100 because the amplitude cannot become less than zero. Such a condition results, obviously, in distortion of the wave envelope — the envelope being the outline of the radio-frequency cycle peaks.

The process of modulation produces additional radio frequencies in pairs either side of the carrier frequency, constituting the *side bands*. These new frequencies are numerically equal to the carrier frequency plus the audio modulation frequency, and carrier frequency minus the modulation frequency. There will be one such pair for each frequency component in the modulating signal, and the frequency band occupied by the transmission therefore will be equal to twice the highest modulation frequency. If the wave form is distorted (as it will be with overmodulation) the high-order harmonics created as a result of the distortion will cause further side bands to be generated and these spurious radiations will broaden the wave accordingly. It is for this reason that government regulations prohibit overmodulation.

Amplitude and Power Relations

The maximum permissible modulation factor, imposed by the requirements that the modulation envelope shall not be distorted, is 100 per cent. Since at the peak of the modulating signal the amplitude is doubled with 100 per cent modulation, the instantaneous *peak power* will be four times the unmodulated power, power being proportional to the square of the current. With continuous modulation by a pure tone the *average* power will be 1.5 times the unmodulated power. The additional power, equal to half the power in the carrier alone, is in the side bands, and is divided equally between the two. The current in the circuit, as indicated by an ammeter, would be 22.6 per cent greater with 100 per cent modulation by a pure tone than with the carrier alone, since the current is proportional to the square root of the power.

World Radio History

Experience has shown that the average power in typical *speech* having the same instantaneous peak *amplitude* as a pure tone is approximately half as great as the average power in the tone. Therefore the average power in a speech-modulated wave is only 1.25 times the unmodulated carrier power, even though the instantaneous peak power is still four times the carrier power just as it is with tone modulation.

With sustained speech, therefore, the current in the circuit would increase only 12 percent over the unmodulated carrier value. Actually the varying nature of speech modulation results in a still smaller percentage indicated increase in practical operation because of the sluggishness of the usual thermal ammeters used for measuring r.f. currents. An increase of about 5 percent is, experience indicates, to be expected under normal conditions with complete modulation. An increase with speech modulation of more than 10 percent in indicated antenna current should be cause for readjustment.

Modulation Capability and Stability

It is entirely possible for the modulation envelope to be distorted at less than 100 per cent modulation. This would be the case with a transmitter whose output power could not be quadrupled instantaneously on the modulation peaks.

Modulation capability is the maximum percentage modulation that is possible without objectionable distortion. It is apparent that the modulating system, whatever type, must be able to effect an undistorted variation in the amplitude of the modulated wave ranging from zero to twice the carrier amplitude if the set is to have a modulation capability of 100 percent. Since the effectiveness of a modulated wave as measured by receiver response depends on the variation in amplitude, it is desirable that the transmitter's modulation capability be high. As a specific instance, a 10-watt carrier modulated 100 percent is practically as effective as a 40-watt carrier modulated 50 percent.

Viewed in another way, this means that if the audio power is held constant, the receiver response, and the understandability of the modulated signal, will remain constant with the radio-frequency power at any setting above that for 100-percent modulation. Thus, if the output added by the modulator to the modulated amplifier input is 100 watts, the audio output of the receiver resulting from detection of the modulated signal will not change if the d.c. input to the modulated amplifier is varied between 200 watts (the value for 100-percent modulation) and 1000 watts (the maximum legal input).

With transmitters of high-percentage modulation, particular care must be exercised to prevent variation in the *carrier* frequency as an accompaniment to amplitude modulation. Such variation constitutes *frequency modulation.* Frequency instability is a serious defect in c.w. telegraph transmission, and it must be realized that frequency modulation is far more

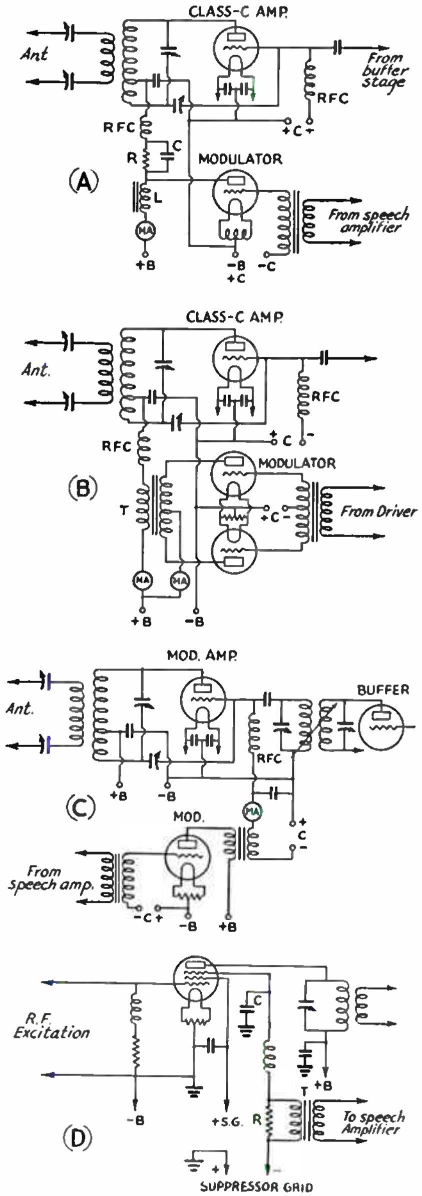


FIG. 1003 — CIRCUITS FOR FOUR METHODS OF MODULATION

A and B are for choke- and transformer-coupled plate modulation, C is for grid-bias modulation, and D is for suppressor-grid modulation.

World Radio History

objectionable in 'phone transmission. Frequency modulation is also a cause of distortion in reception. Modulation of the oscillator in amateur transmitters is therefore prohibited except on the ultra-high-frequency bands. Even when a radio-frequency amplifier following an oscillator is modulated, precautions are necessary to insure against affecting the oscillator's frequency.

BASIC METHODS OF MODULATION

The most widely used type of modulation system is that in which the modulating signal is applied in the plate circuit of a radio-frequency power amplifier (*plate modulation*). In a second type the audio signal is applied to the control-grid circuit (*grid-bias modulation*). A third system involves variation of the suppressor-grid voltage of a pentode-type power tube (*suppressor-grid modulation*). Other systems are occasionally used for special purposes but are not generally suitable for amateur work. Among these is screen-grid modulation in an amplifier using that type tube (limited to approximately 60 per cent modulation capability). Practical arrangements illustrative of plate and grid-bias methods are diagrammed in Fig. 1003. The suppressor-grid modulation system is shown in Fig. 1003-D.

In *A* of Fig. 1003 is shown the circuit of what is known as the Heising or constant-current system of plate modulation. The plate power for the modulator tube and modulated amplifier is furnished from a common source through the modulation choke, *L*, which has high impedance for audio frequencies. When the grid circuit of the modulator tube is excited at audio frequency, the modulator operates as a power amplifier with the plate circuit of the r.f. amplifier as its load, the audio output of the modulator being superimposed on the d.c. power supplied to the amplifier. The r.f. output of the amplifier is therefore identically modulated. For 100 per cent modulation the modulator audio voltage applied to the amplifier plate circuit across the choke, *L*, must have a peak value equal to the d.c. voltage on the modulated amplifier. To obtain this without distortion, the amplifier must be operated at a d.c. plate voltage less than the modulator plate voltage, the extent of the voltage difference being determined by the type of modulator tube used. The necessary drop in voltage is provided by the resistor *R*, which is by-passed for audio frequencies by the condenser *C*.

In Fig. 1003-B is shown another system of plate modulation in which a balanced (push-pull Class-A, Class-AB or Class-B) type modulator is transformer-coupled to the plate circuit of the modulated r.f. amplifier. When the grids of the modulator tubes are excited, the audio-frequency power generated in the plate circuit is combined with the d.c. power in the modulated-amplifier plate circuit by transfer through the coupling transformer, *T*. The power output of the modulated amplifier varies exactly with the power input to its plate, and the carrier power is therefore varied in accordance with the signal at the grids of the modulator tubes. For 100 percent modulation the audio-frequency output of the modulator and the turns ratio of the coupling transformer must be such that the voltage at the plate of the modulated amplifier varies between zero and twice the d.c. operating plate voltage. The plate efficiency with plate modulation of Class-C amplifiers is practically constant at approximately 70 percent.

In *C* of the same figure is the diagram of a typical arrangement for grid-bias modulation. In this system, the secondary of an audio-frequency output transformer, whose primary is in the plate circuit of the modulator tube, is connected in series with the grid-bias supply for the modulated amplifier. When the grid bias, radio-frequency excitation and load circuit of the modulated amplifier are properly adjusted, power output will vary in accordance with the audio-frequency signal applied to the control grid. In this method of modulation the modulator stage furnishes relatively small power to the r.f. amplifier's control-grid circuit. The carrier plate efficiency of the modulated stage is considerably lower than with plate power modulation, being of the order of 30 percent in usual practice. At 100 percent modulation it rises to approximately 60 percent.

The circuit arrangement for suppressor-grid modulation of a pentode type tube is shown in Fig. 1003-D. In this system the modulating signal is also applied to a grid, in which respect it is akin to control-grid modulation. However, it differs in that the r.f. excitation and modulating signals are applied to separate grid elements. This gives the system a simpler operating technique. Best adjustment for proper excitation requirements and, simultaneously, proper modulating circuit requirements, are more or less independent, whereas they are intermingled in the control-grid circuit of the previously outlined system. The carrier plate efficiency figure is approximately the same as for control-grid modulation, approximating 30 percent, rising to approximately 60 percent at full modulation. With tubes having suitable suppressor-grid characteristics, linear modulation up to practically 100 percent can be obtained with negligible distortion.

Choosing a Modulation System

The choice of a modulation system necessarily must be influenced by considerations

World Radio History

which will vary with different individuals. All of the systems described will give practically identical results when properly operated. Economic factors usually are of paramount importance. In considering these, it is necessary to distinguish between two classes of 'phone operators: those who want to get the greatest possible modulated r.f. output for a given investment, and those who wish to modulate an existing c.w. transmitter with the smallest possible expenditure.

On a watts-per-dollar basis, the plate-modulation system with a Class-B audio amplifier as a modulator undoubtedly has the advantage over other systems, offering the opportunity of obtaining quite large values of r.f. output economically. This is particularly true for powers of 100 watts or more. At lower power levels, Class-A or AB modulators using beam power tubes are about on a par with Class-B from the expense standpoint, again with plate modulation.

On the other hand, if a telegraph transmitter is already available and it is desired to modulate it most economically, or if as much power as possible is desired for code work with only occasional phone operation, a form of modulation which does not require a large amount of audio power must be used. The grid-bias system is well-suited to this purpose or, in case pentode-type r.f. output tubes are used, suppressor modulation. The carrier power output, however, must be reduced to about a quarter of that available from the same transmitter as a telegraph set.

From the operating standpoint, the plate-modulation system is very simple to adjust, providing the design has been worked out properly. The suppressor-modulation system also is easy to handle. Adjustments with grid-bias modulation are somewhat more complicated, but with reasonable care good results can be secured.

The linear r.f. amplifier has practically no advantages in amateur work, and hence is but rarely used. It is the most difficult of all systems to adjust for proper operation, and gives no more carrier output than the more easily-applied grid-bias system.

A complete audio system consists essentially of a device for converting sound waves into electrical currents or voltages — the microphone — plus vacuum-tube amplifiers to raise the power level to the value necessary for full modulation of the transmitter by the method chosen. With grid-bias and suppressor modulation, the power level required is quite small; with plate modulation, the audio power must be equal to half the d.c. input power to the modulated r.f. stage, as we have seen.

In every case, the starting point in design is the microphone. We shall therefore first consider the various types of microphones and their characteristics.

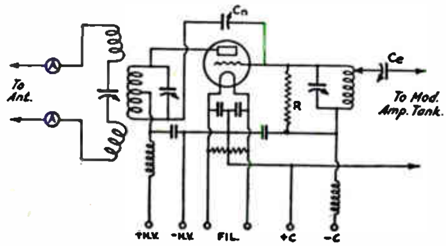


FIG. 1004 — CIRCUIT OF A SINGLE-ENDED CLASS-B LINEAR R.F. AMPLIFIER

The grid-regulation resistor, R, should be capable of dissipating a fair proportion of the exciting amplifier's power output. The excitation can be regulated by the coupling condenser, C_e, or by adjustment of the regulating resistor, or a tap on the exciting amplifier tank coil. The circuit values can be as usual for the frequency and power.

SPEECH INPUT CIRCUITS—TYPES OF MICROPHONES

Typical circuit arrangements of five types of microphones used in amateur transmitters are shown in Fig. 1005. The arrangement of *A* is for a single-button carbon microphone; *B* is for a double-button carbon microphone; *C* is that of a condenser microphone; *D* is for a ribbon (velocity) type; and *E* is for piezo-electric (crystal) type microphone.

Carbon microphones, single- and double-button types, are built of "buttons" filled with carbon grains, so that the button faces may be compressed. One face of each button is fixed to the stationary part of the microphone, while the other face is attached to the center of a diaphragm which vibrates with the sound waves striking it. A fixed voltage source, usually a battery, is provided in series with the button, and the varying resistance caused by compression and loosening of the grains produces varying current in the primary circuit of a transformer. In Fig. 1005-A and -B are shown connections for single- and double-button microphones, with a variable potentiometer resistor included with each circuit for adjusting the button current to the correct value, as specified with each microphone.

The condenser microphone of C consists of a two plate capacitance with one plate stationary and the other, separated from the first by about a thousandth of an inch, a thin membrane serving as a diaphragm. This condenser is connected in series with a resistor and voltage source so that it causes a slight variation of the voltage applied to the tube grid across part of the voltage divider.

In a velocity or ribbon microphone, the element acted upon by the sound waves is a thin

World Radio History

corrugated ribbon of electrically conductive material, suspended between the poles of a magnet. When made to vibrate (the corrugations make vibration easier), the ribbon cuts lines of force between the poles in first one direction and then the other, generating an alternating voltage just as does each of the wires on the rotating armature of a generator.

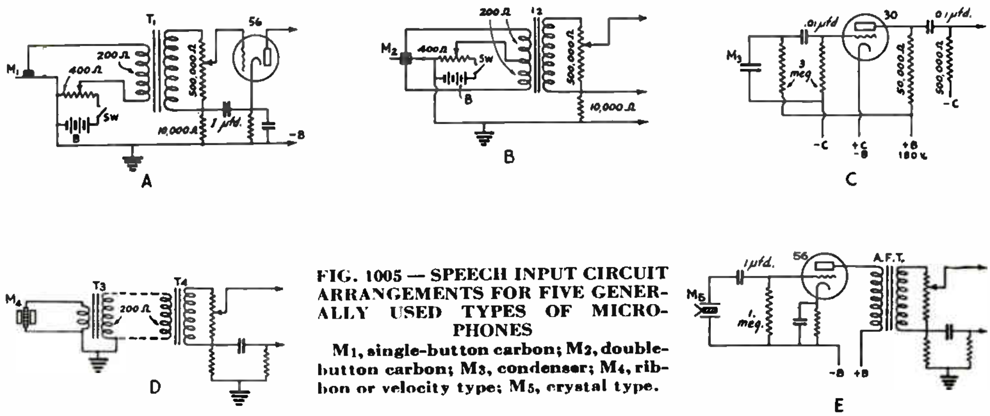


FIG. 1005 — SPEECH INPUT CIRCUIT ARRANGEMENTS FOR FIVE GENERALLY USED TYPES OF MICROPHONES

M1, single-button carbon; M2, double-button carbon; M3, condenser; M4, ribbon or velocity type; M5, crystal type.

The "dynamic" microphone is similar to the ribbon "mike," but in the dynamic type the ribbon is replaced by a coil attached to a diaphragm. The coil provides several turns of wire cutting the magnetic field.

The input circuit for a piezo-electric or crystal type microphone is shown in Fig. 1005-E. The element in this type consists of a pair of Rochelle salts crystals cemented together, with plated electrodes. In the form diagrammed, the crystal is mechanically coupled to a diaphragm. Sound waves actuating the diaphragm cause the crystal to vibrate mechanically and, by piezo-electric action, to generate a corresponding alternating voltage between the electrodes, which are connected across the grid circuit of a vacuum tube amplifier as shown. Unlike the other microphones described, the crystal type requires no separate source of current, polarizing voltage or magnetic field. The diaphragm type illustrated has frequency characteristics entirely adequate for speech transmission. Another type, which has no diaphragm and in which the crystal is directly actuated by sound waves, has more uniform response over a wider range of audio frequencies (up to 10,000 cycles or more) as is required for program transmission.

Single-button carbon microphones are usually characterized by poor but understandable quality. The other four types shown are usually credited with good to excellent quality for voice work, depending on the grade of the microphone and on proper adjustment of the circuit in which it is used.

Wide frequency response speech input equipment is not required for voice transmission, uniform frequency response from 100 to about 3000 cycles being adequate. It is therefore satisfactory to choose a microphone intended particularly for speech transmission, rather than one designed primarily for broadcast program use. Since the high r.f. selectivity of modern amateur 'phone receivers and the use of "tone controls" in receiver audio systems cut off the higher frequencies anyway, the transmitted modulation frequencies above 3000 cycles are largely wasted.

Microphone Output Levels

The sensitivity of the microphone — that is, its electrical output for a given speech intensity input — governs the amount of amplification required between the microphone and the modulator. Sensitivity varies greatly with microphones of different basic types, and also varies between different models of the same type. The output is also greatly dependent on the character of the individual voice and the distance of the speaker's lips from the microphone, decreasing approximately as the square of the distance. It also may be affected by reverberation in the room. Hence, it is practically impossible to give rigid speech output values which will be reproducible in every instance. At best, only approximate values based on averages of "normal" speaking voices can be attempted. These have been obtained through the coöperation of several microphone manufacturers and are representative of the types of microphones most popularly used by amateurs. They are based on close talking; that is, with the microphone six inches or less from the speaker's lips.

World Radio History

Good quality single-button carbon microphones give outputs ranging from 0.1 volt across 50 or 100 ohms to 0.3 volt across 50 to 100 ohms; that is, across the primary winding of the microphone transformer. With the step-up of the transformer, a peak voltage of between 2 and 3 volts across 100,000 ohms or so can be assumed available at the grid of the first tube. These microphones are usually operated with a button current of 50 to 100 ma.

The sensitivity of good-quality double-button microphones is considerably less, ranging from 0.02 volt to 0.07 volt across 200 ohms. With this type microphone, and the usual push-pull input transformers, a peak voltage of 0.4 to 0.5 volt across 100,000 ohms or so can be assumed available at the first speech amplifier grid. The button current with this type microphone ranges from 5 to 50 ma. per button. The operating conditions recommended by the manufacturer should be followed

The output of condenser microphones varies widely from one model to another, the high quality type being about one-hundredth to one-fiftieth as sensitive as the standard double-button carbon mike. Usually an additional resistance-coupled amplifier having a voltage gain of approximately 100 is satisfactory as a "pre-amplifier" for adapting a double-button set-up to condenser mike input.

The sensitivity of the velocity or ribbon-type microphone is between that of the standard double-button carbon and the condenser type. With a suitable microphone coupling transformer, about one stage of pre-amplification having a tube gain of 10 or so will bring the level up to that obtained at the grid of the first tube with a standard double-button microphone.

Although the sensitivity of piezo-electric crystal microphones varies with different models, output of 0.01 to 0.03 volt is representative for amateur communication types and this figure has been found generally satisfactory for speech amplifier design purposes. The sensitivity of this type microphone is affected by the length of the leads connecting to the grid input of the first amplifier stage, decreasing as the lead length and capacitance are increased. The above sensitivity figure is for connecting cable lengths of 6 or 7 feet. The frequency characteristic is unaffected by capacitance of the connecting cable, since the crystal element has a relatively large capacitive reactance to start with. The load resistance (amplifier grid resistor) does affect the frequency characteristic, however, the lower frequencies being attenuated as the shunt resistance becomes less. Grid resistor values of 1 megohm and higher should be used, 5 megohms being a customary figure. Increased series resistance attenuates the higher frequencies, tending to raise the low-frequency response.

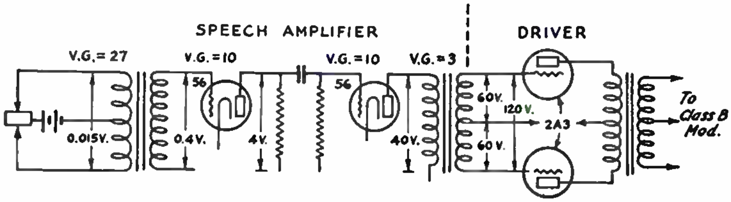
THE SPEECH AMPLIFIER

THE speech amplifier of a 'phone transmitter may be said to include all the audio stages between the microphone and the stage whose output actually modulates the r.f. output of the transmitter. Depending upon the modulating system chosen, all the stages in the entire a.f. system may operate Class-A, or if a Class-B modulator is used, all stages preceding the modulator may be Class-A. Alternatively, one or more of the stages preceding the Class-B modulator may be operated Class-AB. In general, Class-B modulators developing 100 or more audio watts usually are excited by Class-AB amplifiers, since the Class-B grids require appreciable power. A stage from which power is taken to excite a following stage is called a *driver*.

As contrasted to the modulator or driver stage (if the latter is necessary) low-level amplifier stages are always operated purely Class-A, their whole purpose being to get as great a step-up in voltage as possible. Voltage gain with minimum distortion is the important point, since no power is required from a tube working into a Class-A or Class-AB_1 (a Class-AB amplifier which does not draw grid current under any conditions) amplifier. Knowing the microphone output voltage and the peak grid voltage required by the last Class-A or AB_1 stage for full output, the number and kind of voltage-amplifier stages can be determined.

The peak grid voltage swing required by a Class-A power stage will be approximately equal to its grid bias in the case of a single tube or tubes in parallel, and approximately twice the bias value for tubes in push-pull. The approximate voltage gain required of the

FIG. 1006 — SKELETON DIAGRAM OF SPEECH-AMPLIFIER AND DRIVER STAGES, SHOWING APPROXIMATE VOLTAGE GAIN AND PEAK VOLTAGE PER STAGE



World Radio History

TABLE I — RESISTANCE-COUPLED AMPLIFIER DATA

Data are given for a plate-supply of 300 volts; departures of as much as 50% from this supply voltage will not materially change the operating conditions or the voltage gain, but the output voltage will be in proportion to the new voltage. Voltage gain is measured at 400 cycles; condenser values given are based on 100-cycle cut-off. For increased low-frequency response, all condensers may be made larger than specified (cut-off frequency in inverse proportion to condenser values provided all are changed in the same proportion). A variation of 10% in the values given has negligible effect on the performance.

High-frequency cut-off with pentodes is approximately 20,000 cycles with a plate resistor of 0.1 megohm, 10,000 cycles with 0.25 megohm, and 5000 cycles with 0.5 megohm. With triode amplifiers, the high-frequency cut-off is well above the audio range.

	Plate Resistor Megohms	Next-Stage Grid Resistor Megohms	Screen Resistor Megohms	Cathode Resistor Ohms	Screen By-pass μfd.	Cathode By-pass μfd.	Blocking Condenser μfd.	Output Volts (Peak)	Voltage Gain
6A6, 6N7 53 (One Triode Unit)	0.1	0.1	—	1150[1]	—	—	0.03	60	20
		0.25	—	1500[1]	—	—	0.015	83	22
		0.5	—	1750[1]	—	—	0.007	86	23
	0.25	0.25	—	2650[1]	—	—	0.015	75	23
		0.5	—	3400[1]	—	—	0.005	87	24
		1.0	—	4000[1]	—	—	0.003	100	24
	0.5	0.5	—	4850[1]	—	—	0.005	76	23
		1.0	—	6100[1]	—	—	0.003	94	24
		2.0	—	7150[1]	—	—	0.002	104	24
6C6, 6J7, 57 (Pentode)	0.1	0.1	0.44	500	0.07	8.5	0.02	55	61
		0.25	0.5	450	0.07	8.3	0.01	81	82
		0.5	0.53	600	0.06	8.0	0.006	96	94
	0.25	0.25	1.18	1100	0.04	5.5	0.008	81	104
		0.5	1.18	1200	0.04	5.4	0.005	104	140
		1.0	1.45	1300	0.05	5.8	0.005	110	185
	0.5	0.5	2.45	1700	0.04	4.2	0.005	75	161
		1.0	2.9	2200	0.04	4.1	0.003	97	250
		2.0	2.95	2300	0.04	4.0	0.0025	100	240
6F5	0.1	0.1	—	1300	—	5.0	0.025	33	42
		0.25	—	1600	—	3.7	0.01	43	49
		0.5	—	1700	—	3.2	0.006	48	52
	0.25	0.25	—	2600	—	2.5	0.01	41	56
		0.5	—	3200	—	2.1	0.007	54	63
		1.0	—	3500	—	2.0	0.004	63	67
	0.5	0.5	—	4500	—	1.5	0.006	50	65
		1.0	—	5400	—	1.2	0.004	62	70
		2.0	—	6100	—	0.9	0.002	70	70
56, 76	0.05	0.05	—	2400	—	2.8	0.08	65	8.3
		0.1	—	3100	—	2.2	0.045	80	8.9
		0.25	—	3800	—	1.8	0.02	95	9.4
	0.1	0.1	—	4500	—	1.6	0.04	74	9.5
		0.25	—	6400	—	1.2	0.02	95	10.0
		0.5	—	7500	—	1.0	0.009	104	10.0
	0.25	0.25	—	11,100	—	0.7	0.02	82	10.0
		0.5	—	15,200	—	0.5	0.009	96	10.0
		1.0	—	18,300	—	0.4	0.005	108	10.0
6C5 Also 6J7, 6C6, 57 (as triodes)[2]	0.05	0.05	—	2100	—	3.16	0.075	57	11
		0.1	—	2600	—	2.3	0.04	70	11
		0.25	—	3100	—	2.2	0.015	83	12
	0.1	0.1	—	3800	—	1.7	0.035	65	12
		0.25	—	5300	—	1.3	0.015	84	13
		0.5	—	6000	—	1.17	0.008	88	13
	0.25	0.25	—	9600	—	0.9	0.015	73	13
		0.5	—	12,300	—	0.59	0.008	85	14
		1.0	—	14,000	—	0.37	0.003	97	14
6C8G (One triode unit)	0.1	0.1	—	2120	—	3.93	0.037	55	22
		0.25	—	2840	—	2.01	0.013	73	23
		0.5	—	3250	—	1.79	0.007	80	25
	0.25	0.25	—	4750	—	1.29	0.013	64	25
		0.5	—	6100	—	0.96	0.0065	80	26
		1.0	—	7100	—	0.77	0.004	90	27
	0.5	0.5	—	9000	—	0.67	0.007	67	27
		1.0	—	11,500	—	0.48	0.004	83	27
		2.0	—	14,500	—	0.37	0.002	96	28
6F8G (one triode unit), 6J5, 6J5G	0.05	0.05	—	1020	—	3.56	0.06	41	13
		0.1	—	1270	—	2.96	0.034	51	14
		0.25	—	1500	—	2.15	0.012	60	14
	0.1	0.1	—	1900	—	2.31	0.035	43	14
		0.25	—	2440	—	1.42	0.0125	56	14
		0.5	—	2700	—	1.2	0.0065	64	14
	0.25	0.25	—	4590	—	0.87	0.013	46	14
		0.5	—	5770	—	0.64	0.007	57	14
		1.0	—	6950	—	0.54	0.004	64	14

[1] Value for both triode sections, assuming both are working under same conditions. In phase inverter service, the cathode resistor should not be by-passed.

[2] Screen and suppressor tied to plate.

World Radio History

speech amplifier therefore will be the ratio of this maximum grid swing to the peak voltage across the microphone. This gain will include amplification of the tubes and step-up in coupling devices such as transformers. The method is illustrated by the skeleton diagram of Fig. 1006. The voltage step-up in a coupling transformer is assumed the same as its turns ratio. The combination chosen should show a calculated maximum gain of 50 to 100 percent greater than will actually be required, to allow for reserve, the excess being compensated for in operation by adjustment of the volume or gain control.

Sets of operating conditions for various types of tubes are given in Table I. In each case the voltage gain is given. The output voltage is the peak value appearing across the grid resistor of the following stage, and is based on the assumption that grid current does not flow. It is the maximum undistorted voltage that can be obtained from the tube for the operating conditions chosen.

In general, resistance coupling is preferable in low-level stages. Resistance coupling *must* be used with non-power pentodes and high-μ triodes; transformer coupling is unsuitable for these tubes because of the difficulty of securing a sufficiently high load resistance with transformers of ordinary construction. Transformer coupling out of tubes having high plate impedance results in poor gain and greatly reduced low-frequency response. On the other hand, transformer coupling can be used with triodes having an amplification factor of 20 or less, in which case the gain of the stage is approximately equal to 60 to 70 percent of the μ of the tube times the turns ratio, secondary to primary, of the transformer. Transformer coupling must always be used with tubes which are required to deliver power to the next stage, as in the case of a stage working into a Class-AB_2 (a Class-AB amplifier which draws grid current over part of the cycle) or Class-B amplifier. Resistance coupling into such a stage will give bad distortion whenever the grid-current point is reached.

Where only voltage amplification is required, the tube types listed in the table will be sufficient to take care of practically all needs. Tubes built for delivering power need not be used unless actual power output is required of them; in most cases a power tube will give less actual voltage gain than one of the smaller tubes listed in the table.

When high voltage is required, as with low-output microphones such as the crystal type, it is good practice to use a pentode in the first speech-amplifier stage, following it with one or more triode stages. It is best not to attempt to cascade two very high-gain stages because of the danger of instability.

If good high-frequency response is necessary, either a pentode or a triode having a fairly low μ should be used. Under conditions giving high voltage amplification, the input capacity of a high-μ triode is quite large, and since the input capacity shunts the grid resistor its "tone control" action reduces the amplification at the higher audio frequencies. Consequently, such tubes, if used, should be operated with grid resistors of fairly low value — 100,000 ohms or less — to minimize the shunting effect of tube capacity. Since this usually will reduce the gain of the previous stage, the high-μ triode does not show up quite as favorably as the table, based on a frequency of 400 cycles, might indicate. Screened pentodes are quite free from this effect and will give substantially uniform gain over a wide range of frequencies.

General Construction Practice

Audio units for simple transmitters can be built up bread-board style, although a metal chassis foundation is preferable for a permanent job. Present practice tends toward unit construction on metal chasses, with rack mounting. Shielding is important where high-gain audio systems are used, it being especially important to keep r.f. from overloading the low-level grid circuits. When two or more stages of speech amplification are used, particular care must be taken to prevent motorboating and distortion resulting from interstage feed-back. Coupling transformers should be isolated from each other or placed for minimum reaction between their magnetic fields. Proper positions can be determined by turning the transformers, one with respect to the others, until minimum hum or instability is obtained with the unit in operation at full gain. It is advisable to keep modulation chokes and transformers well away from other audio equipment because the strong magnetic field about the high-level audio unit is likely to cause trouble. Transformer cases should be grounded to the negative side of the circuit.

Microphone cables should be shielded and the shield should be connected to ground. It is generally good practice to shield the high-gain input circuit separately and keep it away from the high-level audio and r.f. sections of the transmitter. It is advisable to couple a speech-input amplifier by a step-down transformer (tube-to-line) in its output, through a twisted-pair to a line-to-tube step-up transformer into the higher-level audio circuit. Such an impedance matching combination is especially recommended with high-impedance microphones which require short leads to the first audio stage or pre-amplifier. Interconnecting leads and cables should be thoroughly shielded and the shields grounded. Radio-frequency chokes

World Radio History

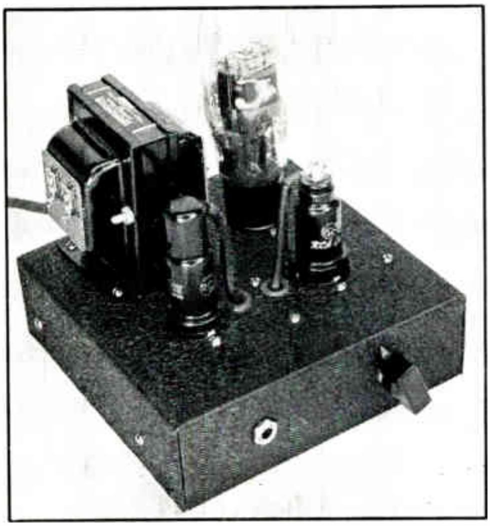


FIG. 1007 — THE 3.5-WATT SPEECH AMPLIFIER

It is shown in this view equipped with high-gain input tube for use with low-output microphones. For carbon mikes, a microphone transformer replaces the 6J7 (the tube at left). The 6F5 tube is at the right in front of the 6B4G power output tube. The output transformer is at the rear left corner.

may be necessary between modulator and modulated amplifier in high-voltage supply leads.

A.c. filament and power-pack high-voltage supplies may be used for all stages, although more than ordinary filtering should be used for high-gain amplifiers. Filtering or decoupling in individual plate- and grid-feed circuits is advisable, as illustrated in some of the high-gain circuits which will be described.

Combinations of Speech Amplifier and Audio-Power Output Stage

The modulators used in amateur 'phone transmission are really audio power amplifiers, with required power output and type of output transformer or other coupling device determined by the application. Thus, a well-designed Class-A or Class-AB amplifier stage capable of 15 watts audio power output may be used to plate modulate a r.f. amplifier of 30 watts input, to grid modulate a stage of 300 watts input, or to drive a Class-B modulator stage of 250 watts audio output. The output transformer of the 15-watt stage must be suitable for the modulation or driver application, so that the output winding matches the load; or the transformer may be one designed for matching a 500-ohm line, so that the amplifier is readily adapted to any of the above uses by connecting the secondary winding to the 500-ohm primary of a suitable input or modulation transformer.

ECONOMICAL SPEECH AMPLIFIER AND 3.5-WATT OUTPUT STAGE

The amplifier of Fig. 1009-A designed for use with crystal and velocity microphones (and the version in Fig. 1009-B designed for carbon single- and double-button microphones) is a simple arrangement for grid modulating r.f. amplifiers of 150 watts input or less. It is also suitable for driving a Class-B modulator of 25 to 50 watts output, as a Class-B input transformer designed for such modulators may readily be substituted for the grid-modulation transformer shown.

The amplifier is built on a steel chassis 7 inches wide, 7 inches deep, and 2 inches high. The 6J7 (or the microphone transformer in the model of Fig. 1009-B) is located on the left front corner of the unit, with the output transformer directly behind. The 6F5 occupies the other front corner, and the 6B4G output tube takes the remaining space at the rear of the chassis. A paper-carton type 8-μfd. electrolytic condenser is mounted beneath the left edge of the chassis in the high-gain version, and is used for a filter and decoupling condenser with resistor R_5. With the higher output afforded by the carbon microphones, the large amount of decoupling and filtering effect provided by this condenser is not needed. The amplifier is designed for separate power supply so that an r.f. exciter supply may be used, and because of this fact, special wiring precautions are unnecessary.

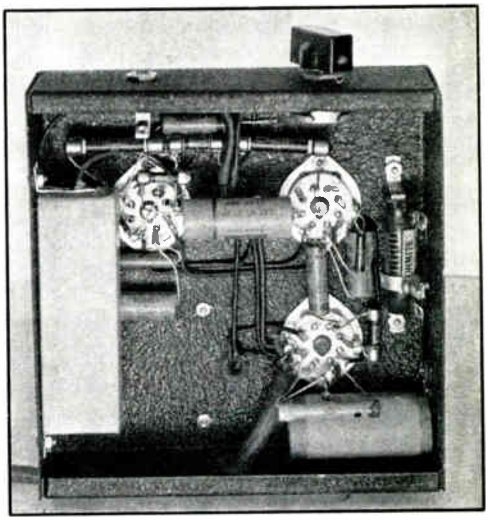


FIG. 1008 — BOTTOM VIEW OF THE 3.5-WATT AMPLIFIER

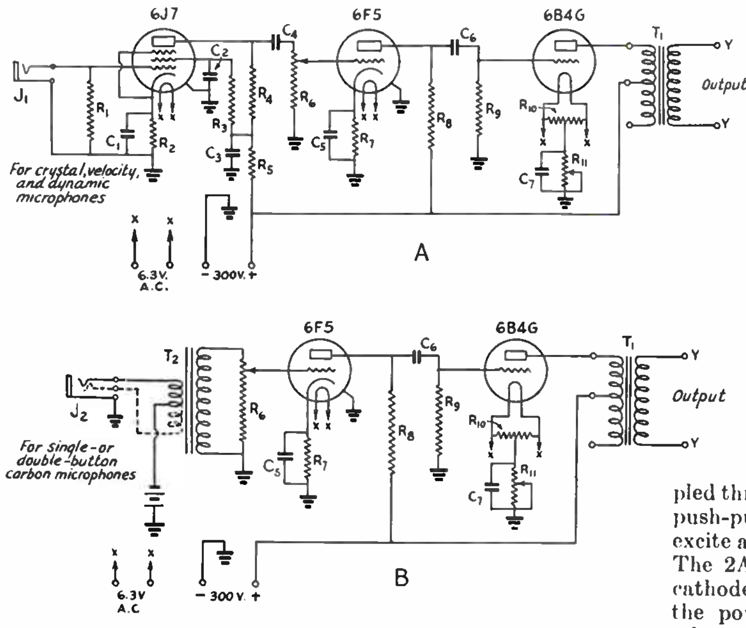


FIG. 1009—CIRCUITS OF THE 3.5-WATT SPEECH UNIT

- C_1 — 5-μfd. electrolytic, 25-volt.
- C_2 — 0.05-μfd. paper, 600-volt.
- C_3 — 8-μfd. electrolytic, 425-volt.
- C_4 — 0.01-μfd. paper, 600-volt.
- C_5 — 5-μfd. electrolytic, 25-volt.
- C_6 — 0.01-μfd. paper, 600-volt.
- C_7 — 25-μfd. electrolytic, 50-volt wkg.
- R_1 — 5-megohm, 1-watt carbon.
- R_2 — 1700-ohm, 1-watt carbon.
- R_3 — 2.5-megohm, 1-watt carbon.
- R_4 — 0.5-megohm, 1-watt carbon.
- R_5 — 50,000-ohm, 1-watt carbon.
- R_6 — 0.5-megohm potentiometer.
- R_7 — 4500-ohm, 1-watt carbon.
- R_8, R_9 — 0.5-megohm, 1-watt carbon.
- R_{10} — 50-ohm center-tapped.
- R_{11} — 800-ohm, 10-watt adj.
- J_1 — 2-wire jack.
- J_2 — 2- or 3-wire jack for s.b. or d.b. mike.
- T_1 — 1-to-1 ratio grid modulation trans.
- T_2 — S.b. or d.b. carbon mike transformer.

A UNIVERSAL SPEECH AMPLIFIER DRIVER WITH 10-WATT OUTPUT

Figs. 1010–1015 inclusive show a 10-watt output speech amplifier and driver, with power supply, suitable for grid-modulating a high-power stage or for working into a Class-B modulator whose input requirements are 10 watts or less. This classification includes Class-B modulators capable of delivering sufficient audio output to plate-modulate 500 watts input to the Class-C r.f. stage. The input circuit is arranged so that either crystal or double-button carbon microphones can be used, and the gain is such that the full output is developed with a peak voltage of less than 0.002 volts applied to the first tube. The frequency response with the audio transformers specified (or with those of equivalent construction) is practically flat over the range required for voice communication. The noise level, with the power supply shown, is approximately 46 db below the rated output, while the distortion is negligible at the 10-watt level.

The circuit diagram is given in Fig. 1011. The first tube, a 6J7 pentode-connected, is followed by a 6C5 which in turn is coupled through a transformer into push-pull 6C5's. These tubes excite a pair of 2A3's Class-AB. The 2A3's are self-biased, the cathode resistor being built in the power-supply unit shown schematically in Fig. 1014. The power supply is equipped with a voltage-regulator which handles all the tubes in the speech amplifier except the 2A3's. In the power-supply unit, the 6J7 is the control tube for the regulator portion, while the 2A3 is the regulator tube. R_3 controls the output voltage; the resistor should be set so that the voltage as measured by a high-resistance voltmeter is 275 volts. A

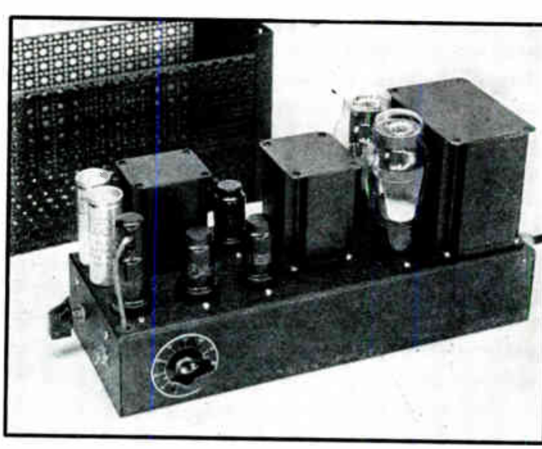


FIG. 1010 — TEN-WATT SPEECH-AMPLIFIER OR DRIVER FOR USE WITH EITHER CRYSTAL OR DOUBLE-BUTTON CARBON MICROPHONES

World Radio History

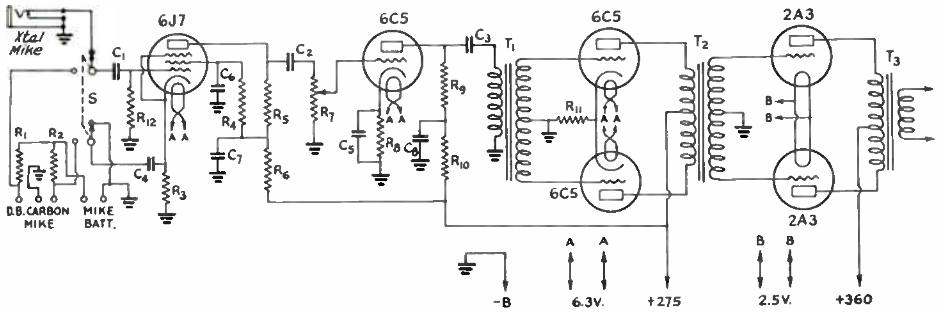


FIG. 1011 — CIRCUIT DIAGRAM OF THE 10-WATT SPEECH AMPLIFIER

R_1, R_2 — 200 ohms, ½-watt.
R_3 — 1000 ohms, ½-watt.
R_4 — 1 megohm, ½-watt.
R_5 — 0.25 megohm, ½-watt.
R_6 — 50,000 ohms, ½-watt.
R_7 — 0.25-megohm volume control.
R_8 — 2000 ohms, ½-watt.
R_9 — 50,000 ohms, 1-watt.
R_{10} — 10,000 ohms, ½-watt.
R_{11} — 500 ohms, 1 watt.
R_{12} — 5 megohms, ½-watt.
C_1 — 0.1-μfd. paper.
C_2 — 0.01-μfd. paper, 400-volt.
C_3 — 0.1-μfd. paper, 400-volt.
C_4, C_5 — 5-μfd., 25-volt electrolytic.
C_6 — 0.1-μfd. paper, 400-volt.
C_7, C_8 — 8-μfd. electrolytic, 450-volt.
T_1 — Interstage audio, single plate to push pull grids (Kenyon T-52).
T_2 — Interstage audio, p.p. plates to Class-AB grids (Kenyon T-256).
T_3 — Output, Class-AB plates to line (Kenyon T-301).

1-watt neon bulb, with base resistor removed, serves as a constant-drop cathode resistor for the 6J7.

Both amplifier and power supply are built on standard chasses (with covers) measuring 5 by 13½ by 2½ inches. In Fig. 1010, the tube at the left along the front edge of the chassis is the 6J7, followed by the first 6C5. The single-tube to push-pull transformer, T_1, is behind this tube; to its right are the push-pull 6C5's, then T_2, the 2A3's, and the tube-to-line transformer, T_3. The gain control, R_7, is at the left end of the front edge of the chassis. On the left edge are the jack for a crystal microphone and the switch, S, to change the input from crystal to double-button carbon.

The general layout of parts underneath the speech-amplifier chassis is shown in Fig. 1012. Nothing is particularly critical as to lead lengths, although the input leads should be well shielded. The layout for the power supply, Figs. 1015 and 1013, is likewise not at all critical.

It is important that the filament voltage for the Class-AB 2A3's be at the rated value if full performance is to be secured from the tubes. To this end the filament

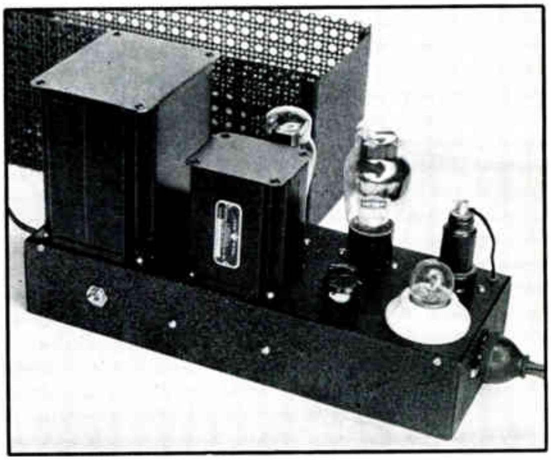


FIG. 1013 — POWER-SUPPLY FOR THE 10-WATT AMPLIFIER

A voltage-regulator is incorporated for all speech-amplifier tubes except the 2A3's.

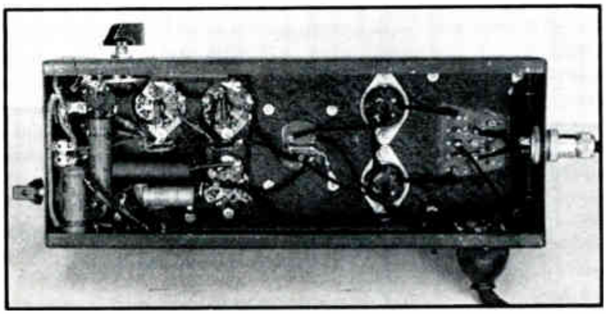


FIG. 1012 — A VIEW UNDERNEATH THE CHASSIS OF THE 10-WATT SPEECH UNIT

World Radio History

leads between power supply and speech amplifier should be quite heavy, and the filament voltage under operating conditions should be checked. If the voltage is more than 5 per cent low heavier filament leads should be used.

For carbon-microphone input, resistors are connected across the microphone as a load, rather than the customary transformer. The high gain of the amplifier permits dispensing with the voltage step-up provided by the microphone transformer. The microphone battery voltage should be adjusted to give the button current recommended by the manufacturer of the microphone.

Although the disadvantage of filament voltage drop in the connecting cable becomes a problem if amplifier and power supply unit are greatly separated, this disadvantage is somewhat offset by the freedom from tendencies toward electromagnetic or electrostatic coupling between the a.c. power circuits and the speech amplifier circuits. Furthermore, the design of the amplifier is such that a larger regulated supply already serving another purpose may be made to supply the speech amplifier, and thus construction of a separate supply for this amplifier may be saved.

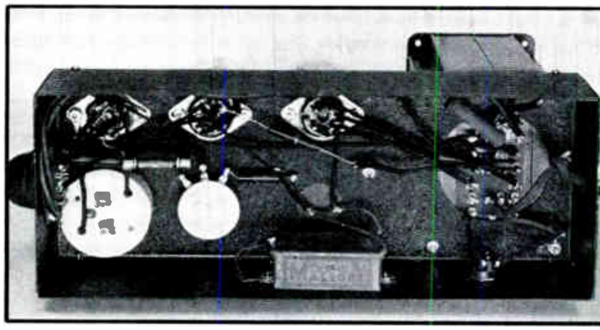


FIG. 1015 — BOTTOM VIEW OF THE POWER-SUPPLY UNIT

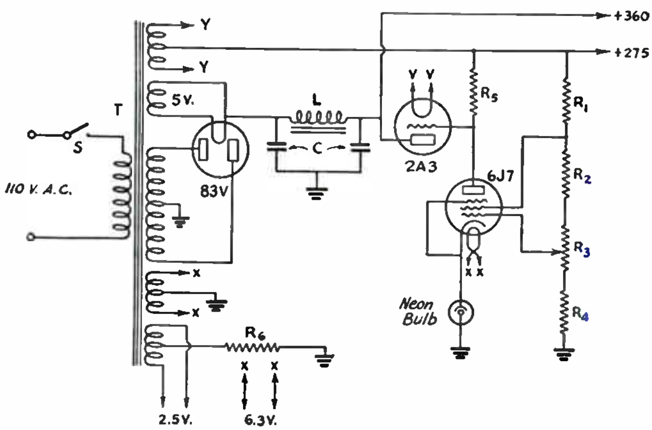
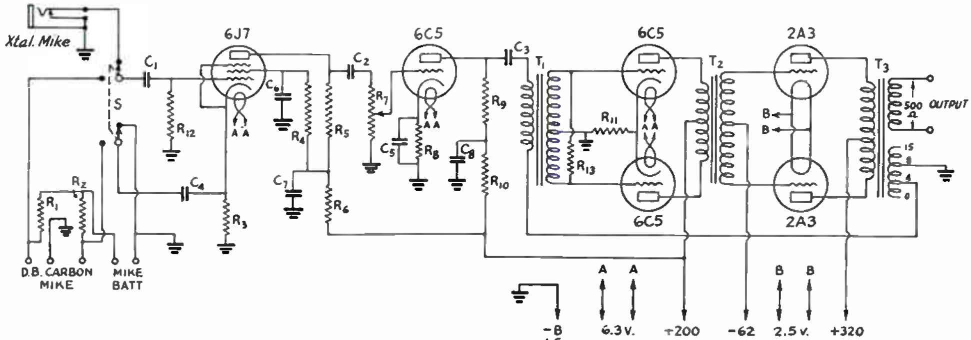


FIG. 1014 — CIRCUIT DIAGRAM OF THE POWER SUPPLY

T — Power transformer; high-voltage winding, 360 volts each side center-tap, 150 ma.; 5 volts, 3 amp. (rectifier); 2.5 volts, 3 amp. (2A3 regulator filament); 2.5 volts, 5 amp. (2A3 speech-amp. filaments); 6.3 volts, 3 amp. (speech-amplifier and voltage-control tubes). (Kenyon T-214.)
L — Filter choke, 15 henrys, 165 ma. (Kenyon T-154).
C — 8-8 μfd. 450-volt electrolytic.
R_1 — 10,000 ohms, 1-watt. R_5—0.5 megohm, 1-watt.
R_2 — 20,000 ohms, 1-watt. R_6—800 ohms, 10-watt.
R_3 — 10,000-ohm volume control.
R_4—5000 ohms, 1-watt.
The neon bulb (1-watt size) should have its base resistor removed.

FIG. 1016 — REVISED CIRCUIT DIAGRAM OF THE UNIVERSAL SPEECH AMPLIFIER, INCLUDING INVERSE FEEDBACK

Constants are the same as given in Fig. 1011 with the following exceptions: C_4, 15-μfd., 25-volt electrolytic, 200-volt; R_{13}, 250,000 ohms, ½-watt.



World Radio History

Inverse Feedback Added to the Universal Amplifier

Although the above speech amplifier is adequate for high-quality 'phone transmission, the frequency range may be extended to one meeting requirements for high-quality amplification of music by incorporation of the circuit shown in Fig. 1016. With this unusually wide response range the amplifier, with the universal output transformer shown, is suitable for public address and theater work as well as for the 'phone transmitter, and thus may be made to serve several purposes.

Details of the principles of operation, results, and adjustment of the amplifier with inverse feed-back are given in an article in *QST*.[1]

As shown in Fig. 1016, the grid bias provision for the 2A3 output stage has been changed from "self-bias" to "fixed-bias," with an increase from 10 to 15 watts in audio output.

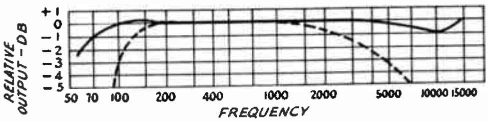


FIG. 1017 — FREQUENCY RESPONSE CURVES WITH AND WITHOUT INVERSE FEEDBACK

Solid line, with negative feedback applied; dotted line, without feedback. Reference frequency, 400 cycles. Output level approximately 9 watts.

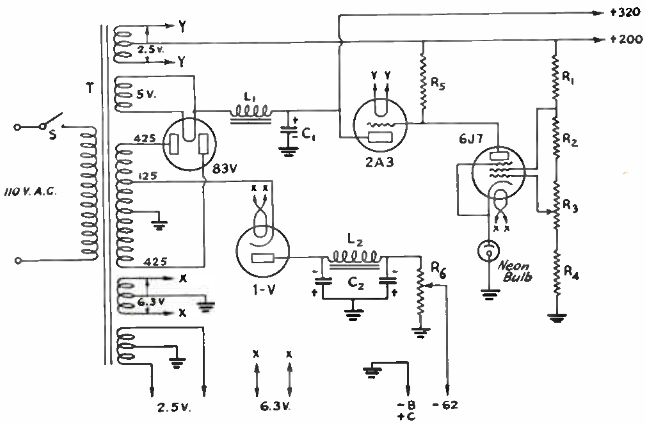


FIG. 1018 — REVISED POWER SUPPLY DIAGRAM, WITH BIAS SUPPLY INCLUDED

Constants are the same as given in Fig. 1014 with the following exceptions: R_6, 12,000-ohm semi-variable resistor (25-watt slider type); L_2, midget filter choke; C_2, double 8-μfd. 250 volt electrolytic. L_1 and C_1 are the same as L and C in Fig. 1014, with the two sections of C_1 in parallel.

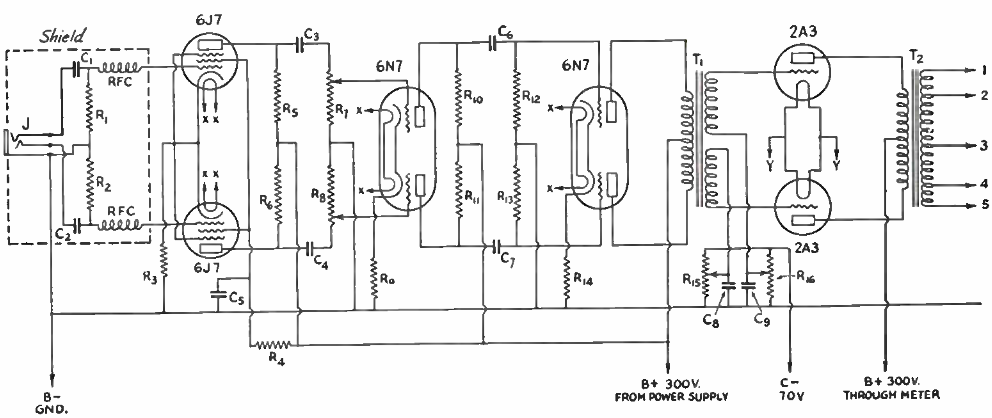
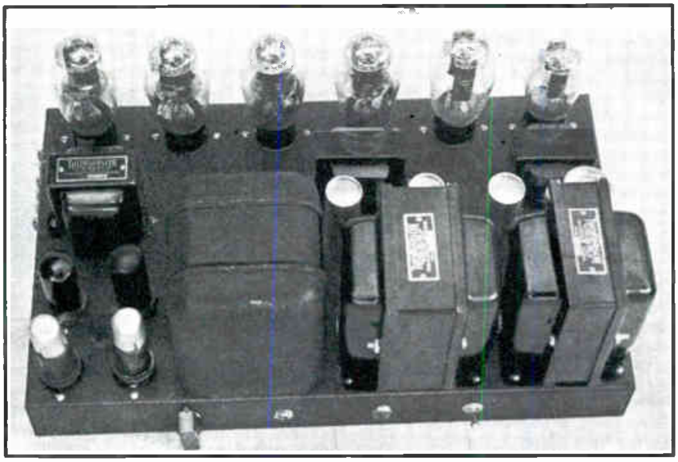


FIG. 1019 — CIRCUIT OF THE 15-WATT ALL-PUSH-PULL AUDIO SYSTEM

C_1, C_2 — 0.002-μfd. mica, 600-volt.
C_3, C_4, C_6, C_7 — 0.01-μfd. paper tubular, 600-volt.
C_5, C_8, C_9 — 1-μfd. paper, 600-volt.
J — Three-wire jack.
R_1, R_2 — 2-megohm, ½-watt carbon.
R_3 — 600-ohm, 1-watt carbon.
R_4 — 0.6-megohm, 1-watt carbon.
R_5, R_6, R_{10}, R_{11} — 0.25-megohm, 1-watt carbon.
R_7, R_8 — 2-gang 250,000-ohm potentiometer.
R_9 — 2000-ohm, 1-watt carbon.
R_{12}, R_{13} — 0.5-megohm, 1-watt carbon.
R_{14} — 700-ohm, 1-watt carbon.
R_{15}, R_{16} — 5000-ohm, 5-watt wire-wound with sliders.
T_1 — Push-pull input transformer for driving 2A3 tubes.
T_2 — Driver transformer for coupling 2A3 plates to grids of Class-B tubes.

World Radio History



The gain control knob is at the left on the front of the chassis, with microphone jack, pilot light (2.5-volt light in parallel with the 2A3 filaments), and power switch in order toward the right. The two 6J7 tubes are at the left front corner of chassis, with the two 6N7 tubes directly behind. The output transformer is located at the front center of chassis, with power transformer to the right and 250-ma. choke at the right front corner. The four condenser cans are in a row behind the transformers and large choke, and the two small chokes are directly behind the condensers. The input transformer for the 2A3 tubes is directly behind the 6N7 tubes. In the rear row of tubes, left to right, the first four are 2A3 output tubes, the fifth is the 83 and the sixth is the 82.

FIG. 1020 — ALL-PUSH-PULL 30-WATT AMPLIFIER AND POWER SUPPLY

ALL-PUSH-PULL SPEECH AMPLIFICATION

In brief, a push-pull Class-A amplifier has a large number of advantages arising from the relative freedom from audio-frequency variations in total cathode current and total plate current of the stage.

Fig. 1019 and Fig. 1023 are circuit diagrams of amplifiers with audio power output of 15 and 30 watts, respectively, based on use of push-pull stages exclusively. These amplifiers are characterized by a frequency response range comparable to that obtained by use of inverse feedback in well-designed amplifiers; and in addition, are relatively free from a.c. hum caused by slight ripple of power supply voltage. With amplifiers of this type, the necessity for decoupling circuits is largely removed, so that the circuit complications are not increased by use of the push-pull amplifiers.

Two views of the amplifier of Fig. 1023 are given in Fig. 1020 and Fig. 1021. The complete amplifier and power supply is constructed on a

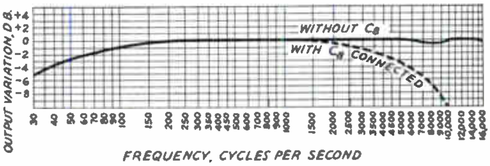


FIG. 1022 — FREQUENCY RESPONSE CURVES TAKEN FROM THE 30-WATT AMPLIFIER WITH AND WITHOUT LIMITING CONDENSER C_8 CONNECTED

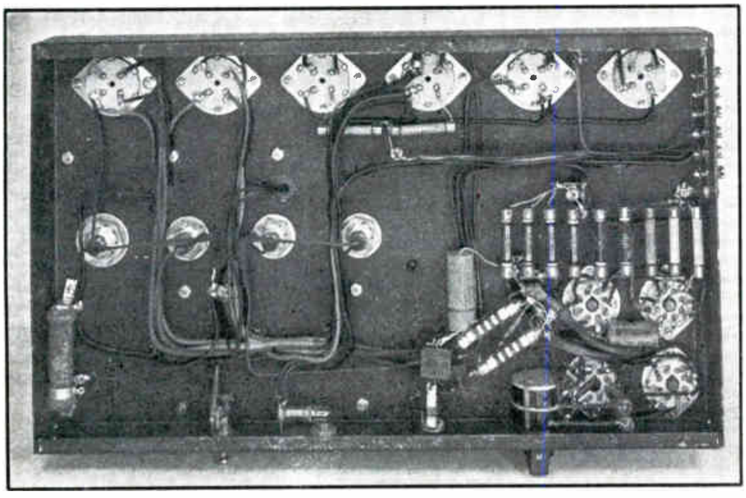


FIG. 1021 — BOTTOM VIEW OF 30-WATT AMPLIFIER

Note that the power supply components and wiring are confined to the half of the chassis at left in this view. The input condensers and chokes are located at the microphone jack, and from the ends of the chokes, shielded wires go through the chassis to the grids of the 6J7 tubes. Plate and grid coupling condensers for the voltage amplifier stages are mounted in a compact group behind the 6N7 tubes. The whole layout is planned for simplicity, with placement of parts for the output of one stage to feed right into the input of the next.

World Radio History

steel chassis 17 inches long, 10 inches deep, and 2 inches high. The power transformer and chokes above the chassis and the power supply wiring beneath are well-separated from the audio-frequency circuits. A.c. hum induced in the audio circuits is thus kept to a minimum.

50-WATT 6L6 MODULATOR OR HIGH-POWER CLASS-B DRIVER

The 6L6 speech-amplifier unit shown in Fig. 1024 is also a general purpose arrangement, in that substitution of a suitable output transformer makes it adaptable either as a complete modulator or as a driver for Class-B units employing anything up to a pair of 354's or 204-A's. The voltage gain to the grids of the 6L6's is more than sufficient for crystal microphones of the diaphragm type, a peak input of

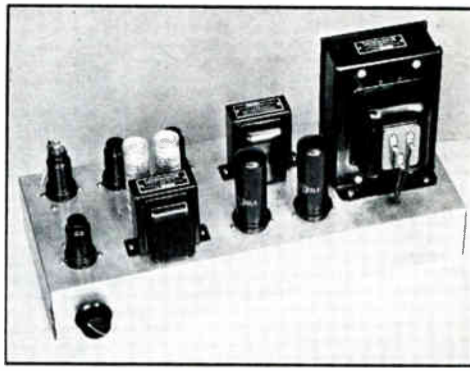


FIG. 1024 — METAL-TUBE SPEECH UNIT WITH PUSH-PULL 6L6 OUTPUT

The gain is sufficient for the popular diaphragm-type crystal microphone.

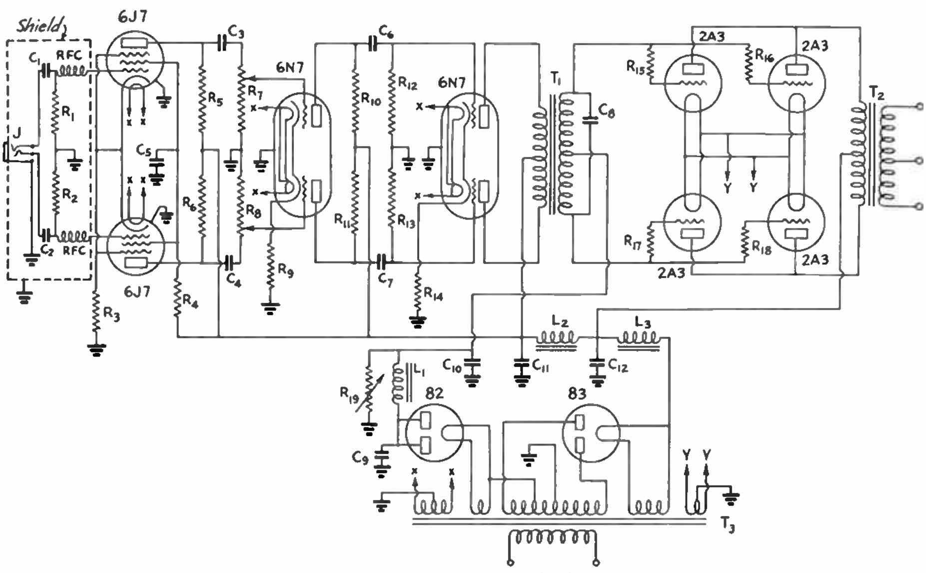


FIG. 1023 — CIRCUIT OF THE 30-WATT AMPLIFIER AND SUPPLY

C_1, C_2 — 0.006-μfd. mica, 600-volt.
C_3, C_4, C_6, C_7 — 0.01-μfd. paper tubular, 600-volt.
C_5 — 0.1-μfd. paper tubular, 600-volt.
C_8 — 0.002-μfd. mica, 600-volt.
C_9, C_{10} — 8-μfd. sections of dual electrolytic, 250-volt working (Mallory RM252), positive leads grounded, negative leads connected to ends of L_1.
C_{11} — 16-μfd. electrolytic, 500-volt working (two Mallory HD683 connected in parallel).
C_{12} — 8-μfd. electrolytic, 500-volt working (Mallory HD683).
J — 3-wire jack.
R_1, R_2 — 2-megohm, ½-watt carbon.
R_3 — 600-ohm, ½-watt carbon.
R_4 — 0.6-megohm, 1-watt carbon.
R_5, R_6, R_{10}, R_{11} — 0.25-megohm, 1-watt carbon.
R_7, R_8 — 2-gang 500,000-ohm potentiometer (Centralab 4-010804).
R_9 — 2000-ohm, 1-watt carbon.
R_{12}, R_{13} — 0.5-megohm, 1-watt carbon.
R_{14} — 7000-ohm, 1-watt carbon.
R_{15}, R_{16}, R_{17}, R_{18} — 100-ohm, 1-watt carbon.
R_{19} — 2500-ohm, 25-watt, semi-variable. (See text.)
T_1 — Push-pull driver input transformer (Thordarson 74D32).
T_2 — Multi-match driver transformer (Thordarson 15D80).
T_3 — Power transformer to deliver a.c. voltages as follows: 435 volts each side of center-tap at 250-ma. d.c. load, 80 volts (single tap) for bias rectifier, 2.5 volts, center-tapped, at 10 amperes, 2.5 volts at 3 amperes, 5 volts at 3 amperes, 6.3 volts, center-tapped, at 1.5 amperes (Thordarson 75R50).
L_1 — 7.2-henry, 120-ma. choke (Thordarson 75C49).
L_2 — 22-henry, 35-ma. choke (Thordarson 18C92).
L_3 — 13-henry, 250-ma. choke (Thordarson 75C51).
RFC — 2.5-millihenry, 125-ma. r.f. chokes.

World Radio History

about 0.005 volt being sufficient to drive the final tubes to full output. As shown in Fig. 1025, the input stage uses a 6J7 (equivalent to the 57 or 6C6) pentode; this tube is resistance-coupled to a 6C5 triode intermediate amplifier. The driver consists of a pair of 6C5's in push-pull, transformer-coupled to the preceding stage. The 6C5's are capable of delivering sufficient power for excitation of the 6L6 grids. The input transformer, T_2, is specially designed for the purpose. The 6L6 output transformer, T_3, also is a special job, arranged with a tapped secondary to work into loads of 2500, 5000 or 7500 ohms for modulation purposes; its turns ratio is such that the plate-to-plate load on the 6L6's is 3800 ohms.

The chasses for both amplifier and power-supply measure 17 by 7 by 3 inches, and are therefore of suitable dimensions for relay-rack mounting. The addition of a standard panel with mounting brackets for rigid assembly to the chassis will fit either unit out for this purpose.

The low-level speech-amplifier section occupies the left-hand section of the chassis in Fig. 1024. The microphone jack is on the back of the chassis near the 6J7 tube; the first 6C5 is at the front left-hand corner, with the gain control conveniently situated. To its right is the single-tube to push-pull coupling transformer; back of the coupling transformer are two electrolytic by-passes, C_6 and C_7, followed by the push-pull 6C5's. The input and output transformers, as well as the 6L6's, are readily identified. The jack for measuring 6L6 plate current is mounted on the back of the chassis, along with a two-terminal strip for the output.

Two power supplies are used, one furnishing 400 volts at 100 to 200 ma. for the 6L6 plates and the other (rated to deliver 300 volts) furnishing plate power to the low-level stages as well as screen voltage and grid bias for the 6L6's. The circuit is shown in Fig. 1026. All tubes except the 6L6's get filament power from the first transformer, T_1. A separate filament transformer, T_2, takes care of the 6L6's and the 83 rectifier of the 400-volt supply. An ordinary condenser-input filter with one choke (this choke is mounted underneath the power-supply chassis) is used on the 300-volt supply. The 400-volt supply has choke input, with the two sections of a double-8 electrolytic condenser in parallel across the output.

The fixed bias for the 6L6's is obtained from the 300-volt supply. Reference to Fig. 1026 will show that there is no ground on the negative side of the 300-volt supply (outlet A). The total current from this supply is made to flow through the right hand section of R_{15} (Fig. 1025) to ground; by means of the adjustable tap on R_{15} the bias voltage is set at 25 volts. R_{14} is a bleeder resistor to load the 300-volt transformer to full capacity. It is desirable to do this so that the current through R_{15} will be

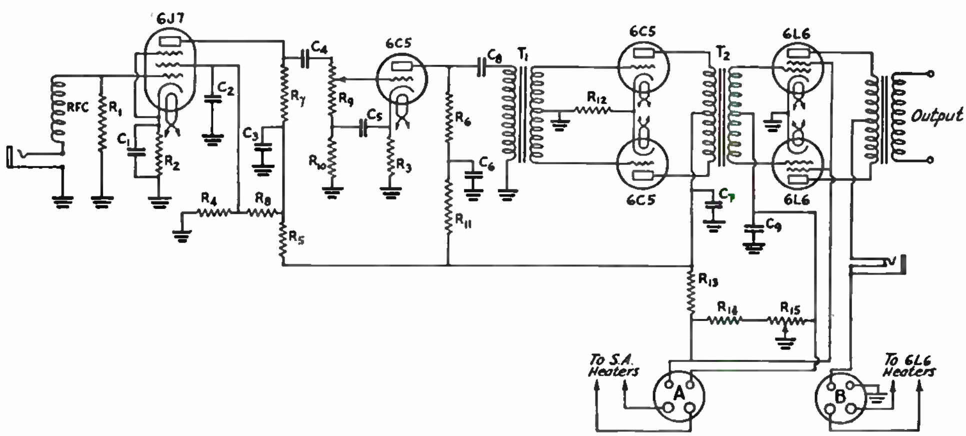


FIG. 1025 — WIRING DIAGRAM OF THE 6L6 SPEECH-AMPLIFIER-MODULATOR

C_1 — 10-μfd., 25-volt electrolytic.
C_2, C_3 — 2-μfd., 200-volt electrolytic.
C_4 — 0.1-μfd. paper, 400-volt.
C_5 — 0.5-μfd. paper (or larger).
C_6, C_7 — 4-μfd., 400-volt electrolytic.
C_8 — 0.25-μfd. paper, 400-volt.
C_9 — 25-μfd. electrolytic, 50-volt.
R_1 — 5 megohms, ½-watt.
R_2, R_3 — 3500 ohms, ½-watt.
R_4, R_5, R_6 — 50,000 ohms, ½-watt.
R_7, R_8 — 0.25 megohm, ½-watt.
R_9 — 0.5-megohm volume control.
R_{10} — 100,000 ohms, ½-watt.
R_{11} — 10,000 ohms, ½-watt.
R_{12} — 500 ohms, ½-watt.
R_{13} — 2500 ohms, 1-watt.
R_{14} — 15,000 ohms, 10-watt.
R_{15} — 1000 ohms, 10-watt.
T_1 — Audio transformer, single plate to push-pull grids, ratio 3:1 (Thordarson T-5741).
T_2 — Input transformer for coupling push-pull 6C5's to 6L6 grids (Thordarson T-8459).
T_3 — Output transformer, 3800-ohm load plate to plate, see text (Thordarson T-8470).

World Radio History

as heavy as possible, thus maintaining the bias fairly constant even though grid current flows. R_{13} drops the voltage to the proper value for the speech-amplifier plates.

The power terminals on both speech and power-supply units are four-prong tube sockets. Connections are made by means of four-wire cables with plugs at each end.

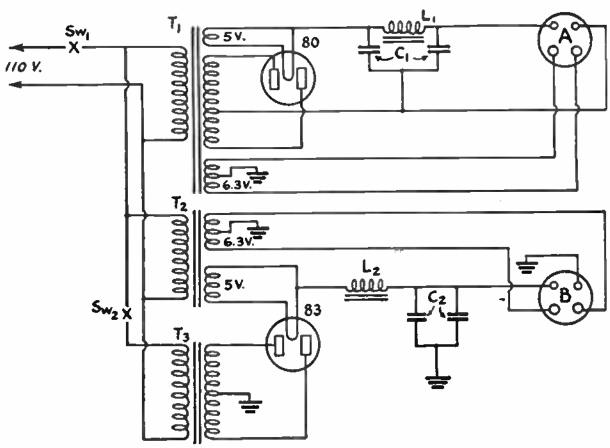


FIG. 1026 — DIAGRAM OF THE 6L6 POWER-SUPPLY UNIT

T_1 — Receiver power transformer; high-voltage winding to deliver app. 325 volts d.c. at 50 ma.; 5-volt, 2-amp. rectifier winding; 6.3-volt, 1.5-amp. filament winding (Thordarson T-70R78).
T_2 — Filament transformer, 5 volts at 3 amps., 6.3 volts at 2 amps. (Thordarson T-79F84).
T_3 — Plate transformer, to deliver 400 volts at 150 ma. through choke-input filter (Thordarson T-53P03).
L_1 — 50-ma. filter choke, 30-henry commercial rating.
L_2 — Input choke, 26 to 12 henrys, 250 ma. (Thordarson T-75C51).
C_1, C_2 — Double 8-μfd. dry electrolytics, 450-volt.
SW_1, SW_2 — S.p.s.t. toggle switch.

Provided the values given are followed, the only adjustment to be made is that of the bias on the 6L6's. Preferably, this should be done with the aid of a high-resistance voltmeter, with everything except the 400-volt plate transformer turned on. However, if no such voltmeter is available, a method which works about as well is to set the tap on R_{15} so that the plate current to the 6L6's is slightly over 100 ma. It is essential that the screen voltage be exactly 300 volts, since the plate current is quite sensitive to changes in screen voltage.

With a good ground connection the hum level should be negligible. Should the hum increase perceptibly when the microphone plug is inserted, it will be necessary to shield the grid cap of the 6J7. (See June 1936 *QST* for a more detailed description.)

The same circuit is used in the unit at the left in Fig. 1035, in which both amplifier and power supply are built on the same chassis for 19-inch rack mounting. All components are as given in Figs. 1025 and 1026 except for the transformers T_2 and T_3. To minimize power-supply hum in the unit assembly a balanced type coupling transformer is used for T_2 (Thordarson T-9004), and a Class-B input transformer for coupling 6L6's to 354's (UTC Type 18126) is used for T_3.

GRID-MODULATED TRANSMITTERS

For best results with grid-bias modulation, a few simple requirements must be observed. Grid bias should be obtained only from B batteries, or a bias supply equipped with a low-resistance bleeder and provided with a high-capacity (4- to 8-μfd.) condenser across the portion of the bleeder included in the grid circuit of the amplifier. The bias voltage used should be between three and six times cut-off bias for the modulated stage at the plate supply voltage used (cut-off bias for a triode is the voltage obtained by dividing the plate voltage by the amplification factor). Some means of conveniently varying the bias voltage, continuously or in steps, should preferably be provided. It is desirable that the plate voltage be the maximum rated voltage for the tube. The r.f. driving power which gives best operation with grid-modulation at the maximum rated plate voltage of the tube is one-fourth to one-half that required for normal telegraphy (Class C, unmodulated) operation. The r.f. grid circuit of the modulated amplifier should be loaded with a dissipative load, for which purpose either a non-inductive resistor may be connected across the grid tank circuit of the modulated amplifier (across the plate tank circuit of the preceding stage if capacity coupling is used), or a lamp bulb may be connected to a one- to three-turn loop and coupled to the grid coil of the amplifier (to driver plate coil with capacity coupling). Some means should be provided for conveniently varying the amount of r.f. excitation given to the grid of the modulated amplifier, for this is the last step in the process of adjustment of the system for proper modulation.

The first move in the tuning-up process is application of the maximum plate supply voltage available (within the rating of the tube for Class C telegraph operation), and loading and exciting the amplifier to the maximum obtainable r.f. output with the grid-bias voltage set for the cutoff value at the plate voltage used. While making this first adjustment, care should

World Radio History

be used to operate the key only for short dashes rather than to leave the transmitter running for an appreciable length of time, since this type of operation would greatly overload the tube or tubes of the modulated amplifier. The value of plate voltage available with the supply lightly loaded should then be divided into half the total dissipation rating of the modulated amplifier, and the value obtained should be multiplied by three to obtain the current (in amperes) at which the stage should operate with grid modulation. If the current drawn by the amplifier is greater than double the value obtained by the above process, the excitation to the modulated amplifier should be reduced until the double-normal-current value is obtained. The bias on the grid-modulated amplifier stage should then be increased until the plate current is reduced to the value obtained above (3/2 total rated plate dissipation divided by plate supply voltage) and modulation should be applied in series with the bias batteries or supply. It should be remembered that the plate supply voltage changes with the varying load of the grid-modulated amplifier during the adjustment of the latter.

With no audio signal applied, the efficiency of the grid-modulated amplifier, properly adjusted, is approximately 30 per cent. On positive modulation peaks, the efficiency becomes approximately 60 per cent and the instantaneous value of peak plate supply current is approximately double the no-signal value. Hence, with the plate supply voltage remaining constant through an audio cycle, the peak power output of the modulated amplifier is approximately four times the normal carrier, as required for proper modulation. On the opposite (negative) peak of the audio cycle, the instantaneous value of plate current becomes zero (provided proper adjustment with stable excitation is used) and the output falls to zero. The average efficiency of the grid-modulated amplifier is lowest with no modulation, and rises noticeably with 100-percent modulation. The limit of the power input to 3/2 times the total plate dissipation of the stage is based on the no-modulation efficiency.

25 WATTS OUTPUT FROM P.P. 809'S GRID MODULATED

THE 3.5-watt amplifier of Fig. 1009 is a very suitable unit for grid modulation of popular small tubes. It is shown in Fig. 1027 (circuit arrangement in Fig. 1028) as a modulator for a push-pull 809 amplifier. The changes in the r.f. amplifier include removal of a grid leak and provision for battery bias, and loading the grid coil of the modulated amplifier with a lamp and loop. This load, coupled in the manner used normally to test or adjust an amplifier at full input power, retains a relatively heavy fixed load on the driver stage while the lighter load of the modulated amplifier grid circuit varies widely through the modulation cycle. This tends to maintain the r.f. excitation voltage constant with modulation, and it is usually a convenient means for reducing the excitation available at the grid circuit of the amplifier to a value suitable for modulation — an amount much smaller than is usually used for c.w. telegraphy.

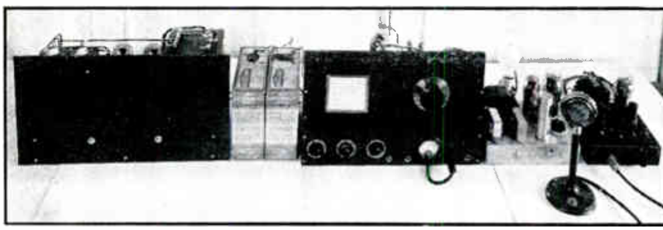


FIG. 1027 — A COMPLETE GRID-MODULATED PHONE TRANSMITTER OF 25 WATTS OUTPUT (75 WATTS INPUT)

Two power supplies and two 45-volt batteries are sufficient for satisfactory operation of this layout. The 750-volt supply used for the 809 stage for telegraphy is ideal for use when the amplifier is grid modulated. A small power supply delivering 350 volts at 150 ma. and 6.3 volts filament source is suitable for the requirements of the two 6L6 stages and the speech amplifier-modulator unit.

The total plate dissipation of the 809 tubes is 50 watts (25 watts per tube), and the input should therefore be 75 watts when the adjustment of the stage is completed. At 750 volts, this means a plate current of 100 ma. Cutoff bias for the tubes (obtained by dividing 750 volts by 50, the amplification factor) is approximately 15 volts; the 22.5-volt tap of the battery is accordingly used for first setting the stage to adjust loading and excitation. With 22.5 volts negative grid bias and 750 volts plate supply, the stage is then loaded up to obtain the maximum available output. Since this involves large plate dissipation of the tubes, the key must be pressed only long enough at a time to make readings of meters and to make any tuning adjustments necessary. If maxi-

World Radio History

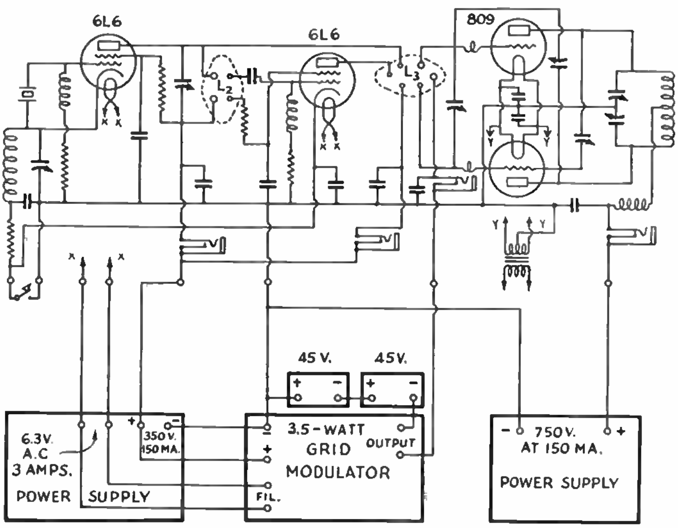


FIG. 1028 — CIRCUIT OF GRID-MODULATED PUSH-PULL 809 TRANSMITTER

With the exception of a few minor changes, the r.f. section of this transmitter is that of Fig. 1, page 13, *QST* for February, 1938. Although not indicated on the diagram here, a 110-volt, 25-watt lamp bulb is coupled by means of a few turns of wire around the amplifier grid tank coil. This lamp, of course, does not glow at full brilliance under proper operating conditions. Loading of the buffer stage, and the amount of excitation available at the grids of the final r.f. amplifier, may be varied by change of the degree of coupling of the lamp pickup coil.

mum output is obtained with much more than 200 ma. plate current, the amount of excitation at the grids of the amplifier tubes must be reduced either by an increase of loading of the buffer stage by the lamp, or by a reduction of the plate voltage applied to the preceding stage. When the plate current has been thus reduced to 200 ma., the bias voltage should be increased (that is, the amount of negative grid voltage should be made greater) in steps of 22.5 volts, until the total plate current of the modulated amplifier is reduced to 100 ma., the proper operating current.

When tone modulation is applied, it should be possible to cause the antenna current to increase and the plate current to rise simultaneously. This is not the operating condition for speech modulation, however. With speech modulation the antenna current should show rise of not more than 5 per cent on peaks, while the plate current of the amplifier should no more than flicker. Inability to obtain antenna current rise with test modulation shows that the positive peaks are being flattened off as shown in 1031-B. This figure shows oscillograph patterns for both audio-frequency a.c. sweep (left) and synchronized linear sweep (right). If the antenna current cannot be made to rise, either there is insufficient audio modulation available, or the modulation characteristic is flattening equally on positive and negative peaks, as shown in Fig. 1031-C. The latter should be corrected by adjustment of coupling to the antenna and variation of the r.f. excitation. *The amplifier should not be adjusted for maximum carrier efficiency.* In fact, for proper modulation the antenna loading will be somewhat greater than is ordinarily the case, the efficiency being necessarily reduced to obtain linear modulation.

The plate current should be practically

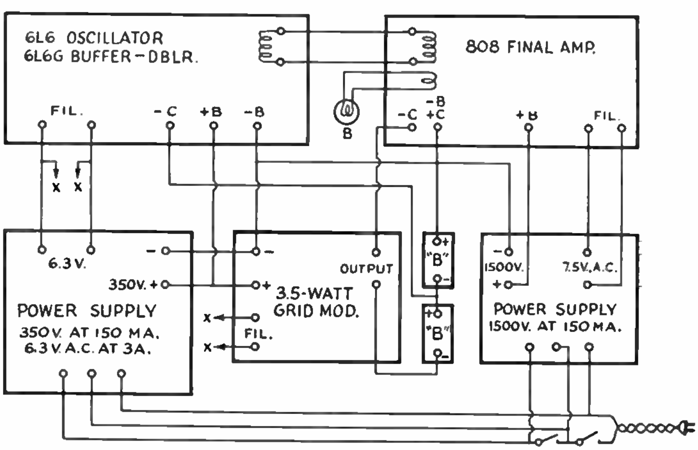


FIG. 1029 — ARRANGEMENT OF UNITS OF ANOTHER 25-WATT OUTPUT GRID-MODULATED 'PHONE

The 6L6G r.f. amplifier delivers adequate excitation for Class-C telegraph operation, and thus gives far more than the desired excitation power for grid modulation of the 808 final amplifier; it consequently may be heavily loaded by a lamp coupled to the grid coil of the final amplifier, so that a very stable r.f. voltage source is provided at the grid of the 808.

World Radio History

steady at a fixed value either with or without modulation, although a slight upward kick (not more than 5 per cent) is permissible on modulation peaks. If there is a downward kick in plate current or a pronounced upward kick, one or more of the following may be the cause, in addition to improper neutralization and the possibility of parasitic oscillations:

Downward kick: Too much r.f. excitation; insufficient operating bias; distortion in modulator or speech amplifier; too-high resistance in bias supply; insufficient output capacity in plate-supply filter to modulated amplifier; amplifier plate circuit not loaded heavily enough; plate-circuit efficiency too high under carrier conditions; too-low C in tank circuit.

Upward kick: Overmodulation (excessive audio voltage); too-low C in tank circuit; distortion in audio system; regeneration because of incomplete neutralization; operating grid bias too high.

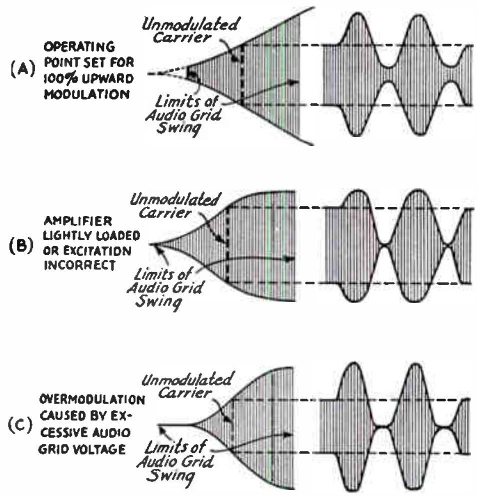


FIG. 1031 — OSCILLOSCOPE PATTERNS REPRESENTING PROPER AND IMPROPER GRID-BIAS OR SUPPRESSOR-GRID MODULATION

The pattern obtained with a correctly adjusted grid-bias modulated amplifier is shown at A. The other two drawings indicate non-linear modulation, accompanied by distortion and a broad signal.

A downward kick in plate current will accompany an oscilloscope pattern like that of Fig. 1031-B; the pattern with an upward kick will look like Fig. 1031-A with the shaded portion extending farther to the right and above the carrier, for the "wedge" pattern.

The source of grid bias should have low internal resistance so that when the grid current varies with modulation there will not be an appreciable shift in the operating grid bias. Since the grid current usually is small compared to the values used for telegraph or plate-modulation service, a grid-bias power pack can be used with satisfactory results, provided it is equipped with a low-resistance bleeder.

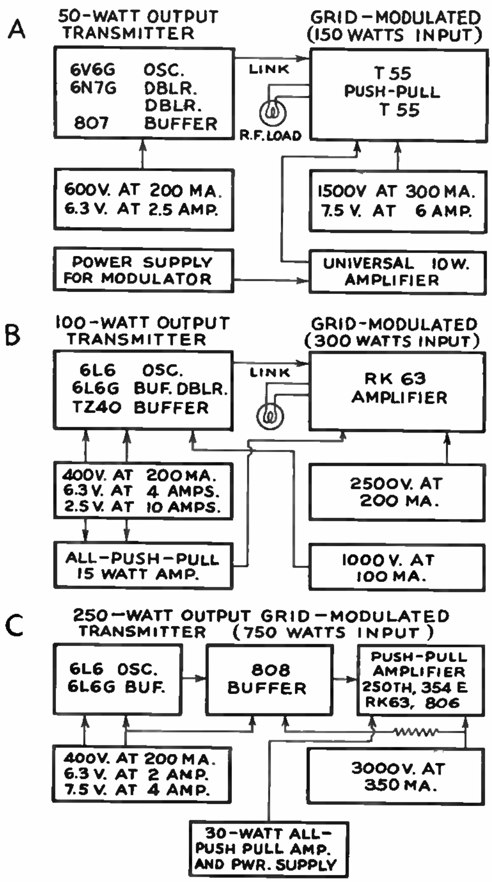


FIG. 1030 — BLOCK DIAGRAMS OF THREE COMPLETE GRID-MODULATED TRANSMITTERS

Each final amplifier grid circuit is link coupled to the plate circuit of the preceding amplifier, and each is loaded with a 110-volt lamp and loop. The r.f. and audio units are all covered in Chapters Eight and Ten.

ANOTHER 25-WATT GRID-MODULATED 'PHONE

A HIGHLY successful layout for grid modulation of a single-tube amplifier is shown in Fig. 1029. This transmitter, incorporating the 6L6-6L6G exciter of Fig. 839, the 808 amplifier of Fig. 852, and the modulator of Fig. 1009, along with two power supplies and a source of fixed bias, requires much the same tuning and adjusting procedure used for the transmitter described above. The plate dissipation of the 808 tube is 50 watts, and at the maximum rated plate voltage for this tube, 1500 volts, the proper operating current is 50 ma.

World Radio History

GRID-MODULATED 'PHONE TRANSMITTERS OF 50, 100, AND 250 WATTS OUTPUT

The transmitters of the block diagrams in Fig. 1030 are all designed to make use of the r.f. units of Chapter Eight and the audio amplifiers of this chapter. The exciters chosen for these transmitters are all capable of supplying full excitation for Class-C telegraphy, and the power supplies specified for use with the grid-modulated combinations are also adequate for full-power c.w. operation. The modulators used in these arrangements are all capable of supplying much more than the minimum audio power for 100-per cent modulation, since the reserve audio power gives the effect of better output regulation of the modulator with the load of the amplifier grid circuit varying over the audio cycle. Smaller amplifiers may be used for modulating these stages fully, but slightly inferior quality should be expected. Furthermore, the sizes chosen are quite suitable for driving the Class-B modulators desirable for plate modulating these transmitters.

ADJUSTMENT OF SUPPRESSOR-MODULATED AMPLIFIERS

The operating principles in suppressor-modulation of a pentode r.f. amplifier are identical with those described for grid-bias modulation. Adjustments are somewhat simpler, however, because the bias on the suppressor grid can be adjusted independently of bias and excitation to the control grid. Except for suppressor bias, the tube should be operated under the same conditions as for c.w. telegraph service, although it is sometimes beneficial to supply somewhat more excitation when suppressor modulation is to be applied.

To set the operating conditions, adjust the amplifier for maximum output at rated maximum input, using the maximum positive recommended suppressor bias. Then apply negative bias to the suppressor, adjusting its value until the antenna current drops to half the figure obtained under maximum conditions. Simultaneously, the plate current also should drop to half its maximum value. The amplifier is then ready for modulation. Should the plate current not follow the antenna current in the same proportion when the suppressor bias is made negative, the loading and excitation should be readjusted to make them coincide.

The oscilloscope patterns of Fig. 1031 are typical of suppressor modulation.

CLASS-B MODULATOR DESIGN

A Class-B modulator is simple both in circuit and construction. The same diagram serves for all types of tubes, and the three examples to be given later are typical. The important points about a Class-B amplifier are the choice of proper turns ratios for the input and output transformers, proper adjustment of the load (Class-C amplifier plate circuit input) so that the load resistance presented to the Class-B plates is optimum, and provision for adequate excitation power. Typical operating conditions for various types of tubes suitable for Class-B audio service are given in Table II.

The general method for calculating the output-transformer turns ratio has already been given. Most manufactured transformers, however, are catalogued according to the purpose for which they are intended, a relatively small number of standard combinations being available. For example, the manufacturer's data seldom give the turns ratio directly, but instead specify that the transformer is intended to couple a pair of tubes of a certain type to a particular load resistance, usually a round figure such as 5000, 10,000 ohms, etc. In such case the Class-C amplifier plate voltage and current must be proportioned to give one of the load resistances specified, and the plate power input must be adjusted to twice the rated output of the Class-B modulator. This sometimes results in odd values of plate current and voltage. A Class-B modulator is fairly tolerant of loading, so that some departure from the optimum figures is possible so long as it is remembered that such departure is accompanied by a reduction in audio output.

A similar situation exists with respect to input transformers. These usually are specified to couple between certain combinations of driver and Class-B tubes. In case a tube combination is chosen for which no specific transformer is available, the manufacturer usually can recommend a suitable unit.

Multi-tapped input and output transformers, suitable for matching a wide range of tube combinations, are available. The use of such units often will simplify the matching and adjustment problem.

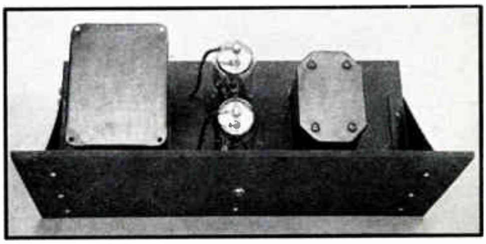


FIG. 1032 — TYPICAL RELAY-RACK ARRANGEMENT FOR CLASS-B MODULATOR STAGE

No special constructional features are involved, and the general arrangement is suitable for practically all tubes up to 100 watts plate dissipation, approximately.

World Radio History

TYPICAL CLASS-B MODULATOR

The arrangement and construction of the Class-B modulator shown in Fig. 1032 is representative for all types of tubes whose power ratings and physical dimensions are such that all the equipment for the modulator stage can be contained in one relay-rack chassis. The tubes shown in the illustration are TZ40's, which are capable of developing 175 watts of audio power, with negligible distortion, when properly excited at maximum ratings.

The modulator circuit diagram is given in Fig. 1033. The input transformer works into the Class-B grids from a line, so that the driver and speech amplifier can be isolated from the modulator. The circuit diagram is typical of all Class-B amplifiers, and needs no particular comment. The tubes shown, TZ40's, operate at 1000 volts with zero bias and deliver 175 watts audio output under these conditions. A separate terminal is provided for use with types of the same power classification which require fixed negative grid bias; this terminal is shorted to ground when the zero-bias tubes are used. The grid-input, filament, negative "B" and negative "C" terminals go to a connection strip mounted in the side of the chassis; the high-voltage and output terminals are porcelain feed-through insulators mounted on the rear edge. The chassis measures 7 by 17 by 2½ inches.

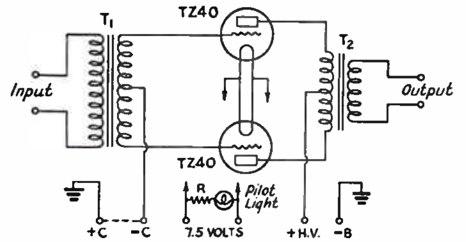


FIG. 1033 — CIRCUIT DIAGRAM OF A CLASS-B MODULATOR

T_1 — Class-B input transformer, line-to-grids (UTC PA-59-AX).

T_2 — Class-B output transformer, multi-tapped (UTC VM-3).

Resistor R should be adjusted according to pilot light used. With a 6.3-volt, 0.3-amp. bulb, a resistance of 3 ohms will be satisfactory.

This modulator represents the maximum size that can be used with amateur transmitters, since it is capable of modulating the 1-kw. maximum input permitted by the regulations. It is adaptable to other types of tubes, such as 204-A and 250TH, as well as to the 354's shown. The driver should be capable of supplying 15 to 25 watts to the Class-B modulator grid circuit, depending on the tubes used and the operating conditions. (See Class-B modulator table for data.) The 6L6 unit previously described is recommended for the purpose. The construction of this type of modulator unit is straightforward, as is also its operation. It should be built up separately from the low-level audio stages, of course, and should have a plate power supply of good regulation capable of 2000 or 2500 volts at 325 or 350 ma.

300-WATT CLASS-B MODULATOR

The new large zero-bias tubes make possible modulation of transmitters of 500 watts input power without the bother of bias batteries, and are usually suitable for still larger outputs when used with a battery supplying a few volts.

ZB120 tubes are used in the 250–300 watt modulator of Fig. 1034. At voltages between 750 and 1250 volts from the plate supply, these tubes operate with grids at ground d.c. potential and deliver 150 to 245 watts output per pair. With 1500-volt plate supply, 9 volts fixed bias (obtainable from two standard 4.5-volt "C" Batteries) is used to limit the zero-signal plate current and plate dissipation of the tubes.

No input transformer is included in this modulator unit; unless the driver and modulator are to be located in separate buildings some distance apart, it is more economical to use three connecting wires between the two and to include a Class-B input transformer in the driver unit, than to make use of driver-to-line and line-to-grids transformers.

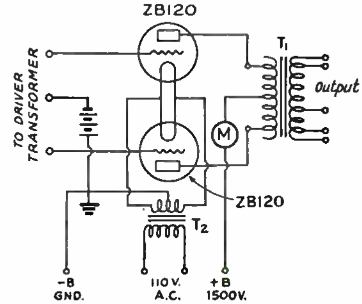


FIG. 1034 — CLASS-B MODULATOR OF 300-WATT OUTPUT

Note that the driver transformer is external of this unit; the speech amplifier and driver unit should include a Class-B input transformer as output coupling device. The grid bias battery shown consists of two 4.5-volt C batteries connected in series; if the modulator supply voltage is lower than 1250, this fixed-bias source may be omitted and the driver center-tap may be connected directly to ground.

T_1 is a multi-match 300-watt Class-B output transformer (UTC VM4), while T_2 is a 10-volt c.t. fil. transformer. M is a 0–500 ma. milliammeter.

500-WATT CLASS-B MODULATOR

Fig. 1036 gives the circuit of the high-power modulator shown on page 246 in Fig. 1035.

World Radio History

TABLE II — CLASS-B MODULATOR DATA

Class-B Tubes (2)	Fil. Volts	Plate Volts	Grid Volts App.	Peak A.F. Grid-to-Grid Voltage	Zero-Sig.[1] Plate Current Ma.	Max.-Sig.[1] Plate Current Ma.[2]	Load Res. Plate-to-Plate Ohms	Max.-Sig. Driving Power Watts [3]	Max.-Sig.[1] Power Output Watts [3]
10	7.5	350 425	−40 −50	120 130	8 8	110 110	6000 8000	2.3 2.5	20 25
801	7.5	400 500 600	−50 −60 −75	270 290 320	8 8 8	130 130 130	6000 8000 10,000	3 3 3	27 36 45
1608	2.5	425	−15	65	36	190	4800	2.2	50
T-20	7.5	800	−40	—	20	136	12,000	—	70
TZ-20	7.5	800	0	—	40	136	12,000	—	70
HY25	7.5	800	−9	—	20	140	9000	2.7	75
HY61	6.3	600	−30	—	60	200	6660	0.4	80
807[8]	6.3	600	−30	—	60	200	6660	0.4	80
825	7.5	850	−67.5	—	50	170	8000	Note 4	82
RK18	7.5	750 1000	−40 −50	180 198	— —	153 172	10,000 12,000	Note 4	65 100
756	7.5	850	−30	—	20	225	6750	Note 4	100
809	6.3	750	−5	140	35	200	8400	2.4	100
1623	6.3	750	−25	200	35	200	8400	4	100
HY57	6.3	800	−9	145	40	200	9000	2.7	110
800	7.5	750 1000 1250	−40 −55 −70	320 300 300	26 28 30	210 160 130	6400 12,500 21,000	6.0 4.4 3.4	90 100 106
RK31	7.5	1250	0	—	—	170	13,000	Note 4	125
RK37	7.5	1250	−32	223	32	158	20,000	2.8	125
35T	5.0	750 1000 1250 1500	−25 −35 −45 −50	— — — —	— — — —	200 185 156 140	7000 11,200 17,200 23,600	8 7 5.5 4.5	90 115 125 135
HY40	7.5	1000	−38	190	20	270	7000	6	175
T40	7.5	1000	−38	190	22	280	6900	6	175
TZ40	7.5	1000	0	75	40	280	6900	3	175
830-B	10.0	800 1000	−27 −35	250 270	20 20	280 280	6000 7600	5 6	135 175
808	7.5	1500	−16	110	30	190	18,300	4.8	185
203-B	10.0	1000	−35	—	40	330	6800	Note 5	200
50T	5.0	1000 1500 2000 3000	−85 −135 −180 −280	— — — —	— — — —	200 166 146 115	6000 9600 12,000 16,000	4.5 4.5 4.5 4.5	100 155 195 250
154	5.0	750 1000 1250 1500	−100 −155 −210 −265	430 510 600 700	40 50 60 80	350 300 256 230	4000 7500 11,400 16,000	10 10 10 10	150 200 223 250
RK52	7.5	1250	0	180	40	300	10,000	7.5	250
RK58	10	1250	0	200	148	320	9000	7.5	260
203-A	10.0	1000 1250	−35 −45	310 330	26 26	320 320	6900 9000	10 11	200 260
838	10.0	1000 1250	0 0	90 90	106 148	320 320	7600 11,200	5 5	200 260
211	10.0	1250	−100	410	20	320	9000	8	260
203Z	10.0	1250	0	—	90	350	7900	7	300

World Radio History

TABLE II — CLASS-B MODULATOR DATA — *Continued*

Class-B Tubes (2)	Fil. Volts	Plate Volts	Grid Volts App.	Peak A.F. Grid-to-Grid Voltage	Zero-Sig.[1] Plate Current Ma.	Max.-Sig.[1] Plate Current Ma.[2]	Load Res. Plate-to-Plate Ohms	Max.-Sig. Driving Power Watts[3]	Max.-Sig.[1] Power Output Watts[3]
ZB120	10.0	750 1000 1250 1500	0 0 0 −9	190 190 180 196	50 70 95 60	320 310 300 296	4800 6900 9000 11,200	5 5 4 5	150 200 245 300
RK-38	5.0	2000	−52	357	36	265	16,000	5.8	330
HF100	10.0 to 11.0	1500 1750	−52 −62	264 324	50 40	270 270	12,000 16,000	2 9	260 350
852	10.0	2000 3000	−155 −250	600 780	22 14	180 160	22,000 36,000	3.5 3.5	220 360
805 & RK57	10.0	1250 1500	0 −16	235 280	148 84	400 400	6700 8200	6 7	300 370
100TL	5.0 to 5.1	1000 1250 1500 2000 2500 3000	Bias adjusted for maximum rated plate dissipation under no-signal conditions				5200 7200 9600 16,000 22,000 30,000	May be driven by push-pull 6L6's	170 230 270 350 435 465
100TH	5.0 to 5.1	1000 1250 1500 2000 2500 3000	Bias adjusted for maximum rated plate dissipation under no-signal conditions Zero bias up to 1250 v. plate				5200 7200 9600 16,000 22,000 30,000	May be driven by push-pull 6L6's	210 260 300 380 460 500
806	5.0	2000	−150	340	20	390	11,500	14	500
HF200	10.0	2000	−100	420	60	380	11,200	9	500
822	10.0	2000	−90	—	50	450	9000	Note 7	500
HD 203-A	10.0	1500 1750	−40 −67	— —	36 36	425 425	8000 9000	Note 6	400 500
250TL 250TH	5.0 to 5.1	1000 1250	Bias adjusted for maximum rated plate dissipation under no-signal conditions 250TH-zero bias up to 1400 v. plate				2360 3280	May be driven by p.p. 6L6's	350 540
204A	11.0	2000	−60	500	80	500	8800	20	600
354 354C	5.0	1000 1500 2000 2500	−60 −95 −125 −165	340 440 500 560	40 60 100 80	252 267 294 236	10,000 10,000 10,000 15,000	14 20 20 20	162 315 448 577
354D	5.0	1500 2500	−60 −112	350 430	50 50	277 290	12,000 20,000	20 20	302 519
354E	5.0	1500 2500	−25 −50	334 384	50 50	325 348	10,000 16,000	20 20	319 595
354F	5.0	1500 2500	−15 −35	274 310	50 50	280 300	12,000 20,000	20 20	290 550
HF300	11–12	2000	−72	404	60	480	9600	14	650
150T	5.25	1000 1500 2000	−80 −130 −170	— — —	— — —	400 400 400	4000 6800 11,000	11 14 16	200 350 490

[1] Values are for both tubes.

[2] Sinusoidal signal values; speech values are approximately one-half for tubes biased to approximate cut-off and 80% for zero-bias tubes.

[3] Values do not include transformer losses. Somewhat higher power is required of the driver to supply losses and provide good regulation.

[4] Can be driven by a pair of 45's in push-pull at 250 volts.

[5] Can be driven by a pair of 2A3's in push-pull at 250 volts.

[6] Can be driven by a pair of 2A3's in push-pull Class-AB at 300 volts with fixed bias.

[7] Can be driven by four 2A3's in push-pull parallel Class-AB or by a pair of 6L6's.

[8] Class-AB_2.

Input transformers must be designed to fit particular driver-Class-B Amplifier combinations. Suitable transformers are available rom various manufacturers.

World Radio History

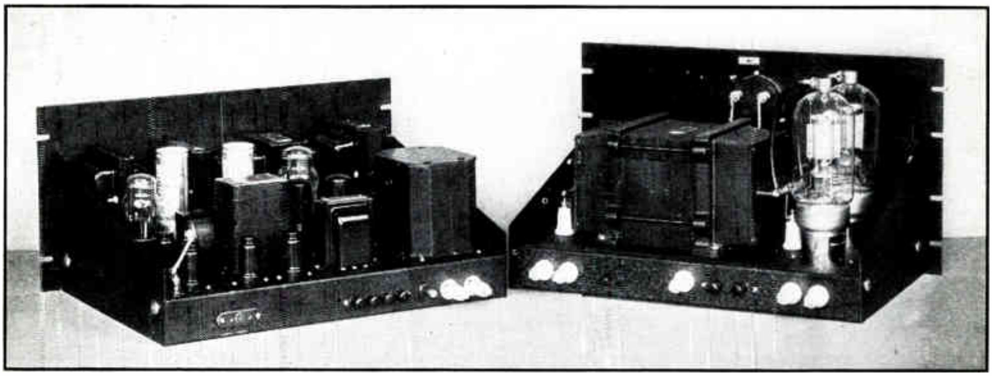


FIG. 1035 — SPEECH-AMPLIFIER AND 50-WATT DRIVER UNIT (LEFT) AND 500-WATT CLASS-B MODULATOR (RIGHT)

The speech amplifier and its power supply, built as one unit, use the circuits of Figs. 1025 and 1026.

Notes on Class-B Audio Operation

Aside from the necessity for adjusting the Class-C amplifier's plate input so that the proper load resistance is presented, through the output transformer, to the Class-B plates, certain other features of Class-B operation require attention. Also mentioned previously was the necessity for supplying sufficient power to the Class-B grids and the selection of the proper input transformer.

Where fixed bias is required, as specified in Table II, the bias source must have very low internal resistance if distortionless operation is to be secured. With tubes particularly suited to Class-B operation, not a great deal of bias is required, and it is preferable to use batteries for the purpose rather than a power pack, unless the latter has an extremely low value of bleeder resistance. High resistance in the grid return circuit shifts the operating point when grid current flows and thereby introduces distortion.

The plate supply for a Class-B modulator should have good regulation, also in the interests of reducing distortion. A choke-input filter should be used, along with mercury-vapor rectifier tubes. Also, the capacity of the last condenser in the filter should be large enough so that its reactance is low (of the order of a few hundred ohms at most) at the lowest audio frequency to be passed by the modulator. A capacity of 4 μfd. usually will meet this requirement.

When the plate load resistance and other operating conditions are according to the tube manufacturer's specifications, pure-tone input to the grids will develop the rated power output when the plate current rises to the values given in Table II. With voice input, however, the plate current will be considerably less under conditions giving the same *peak* output, which is the limiting factor. Usually the modulator will develop its rated peak output when its plate current is about half the maximum-signal value given in the table, although the value will vary with the type of voice, kind of tube, etc. If possible, the output of the transmitter should be checked with an oscilloscope to determine the average value of plate current which, with normal talking, keeps the average modulation percentage as high as possible but does not cause it to rise over 100% under any conditions. The gain may then be adjusted so that the average plate-current value so obtained is not exceeded in regular operation.

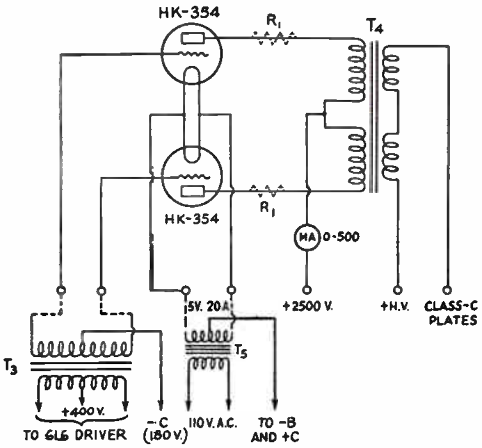


FIG. 1036 — CIRCUIT OF THE 500-WATT CLASS-B MODULATOR

T_3 — Class-AB 6L6 to Class-B 354 input transformer, mounted in driver unit (UTC Type 18126).
T_4 — 500-watt Class-B output transformer, 18,000 ohms to 5000 ohms (UTC Type VM-5).
T_5 — Filament transformer, 5.25-volt 20-amp. secondary (in power supply unit).
R_1 — 100-ohm 10-watt parasitic suppressor resistors (not required unless modulator oscillates).

World Radio History

THE PLATE-MODULATED TRANSMITTER

For distortionless or linear plate modulation with 100 per cent modulation capability (sinusoidal signal), the modulated r.f. amplifier should operate with a steady d.c. power input equal to twice the modulator's maximum rated undistorted power output, and should simultaneously operate so that its plate circuit presents a constant resistance of proper value as viewed from the modulator's output. That is, the d.c. plate current must be directly proportional to the applied plate voltage over the whole range of plate-voltage change during modulation. This condition obtains when the modulated stage operates as what is known as a Class-C amplifier; that is, so that its power output is proportional to its plate power input, as described in Chapter Five.

When the amplifier's operation is truly Class-C, its plate-circuit input resistance, as viewed from the modulator output, will be equal to the mean plate voltage divided by the plate current. Also, the product of the plate voltage and current is the unmodulated power input, equal to twice the modulator's maximum audio power output for 100 per cent modulation. Therefore, regardless of the type, size or number of tubes used in the Class-C amplifier, its mean plate voltage and plate current will be the same for a given modulator.

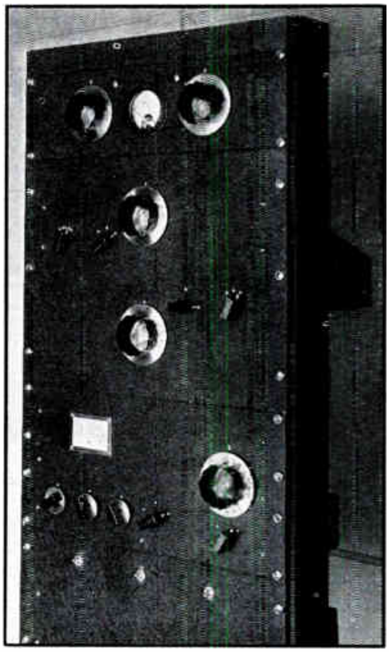
As Class-C amplifiers, triodes in a neutralized circuit are capable of making best use of the modulator audio power output. Screen-grid tubes can be used, but require simultaneous modulation of both plate and screen voltages. In modulated service, tubes should not be operated above the manufacturer's ratings. Excessive plate voltage or plate current will not only shorten tube life but also may cause non-linear modulation, distortion and interfering spurious radiation. This applies particularly to receiving-type tubes when operated as modulated Class-C r.f. amplifiers.

It must be remembered that the power input to the Class-C modulated stage is not just the steady d.c. power input. The audio-frequency power is superimposed on this average input, and with 100 per cent modulation by a sinusoidal signal will be 50 per cent greater than the average power indicated by d.c. meters and approximately 25 per cent greater with a speech signal as already described. Hence, the maximum plate dissipation may be 50 per cent greater than the d.c. meter readings might lead one to believe, and allowance for this additional dissipation should be made in choosing the plate voltage. Of equal importance is the fact that, with a tube whose normal plate-current rating is considerably exceeded, the filament emission may not be great enough to meet the peak demands imposed by the requirement that the peak power output must be four times the carrier power with 100 per cent modulation.

Operating Requirements for Linearity

The general method of operating a tube as a Class-C amplifier has been described in Chapter Five. Adjustment of loading, grid bias and excitation voltage are of first importance. In general, the operating conditions for modulated service as given in the tube tables can be followed; the load or antenna coupling is simply adjusted until the tube draws rated plate current at the operating d.c. plate voltage, assuming that the power input under these conditions is twice the available audio power from the modulator. Should the audio power be insufficient to modulate the full rated input of the Class-C amplifier, either plate current or voltage, or both, should be reduced accordingly. As a general rule, it is better to reduce both in the same proportion rather than to lower the power by maintaining the plate voltage at the maximum figure and using low plate current or vice versa, especially when the Class-C tube is operated considerably under its normal ratings.

Grid bias may be obtained from a fixed supply such as a battery or a bias power pack, or



FRONT VIEW OF R.F. PORTION OF THE 'PHONE TRANSMITTER OF FIG. 1037

World Radio History

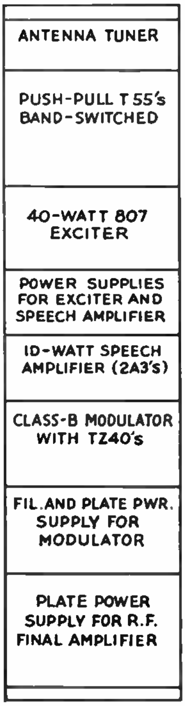


FIG. 1037 — A COMPLETE MODERN RACK-MOUNTED 250-WATT INPUT CLASS-B PLATE-MODULATED 'PHONE

from the flow of grid current through a grid leak. A combination of both usually is preferable to either alone, tending to maintain the operation more closely to ideal Class-C conditions. Fixed bias sufficient for protective purposes, as described in Chapter Eight, plus grid-leak bias to bring the total bias under carrier conditions to twice the cut-off figure, results in satisfactory operation. As an alternative to fixed bias, cathode bias also may be used.

It is highly important that the modulated Class-C r.f. amplifier be supplied with sufficient grid excitation. Unless the excitation is ample linear operation is impossible, because as the plate voltage rises during the modulation cycle, the grid will not be driven sufficiently to cause the plate current to rise in the same proportion. Hence the power output will not vary as the square of the plate voltage, which is a fundamental requirement. Remember that the excitation must be sufficient for peak conditions, when the plate voltage and plate current must both be twice the unmodulated values.

Besides the operating conditions just mentioned, linear operation also requires that a plate tank circuit having adequate flywheel effect be used. This means that the *L-C* ratio must be adjusted for optimum *Q*, at least, as described in Chapter Eight. An unduly high *L-C* ratio will cause non-linearity and distortion.

Matching Modulator to Modulated Amplifier

A modulator is simply an audio power amplifier, and as such requires a definite load impedance or resistance in its plate circuit if maximum power is to be developed with minimum distortion. As we have seen, the plate input circuit of the Class-C amplifier circuit has a definite impedance or resistance value; this value may or may not be the optimum load resistance for the modulator with which it is to be used. The problem, therefore, is that of transforming the Class-C amplifier plate resistance so that, as viewed from the modulator plates, it appears to be the value required for optimum modulator operation. When this is done the Class-C amplifier's plate voltage will swing between the limits of zero and twice the steady d.c. plate voltage during modulation, always assuming the power requirements as already set forth are met.

If the Class-B output (modulation) transformer is to be made for a specific transmitter, the proper turns ratio may be determined by taking the square root of the ratio of the r.f. amplifier load resistance (obtained by dividing the amplifier d.c. plate voltage by the d.c. plate current in amperes) to the plate-to-plate load impedance recommended for the modulator tubes under the conditions of operation. From this calculation is obtained the correct ratio of secondary turns to total primary turns.

COMPLETE 'PHONE TRANSMITTER FOR 250 WATTS INPUT

ARRANGEMENT of units and circuits of a complete transmitter for 250-watt plate-modulated input are shown in Figs. 1037 and 1038. The individual parts of this transmitter — exciter, r.f. amplifier, ant. tuning unit, speech amplifier, and modulator — are described separately in these chapters. Information on power supplies for the various sections is given in Chapter 14.

If control of the transmitter from a separate unit on the operating table is preferred to placement of the rack within the seated operator's reach, the exciter, speech amplifier, and associated power supplies may be removed from the rack arrangement and placed in a small rack or cabinet on the table, with r.f., audio, and power lines connecting. If the distance between the control units and the transmitter is not more than a few feet, the 110-volt a.c. lines from the outlet may be carried directly to the operating table, connected to switches at the control unit, and thence connected to the transmitter. With higher-power transmitters, use of heavy lines directly from outlet or master switch to transmitter, with relays controlled by small switches, is preferable.

For c.w. telegraph operation of this transmitter (any plate-modulated transmitter using secondary of modulation transformer in series with plate supply) the transformer secondary should be removed from the circuit by a shorting switch or by a separate power supply lead.

It is of particular importance that the modulator be operated only when a load is applied

World Radio History

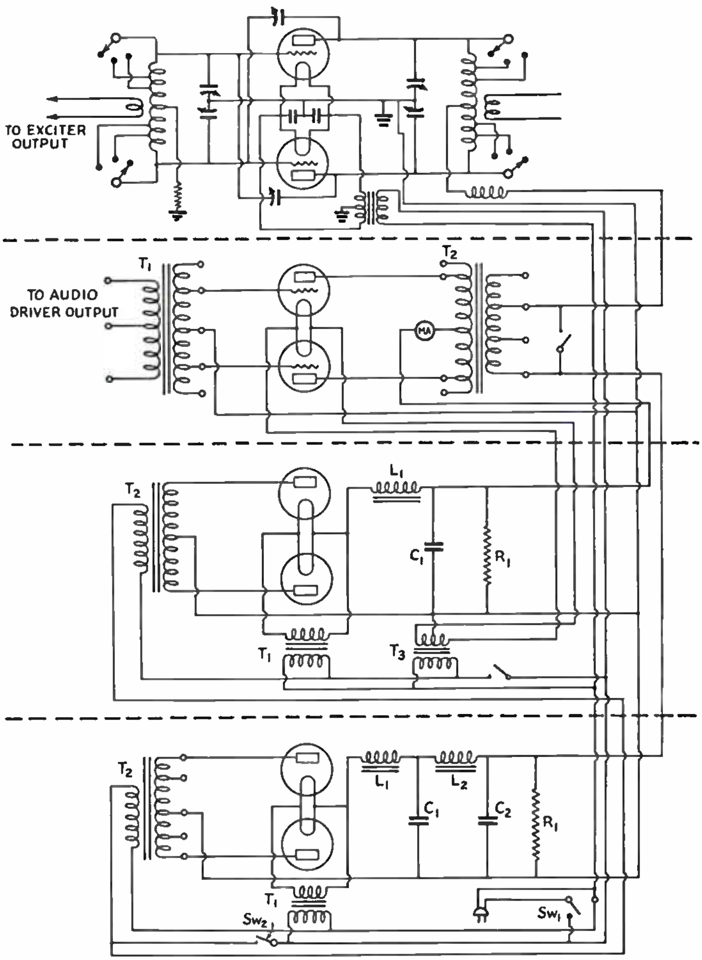


FIG. 1038—CONNECTIONS OF OUTPUT STAGES AND POWER SUPPLIES OF FIG. 1037

adjusting the excitation so that there is no danger of failure of the r.f. driving power to the amplifiers. Adjustment of the various stages should be performed with the plate voltage removed from the following stages, and should preferably be done at reduced voltage on the stage being tuned.

Use of combined grid-leak and fixed bias on the modulated stage is preferred for easily adjusted Class-C operation, and provides a measure of safety for the amplifier tube or tubes. Since the grid current of the half-kilowatt and kilowatt input modulated amplifiers is relatively large, B batteries should not be required to handle the full grid current. If batteries are to be used with amplifiers of this size, a resistor should be connected across the batteries and adjusted by means of a milliammeter in series with the batteries so that the greater part of the current is carried by the resistor. A switch should be provided with this arrangement to remove the load of the resistor from the batteries during idle periods. Information on use of a.c. power supply to provide fixed bias is found in Chapter Fourteen.

across the secondary, for the peak output voltage developed with no load is tremendous.

PLATE-MODULATED TRANSMITTERS FOR 125, 500, AND 1000 WATTS INPUT

In Fig. 1039 are shown three excellent combinations of the r.f. and a.f. units earlier described. All of these phone transmitters (as well as the grid-modulated transmitters described) give linear 100-per cent modulation at full input rating. Adequate excitation is easily provided by the buffer stages operating within the normal ratings for continuous duty.

For economy, grid-leak bias alone may be used throughout the r.f. stages including the final amplifiers, but care should be taken in

Plate Modulation of Screen-Grid Class-C Amplifiers

Screen-grid tubes of the pentode or beam tetrode type can be used as Class-C plate-modulated amplifiers provided the modulation is applied to both the plate and screen grid. The method of feeding the screen grid with the necessary d.c. and modulation voltage is shown in Fig. 1040. Audio as well as d.c. power is dissipated in the dropping resistor *R*. This arrangement is fairly economical with the smaller tubes but the power loss may reach considerable proportions with the larger types.

The dropping resistor, *R*, should be of the proper value to apply normal d.c. voltage to

World Radio History

the screen under steady carrier conditions. Its value can be calculated by taking the difference between plate and screen voltages and dividing it by the rated screen current. In many cases, manufacturers of the tubes specify the optimum value of screen dropping resistor for plate-modulated service.

The load resistance for the modulator is found by dividing the operating d.c. plate voltage on the Class-C stage by the sum of the plate and screen currents. The plate voltage

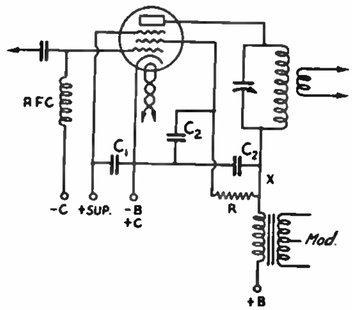


FIG. 1040 — PENTODE PLATE-MODULATION CIRCUIT WITH SCREEN-DROP RESISTOR

Screen and plate by-passes should be about 0.001 μfd.

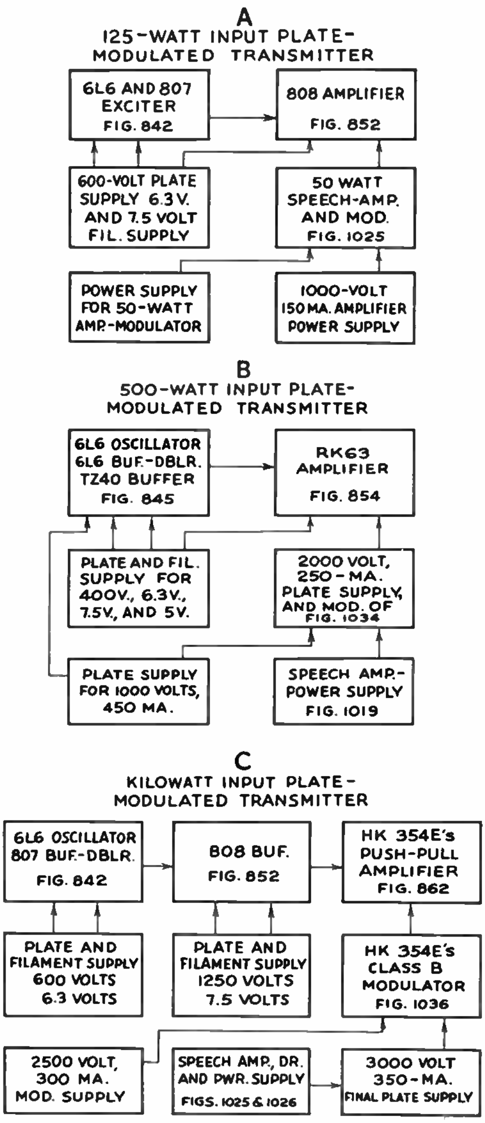


FIG. 1039 — BLOCK DIAGRAMS OF THREE PLATE-MODULATED TRANSMITTERS

multiplied by the sum of the two currents is the power input figure which is used as the basis for determining the audio power required from the modulator.

With the larger pentodes, such as the RK-20, 804, RK-28 and 803, the audio power loss in the screen dropping resistor may be a considerable percentage of the total supplied by the modulator. For these tubes a special Class-B output transformer, having an additional secondary winding for coupling to the screen circuit, can be installed to modulate plate and screen simultaneously, the screen being supplied d.c. through the auxiliary winding. The dropping resistor is thereby eliminated. This auxiliary winding should have approximately 20 per cent as many turns as the plate secondary. Transformers of this type are available as standard units. The secondaries should be connected so that the audio voltage on the screen is in phase with that on the plate of the Class-C amplifier. With this type of coupling, the modulator load can be figured neglecting the screen consumption, since it is relatively small compared to the plate load.

Adjustment of Plate-Modulated Amplifiers

After the audio section of the transmitter, including the modulator, has been checked for specified output with good quality (say with a fixed resistance equal to the specified load value across the modulator output transformer secondary), the r.f. stage should be adjusted to present the proper load to the modulator output. *All transmitter testing excepting final tuning of the antenna circuit should be carried on with a dummy antenna load.* Otherwise, needless and unlawful interference will be caused. Tuning and neutralizing are the same as for c.w. transmitters, described in Chapter Eight. Neutralization should be exact, because even slight regeneration can cause nonlinear modulation.

World Radio History

Operating checks using either cathode-ray oscilloscope or carrier-shift indications are the most certain. Oscilloscope patterns, obtained with a unit of the type described in Chapter Seventeen, are shown in Fig. 1041. These trapezoidal patterns result with the oscilloscope connected to the transmitter as shown in Fig. 1043. The leads marked "sweep terminals" connect to the horizontal cathode-ray plates, while the r.f. leads marked "signal terminals" connect to the vertical plates. The audio input to the oscilloscope should be taken from the modulator output circuit to avoid phase difference between the modulation applied to the carrier and the audio signal applied to the oscilloscope. Such phase shift gives patterns which are difficult to interpret.

The patterns concerned with Class-C amplifier adjustment are Figs. 1041 D, E, and F, which show improper adjustment, and Fig. 1042 showing proper 100% modulation. The overmodulation shown in *F* is particularly to be avoided. The harmonic distortion indicated by *A*, *B* and *C*, revealed by streaking and shifting of the pattern, would most likely be traceable to the audio circuits and should be cleaned up by checking Class-A speech amplifier grid bias, audio overloading, etc., in the preliminary audio-unit testing.

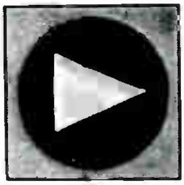


FIG. 1042 — ACTUAL PHOTOGRAPH OF TRAPEZOIDAL FIGURE FOR PROPER 100% MODULATION

A carrier-shift indicator is simply a linear rectifier, such as that diagrammed in Fig. 1044, showing flattening of the positive peaks like that illustrated in Fig. 1041-D by a drop in meter reading, or overmodulation as shown in *F* by an upward shift in meter reading.

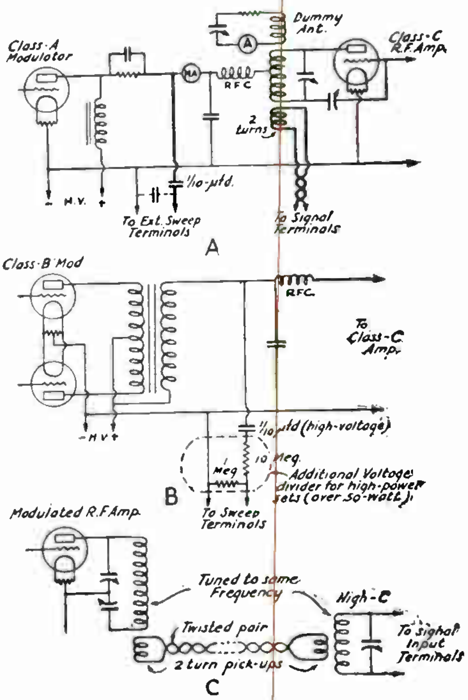


FIG. 1043 — METHODS OF COUPLING THE OSCILLOSCOPE TO 'PHONE TRANSMITTER CIRCUITS

Lacking an oscilloscope for actual viewing of the modulated wave, the plate current to the modulated amplifier may be taken as a criterion of proper operation. With correct operating conditions and undistorted audio modulation, the plate-current reading will remain perfectly steady either without modulation or with any modulation percentage up to 100%.

FIG. 1041 — SKETCHES OF TYPICAL TRAPEZOIDAL FIGURES REPRESENTING VARIOUS OPERATING CONDITIONS

The normal trapezoidal figure obtained with a medium degree of modulation is shown by "A". The modulation percentage is obtained by measurement of the dimensions D_1 and D_2, and substituting in this simple equation

$$\text{Percent modulation} = \frac{D_1 - D_2}{D_1 + D_2} \times 100$$

Output containing even harmonics is represented in B; and C is typical of odd-harmonic content. Flat-topped positive peaks of the modulation envelope, as would occur with insufficient Class-C amplifier excitation, are represented in D, while E shows this condition combined with distortion of the negative peaks. F shows over-modulation, with the negative peaks cut off and with "whiskers" on the positive peaks. Arrows indicate carrier position without modulation. Further explanation of these figures is given in the text.

World Radio History

This is also the case with the carrier-shift indicator. If the needle "kicks" with modulation, a number of things may be wrong. The more common causes are the following:

Downward kick: Insufficient excitation to

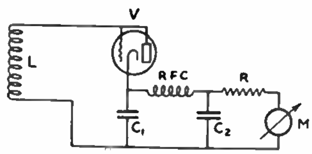


FIG. 1044 — CIRCUIT OF THE SIMPLE DIODE-TYPE CARRIER-SHIFT INDICATOR

Typical circuit values are as follows:

L — Coupling coil to suit frequency. It may be tuned by a midget condenser and coupled to the transmitter by a link.

C_1, C_2 — 0.001-μfd. fixed condensers.

R — 10,000-ohm non-inductive resistor, minimum value for 56, 59 or 89 tubes. Lower minimum value of 5000 ohms may be used with 53, 79 or 2A3 (all diode connected).

M — 0-1 d.c. milliammeter.

V — One of above tubes with grid (or grids) and plate tied together.

the Class-C stage; insufficient bias on the Class-C stage (bias should be at least twice cut-off under carrier conditions); insufficient audio power from the modulator; audio load resistance represented by Class-C plate circuit too high or too low; distortion or overloading in audio system; insufficient output capacity in plate-supply filter for Class-C stage (as in the case of a Class-B amplifier, the reactance of the last filter condenser must be small compared to the audio load resistance represented by the Class-C plate circuit); overloading of Class-C tube or tubes; too-low *C* in tank circuit.

Upward kick: Overmodulation (excessive audio power; gain control set too high); too-low *C* in tank circuit; distortion in audio system; neutralization incomplete; parasitic oscillation in Class-C amplifier. In general, a downward plate-current kick will be accompanied by an oscilloscope pattern like that in Fig. 1041-D, while an upward kick will appear on the oscilloscope like Fig. 1041-F.

When a common plate supply is used for both Class-B modulator and Class-C modulated r.f. amplifier, the latter's plate current sometimes will kick downward with modulation even though the operating conditions are correct. This is traceable to poor voltage regulation in the plate supply, the increased load of the Class-B stage with modulation causing the plate voltage, and hence the Class-C plate current, to drop momentarily. Separate supplies are preferable. A similar effect will often be noted with high-power transmitters, even when separate plate supplies are used, because of poor power-line regulation. In such cases, a filament voltmeter across one of the tubes will show a corresponding downward kick with modulation.

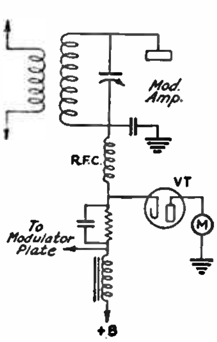


FIG. 1045 — SIMPLE NEGATIVE-PEAK OVER-MODULATION INDICATOR (W8AGW)

AUTOMATIC MODULATION CONTROL

The overmodulation-indication systems just described have the disadvantage that while they disclose the existence of overmodulation with its accompanying sideband "splatter" and unnecessary interference, they cannot prevent it. A circuit which automatically limits the modulation percentage to any predetermined value, regardless of the amplitude of the microphone excitation or setting of the speech-amplifier gain control, is shown in Fig. 1046. It utilizes the principle of the negative-peak indicator of Fig. 1045 to develop a d.c. voltage which is applied as gain-control bias to the No. 3 grid of a 6L7 speech amplifier tube.

Operation under the typical conditions illustrated in Fig. 1046 is as follows: the cathode of the 6L7 is connected at a point 90 volts from ground on the voltage divider, leaving a net voltage of 250 between cathode and plate. The bias on the control grid is set at −10 volts, that on the No. 3 grid at −3 volts (through resistors R_3 and R_2) with respect to the cathode. The plate of the control rectifier has an "advance" bias of 90 volts positive with respect to ground: this is so that the tube will begin conducting before the instantaneous plate voltage on the Class-C stage reaches zero. The advance bias should be about 7 per cent of the d.c. plate voltage on the modulated amplifier (1250 volts in the example shown); thus the automatic control begins working at about 93% modulation. When current flows through the rectifier a voltage is developed across R_1 which increases the negative bias on the No. 3 grid of the 6L7 and thus reduces the amplifier gain. R_2C_2 and R_3C_1 are r.f. and audio filters. The time constant in the No. 3 grid circuit should not be too large or the action will not be rapid

World Radio History

enough to prevent overmodulation before the control voltage builds up.

The 6L7 stage preferably should be at a point in the speech amplifier where the peak signal to its grid will not exceed one volt. With the gain control, R_4, set to give full modulation with low-amplitude speech input, loud talking will not result in an increase in modulator output, but simply in a reduction in gain which maintains the modulation at the same level. Besides avoiding overmodulation, this action has the effect of raising the *average* modulation percentage and thereby increasing the effectiveness of the transmitter.

The 6L7 can in general be substituted for a 6J7 or corresponding pentode in the speech amplifier.

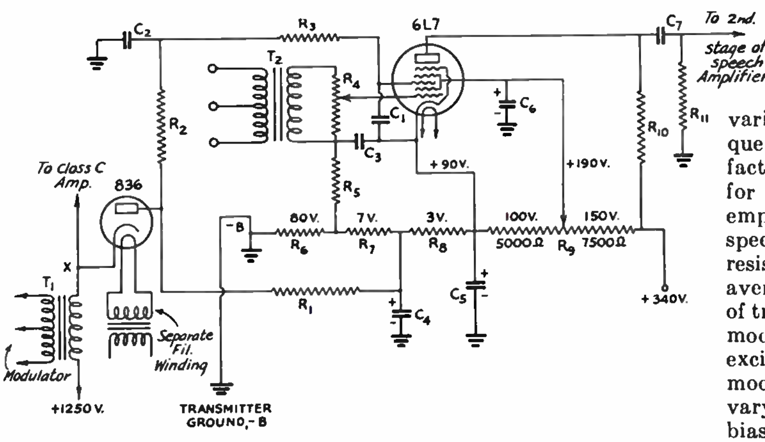


FIG. 1046 — AUTOMATIC MODULATION CONTROL CIRCUIT (W2BRO)

C_1 — 2-μfd. paper, 250-volt.
C_2 — 0.01-μfd. mica.
C_3 — 0.5-μfd. paper.
C_4, C_5, C_6 — 8-μfd. electrolytic, 400-volt.
C_7 — 0.05-μfd. paper.
R_1 — 0.5-megohm, 1-watt.
R_2 — 0.1 megohm, 1-watt.
R_3 — 1 megohm, 1-watt.
R_4 — 0.5-megohm potentiometer.
R_5 — 0.5 megohm, ½-watt.
R_6 — 4000 ohms, 10-watt.
R_7 — 350 ohms, 1-watt.
R_8 — 150 ohms, 1-watt.
R_9 — 12,500-ohm, 25-watt bleeder, tapped as shown.
R_{10} — 0.1 megohm, 1-watt.
R_{11} — 0.5 megohm, 1-watt.

CONTROLLED-CARRIER TRANSMISSION

In the systems previously described, the carrier amplitude is maintained constant and the percentage modulation varied in accordance with the modulating signal. That is, these systems are *constant-carrier* types, and the carrier power radiated is always the same regardless of whether the modulation is shallow or deep, or even when there is no modulation at all. Since speech not only is of varying amplitude but also is intermittent, the average efficiency with constant-carrier transmission is quite small. Also, the heterodyne interference created is just as bad when the carrier is unmodulated as when it is fully modulated. These deficiencies can be overcome to a considerable extent if the carrier amplitude is automatically varied so that it is just sufficient to accommodate the various modulating signal amplitudes as they occur. A system in which this is accomplished is called a *controlled-carrier* system.

The essential difference, so far as the modulated wave is concerned, between constant-carrier and controlled-carrier is illustrated in Fig. 1047. The principle is to vary an operating control in the transmitter automatically by the modulating signal so that the carrier amplitude is approximately proportional to the average of the modulating signal. This control must be fast enough in operation to follow normal syllabic variations in speech intensity, but not so fast as to follow the individual cyclic variations of audio frequency. The most satisfactory methods of control for voice transmission employ vacuum tubes as speech-operated variable resistances to vary the average plate power input of transmitters using plate modulation, or to vary excitation to a grid-bias modulated stage, or to vary the suppressor-grid bias with that system.

OVERMODULATION INDICATORS

The most generally useful device for measuring modulation and for continuous checking against overmodulation is the cathode-ray oscilloscope described in Chapter Seventeen connected to the transmitter circuit as shown in Fig. 1043. The carrier-shift indicator discussed in connection with Class-C amplifiers, and schematically diagrammed in Fig. 1044, is the simplest device for continuous monitoring against overmodulation, although it will not indicate conditions such as that illustrated by Fig. 1031-C where the average amplitude of the modulated wave may remain constant even though modulation distortion is occurring. This particular type of distortion represents a more or less special case, however, and the carrier-shift indicator would be considered a generally satisfactory means to insure against overmodulation. It indicates positive-peak

World Radio History

overmodulation by an upward shift in current reading, and flattening of positive peaks (accompanying modulation capability less than 100 per cent) by a decrease in current reading. If such carrier shift should be observed at very low modulation levels, with speech input or

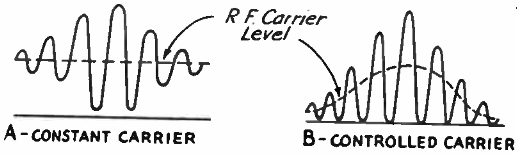


FIG. 1047 — CONTRASTING MODULATED WAVES OF THE CONSTANT-CARRIER TYPE (A) AND CONTROLLED-CARRIER TYPE (B)

with a test signal from an audio source of known pure tone, it is likely that even-order harmonic distortion is occurring in the speech-amplifier or driver stages. This results in a "lop-sided" modulating signal waveform, which will give a correspondingly unsymmetrical modulation envelope. Such distortion commonly occurs with a short-circuited cathode-bias resistor in an early audio stage.

A simple negative-peak indicator is diagrammed in Fig. 1045. This consists essentially of rectifier, *VT*, connected to the output side of the modulation choke of a Class-A system as shown, or to the corresponding side of the secondary of a modulator output transformer. When negative-peak modulation exceeds 100 per cent, current will flow through the rectifier circuit, although no current will flow so long as the filament of the rectifier tube is positive with respect to ground (minus B). The rectifier tube should have insulation capable of withstanding the maximum peak voltage (d.c. plus audio) applied to the modulated amplifier. The rectifier filament winding must be correspondingly insulated from the primary. Rectifiers of the vacuum type are preferable. The indicator, *M*, may be a low-range milliammeter.

In addition to these checking devices, the meters in the modulator and modulated amplifier circuit of the transmitter itself may be used to advantage, particularly when the set is periodically checked by an oscilloscope.

CONTROLLED-CARRIER PLATE MODULATION

THE most practical method for controlled-carrier transmission adapted to Class-B modulation is illustrated by the diagrams of Figs. 1048 and 1049. Tracing the control action in Fig. 1048, it is seen that the d.c. supply path of the Class-C amplifier is from the negative (gnd.) terminal to the filaments of the 841 modulators, thence through their two filament-plate circuits in parallel to the center-tap of the output transformer, from there through the secondary of this transformer to the filament center-tap of the Class-C stage. The positive connection is made to the center-tap of the r.f. tank circuit. The plate resistance of the two modulator tubes in parallel is therefore in series with the d.c. feed to the Class-C stage. This plate resistance varies inversely with the signal level, as the modulator grids are swung from nearly zero to considerably positive, the

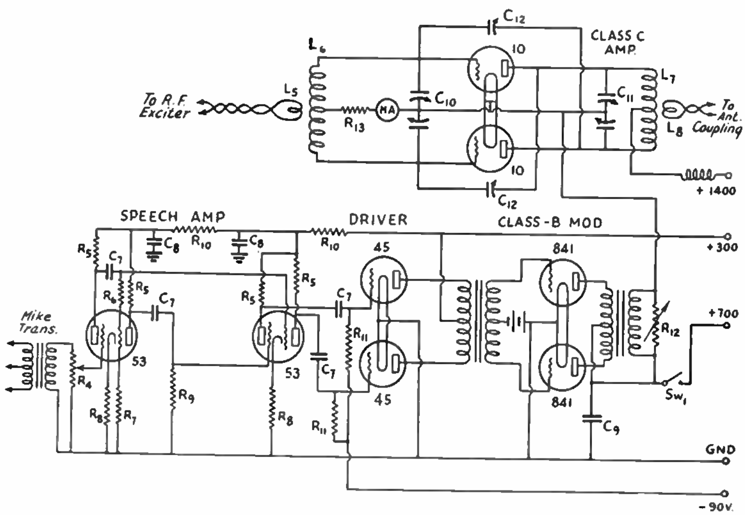


FIG. 1048 — CLASS-B CONTROLLED-CARRIER CIRCUIT FOR 500-VOLT TYPE TUBES (W2CTK)

L_5, L_6, L_7, L_8 — To suit frequency.
C_7 — 0.1 μfd. paper.
C_8 — 1.0 μfd. paper.
C_9 — 2- to 3-μfd. 2000-volt. (See text.)
C_{10} — Double 35-μμfd. midget.
C_{11} — Split-stator double-spaced, 50-μμfd. per section.
C_{12} — Double-spaced 20-μμfd. midgets.
R_4 — 1-meg. vol. control.
R_5 — 0.1-meg. ½-watt.
R_6 — 240,000-ohm ½-watt.
R_7 — 10,000-ohm ½-watt.
R_8 — 3000-ohm ½ watt.
R_9 — 250,000-ohm ½-watt.
R_{10} — 50,000-ohm ½-watt.
R_{11} — ½-meg. ½-watt.
R_{12} — 25,000-ohm 20-watt, variable.
R_{13} — 3000-ohm 15-watt.

World Radio History

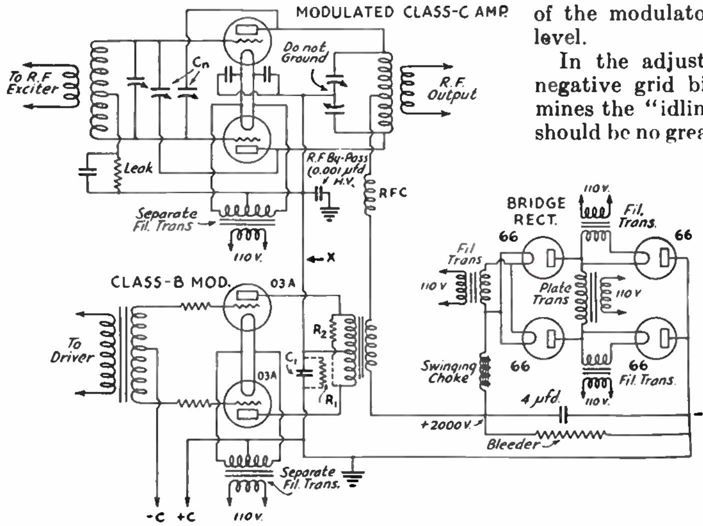


FIG. 1049 — CONTROLLED-CARRIER CIRCUIT FOR 1000-VOLT TUBES (W2HLM)

of the modulator to reduce the audio peak level.

In the adjustment of such systems, the negative grid bias of the modulator determines the "idling" carrier output. This bias should be no greater than for modulator plate-current cut-off at one-half the total plate supply voltage, because the modulator plate voltage falls to this value when the effective series plate resistance of the modulator tube becomes equal to the Class-C amplifier plate circuit resistance, which is the condition at full modulation. If the bias is greater than cut-off, audio cycle bottoms will be clipped with resulting distortion.

In the circuit of 1048, a power pack utilizing two 700-volt rectifier-filter units in series is used. The plus 700-volt terminal is connected to the midpoint of this supply system. Closing switch SW_1 places a fixed voltage of this value on the modulator and equal voltage on the Class-C stage for constant-carrier operation. In the system of Fig. 1049, the negative feed lead to the Class-C stage would be opened at X and half-voltage similarly applied to both modulator and r.f. amplifier for continuous-carrier operation and adjustment. Tubes of similar voltage and plate-dissipation ratings should be used in both modulator and Class-C amplifier in controlled-carrier combinations of

Class-C amplifier plate circuit resistance remaining practically constant. Condenser C_9 filters off the audio-frequency ripple in this circuit, while the normal audiofrequency output of the modulator is super-imposed on the d.c. flowing in the series circuit in normal fashion. The circuit of Fig. 1049 is the same in principle, the only difference being that the secondary of the Class-B output transformer is in the positive side of the supply circuit instead of the negative. Resistance R_{12} of Fig. 1048 and R_2 of Fig. 1049 may be used for the same purpose; that is, to pre-load the output circuit

TABLE III — CLASS-A MODULATOR DATA *

Type Tube	Fil. Volts, E_f	Plate Volts, E_b	Plate Ma., I_b	Neg. Grid Volts,[1] E_c	Load Imp.,[2] Ohms	Audio Output,[3] Watts
211 242A 276A	10.0	1000	65	52	7000	10.0
845	10.0	1000	75	150	7500	28.0
284A	10.0	1250	60	228	10,000	41.5
849	11.0	2000 2500 3000	125 110 100	75 104 132	12,000 12,000 20,000	42.5 81.0 100.0

* For data on receiving type tubes (2A3, 6L6, etc.), see tube tables of Chapter Five.
Ratings are for a single tube. For tubes in parallel multiply I_b and Output Watts by number used, and divide Load Impedance by number used.
[1] Peak audio grid voltage equal to bias value for single tube or tubes in parallel.
[2, 3] To be used in determining Class-C amplifier operating conditions by method described in text.

World Radio History

this type. The adjustment is not especially critical, once the circuits have been tuned in normal procedure. Condensers C_9 of Fig. 1048 and C_1 of Fig. 1049 should have a capacity of approximately 2 or 3 μfd. No direct ground connnection should be made to the Class-C filament circuit.

CHOKE-COUPLED CLASS-A MODULATORS

PLATE modulation with choke coupling between modulator and modulated amplifier, using a Class-A modulator (Heising modulation), has been almost completely superseded by the more efficient transformer-coupled Class-B system, and hence has not been included in the practical treatment of modulation systems. While the operating principles are identical with other methods of plate modulation, the lack of impedance-transformation provided by a coupling transformer makes the method of calculation somewhat different.

As has been stated, for 100 per cent sinusoidal modulation the Class-C amplifier d.c. input power should be twice the modulator's rated maximum undistorted power output. This input will be equal to the product of the Class-C amplifier's mean (d.c.) plate voltage and plate current. At the same time, the mean plate voltage divided by the plate current gives the *modulating impedance,* which in this case should equal the modulator's rated load impedance. By Ohm's law,

$$I_b = \sqrt{\frac{P_o}{R_p}} \text{ and } E_b = \frac{P_o}{I_b}$$

where P_o = unmodulated d.c. power input to r.f. stage = *twice modulator power output, watts.*

R_p = optimum load resistance for modulator, ohms.

I_b = mean current to r.f. amplifier plate, amperes d.c.

E_b = r.f. amplifier mean plate voltage, d.c.

For the case of a Type 845 tube operating as a Class-A modulator with plate supply of 1000 volts at 75 ma. (grid bias −147 volts), the rated power output with negligible distortion is 23 watts for a load resistance of 7500 ohms (See Table III). Substituting in the above equations,

$$I_b = \sqrt{\frac{2\times 23}{7500}} = 0.078 \text{ amp.} = 78 \text{ ma}$$

the Class-C amplifier d.c. plate current.

$$E_b = \frac{2\times 23}{0.078} = 590 \text{ volts,}$$

the Class-C amplifier d.c. plate voltage.

The plate voltage drop for the Class-C amplifier is, therefore, 1000 − 590 = 410 volts. The proper value for the dropping resistor, R of Fig. 1003-A, is this value divided by the Class-C amplifier plate current,

$$R = \frac{410}{0.078} = 5256 \text{ ohms (5250 ohms satisfactory).}$$

The dissipation rating of this resistor should equal the voltage drop multiplied by the current, or 410 × 0.078 = 32 watts. A 50-watt type resistor therefore would be satisfactory. It should be by-passed for audio frequencies by condenser C (2-μfd. or larger). A coupling choke, L, of 30-henry *effective* inductance at 150-ma. d.c. will be suitable. Any one of several tubes capable of operating with 78 or 80 ma. input at 590 or 600 volts could be used in the Class-C amplifier.

World Radio History

CHAPTER ELEVEN

RECEIVERS FOR THE ULTRA-HIGH FREQUENCIES

General Aspects of Ultra-High-Frequency Working — Suitable Receiver Types — Superregeneration — Adding R.F. Amplifiers — Superheterodyne Converters — Advanced Receivers

It is important that the amateur about to undertake ultra-high-frequency work should realize that the very high frequency waves behave in a different manner to those of lower frequencies. On frequencies of 56 Mc. and above, bending of the waves in the Kennelly-Heaviside layer only infrequently brings the waves to earth at far-distant points. During brief, occasional periods during the summer and fall, 56-Mc. signals have covered distances in excess of 500 miles. Such working, though extremely "spotty," is steadily increasing in extent and constitutes an extremely interesting field for the experimenter.

For a time it was considered that only the "ground wave" was of any value for ultra-high-frequency communication and that the range to be obtained from a low-lying station would be restricted substantially to the range of vision from that point. During the latter part of 1934, experimental work at A.R.R.L. Headquarters served to establish that ultra-high-frequency waves are bent very appreciably in the lower atmosphere under certain atmospheric conditions. This work indicated that, on occasions when warm, moist tropical air was over-running relatively cold and dry Polar air, communication could be had, even from low-lying stations, over distances of a hundred and sometimes two hundred miles. It was also shown that considerable bending of the waves in the lower atmosphere occurs at all times when a layer of warm air overruns a layer of colder air. Since this effect is to be found almost every night, one can expect to find that communication with points beyond the visible range is prone to become much more effective at night than during the day.

The many factors concerned make it impossible to forecast the actual range of communication possible on the ultra-high-frequency bands. It is generally considered, however, that the range to be obtained reliably with a very low-power transmitter and a normal type of antenna is about 10 percent greater than the visual range from the antenna. An increase of power immediately extends this range irrespective of whether the additional effective power is gained by using a bigger transmitter or a directive antenna. The combination of a fairly powerful transmitter (say 100 watts input), and a good directive antenna immediately permits a considerable extension of the range. One experimental station, maintained by the League, with such a transmitter set-up and with the antenna approximately 300 feet above sea level, maintained daily schedules

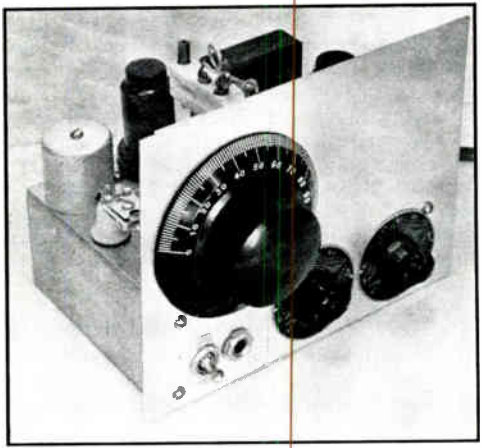


FIG. 1101 — A THREE-BAND PLUG-IN COIL SEPARATELY QUENCHED SUPERREGENERATIVE RECEIVER

The circuit for this receiver is given in Fig. 1110. An excellent general-purpose u.h.f. set.

World Radio History

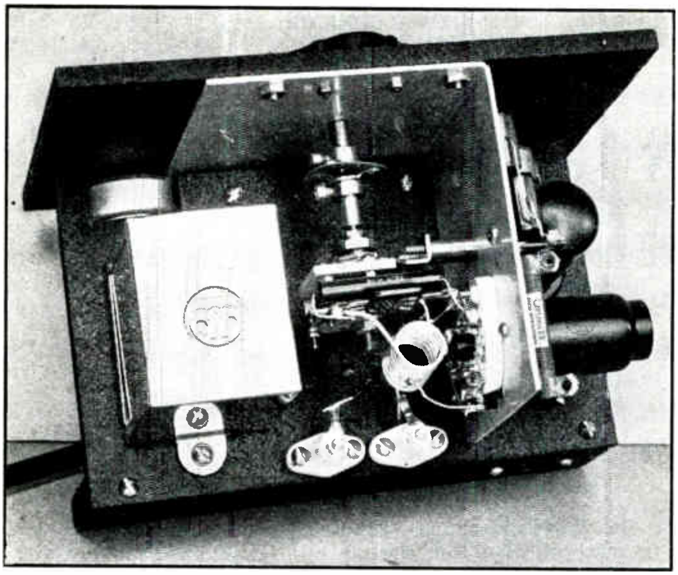


FIG. 1102 — THE SUPERREGENERATIVE RECEIVER IN ONE OF ITS SIMPLEST AND MOST EFFECTIVE FORMS: A 56- and 112-MC. RECEIVER USING METAL TUBES

The detector in this receiver is of the self-quenched superregenerative type and feeds a conventional pentode audio amplifier. Particular care is necessary in the placement and wiring of the detector components in this type of set.

over a distance of about 95 miles for more than a year. A great many amateur stations with plain antennas, lower-powered transmitters and lower elevation have communicated over even greater distances but it is obvious that a reduction of elevation, of transmitted power or a simplification of the antenna makes for a sacrifice of reliability over such long ranges.

What Is DX?

From all this it is seen that there are two sorts of DX in u.h.f. work. To the man working over distances beyond the line of sight by means of atmospheric refraction, 100 miles is DX. To the experimenter interested in waiting for those exceptional periods when the ionosphere enters the picture, 1000 miles is the sort of distance that can be considered DX. There is obviously no way of saying what the range of any particular u.h.f. equipment is to be and it is this particular thing, in the minds of many, which makes the work of special interest. With equipment being improved steadily and with many more stations coming on the air in these bands, the unexpected is happening right along.

Suitable Receiving Equipment

The problems in devising receivers for the ultra-high frequencies differ considerably from those met on the low-frequency bands. In the early days of u.h.f. working the first equipment used was adapted from the straight autodyne receiver and the superheterodyne. These receivers suffered from poor sensitivity, tuning difficulties and severe interference from ignition and other similar noise. A big step forward was made by utilizing Armstrong's superregeneration principle for u.h.f. reception. Superregeneration immediately provided a receiver of tremendous sensitivity and a receiver in which an inherent operating characteristic resulted in invaluable discrimination against ignition noise. This type of receiver tuned very broadly and therefore removed, for the time being, the tuning difficulties. The superregenerative receiver has played probably the biggest part of all in popularizing ultra-high-frequency working. It was, and remains, one of the most extraordinary pieces of radio equipment ever developed — from the point of view of performance from a given amount of equipment.

The trend today, at least on the 56-Mc band, is toward the use of the superheterodyne principle for the prime purpose of gaining greater selectivity. In such receivers the intermediate frequency is often made relatively high for the purpose of avoiding excessive selectivity and gaining a reasonable freedom from image interference. Such receivers would have been impractical a year or two ago because almost all ultra-high-frequency transmitters were then of the unstable modulated-oscillator type. With the recent extension of transmitter stability requirements already in force on the lower frequencies to the 56-Mc. band, it is now possible to put selective superheterodyne receivers to work even in routine communication.

Further developments which have recently modified the place of the superhet in the u.h.f. picture are the various noise silencers. With such silencers the modern u.h.f. superhet is

World Radio History

capable of much more effective discrimination against ignition noise than is the superregenerative receiver — a type of receiver which has always been valued for its abilities in this respect. Of course the complete superhet with noise silencer is a complex array of equipment obviously unavailable to many amateurs. Then its use is hardly practical or desirable for portable or mobile work. For these reasons the superregenerative receiver is still deserving of careful consideration.

THE SUPERREGENERATIVE RECEIVER

Though Armstrong announced the principle of superregeneration in 1922, it found little application in any actual receiving equipment until serious work began on the ultra-high frequencies. The general outline of superregenerative action is treated briefly in Chapter Five.

From a practical aspect, superregenerative receivers may be divided into two general types. In the first the quenching voltage is developed by the detector tube itself — so-called "self-quenched" detectors. In the second, a separate oscillator tube is used to generate the quench voltage. The self-quenched receivers have found wide favor in amateur work. The simpler types are particularly suited for portable equipment where the apparatus must be kept as simple as possible. However, it is our strong recommendation that the separately quenched type be used in all cases where the ultimate performance is expected. One enormous advantage of the separately quenched type is that it is readily possible to adjust the operating conditions so that the receiver is extremely sensitive even under conditions when relatively little hissing or "mush" noise is had. In the separately quenched superregenerative detector it would appear to be of little consequence just how the quench voltage is introduced into the circuit providing the voltage is of the correct order and that quench frequency is something near the optimum value. Many amateurs have "pet" circuits which are claimed to be superior to all others. The probability is that the arrangement of their particular circuit has led to the use of correct operating conditions. It is certainly a fact that any of the various separately quenched circuits can be made to operate in substantially the same fashion by careful adjustment. Likewise, the self-quenched circuits are all capable of a somewhat similar performance. The latter, however, though very simple in appearance, require particularly careful handling in order to obtain smooth operation and freedom from howling and generally irregular performance.

Building Self-Quenched Receivers

The circuit given in Fig. 1103 is representative of a very successful type. The entire receiver consists merely of a superregenerative detector feeding, through an ordinary audio frequency transformer, a pentode audio output tube. Such a receiver can be built inexpensively and quickly yet it is capable of entirely satisfactory performance. The sensitivity of even this simple type of set is such that the normal background noise is the limiting factor in the reception of weak signals.

In this, and for that matter all other ultra-high-frequency receivers, the mounting of the components and the location of the various leads are prone to play an important part in the behavior of the set. Because no two layouts are likely to be precisely the same, it is therefore always advisable to experiment with the resistance and connection of the grid leak; taps on coils; the value of any r.f. choke and the size and placement of by-pass condensers. It is

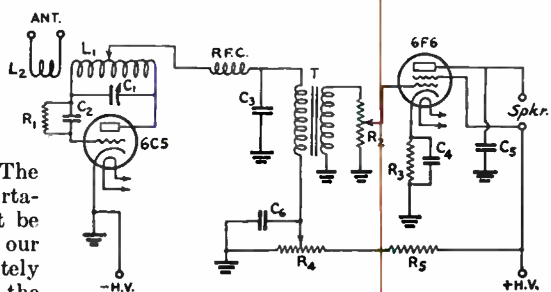


FIG. 1103 — CIRCUIT OF THE METAL-TUBE SELF-QUENCHED RECEIVER

C_1 — 15 μμfd. Cardwell Trim-Air midget condenser (with mounting bracket).
C_2 — 50 μμfd. midget fixed condenser.
C_3 — .003 μfd. fixed condenser. Other values between .002 and .006 μfds. are sometimes found more satisfactory.
C_4 — 25 μfd. 50-volt electrolytic condenser.
C_5 — .002 μfd. fixed condenser (not always essential).
C_6 — .25 μfd. condenser — anything above 200-volt rating.
R_1 — 5 to 10 megohm gridleak — latter size used in original set.
R_2 — 500,000-ohm potentiometer.
R_3 — 500-ohm 2-watt fixed resistor.
R_4 — 50,000-ohm potentiometer.
R_5 — 50,000-ohm half-watt resistor.
L_1 — Eight turns of No. 14 wire ½-inch diameter spaced to occupy 1 inch for 56-Mc. band. Four similar turns spaced to same length for 112-Mc. band. Change of these values may be necessary in cases where the layout differs.
L_2 — Four turns of No. 18 wire ⅜-inch diameter. This will usually serve for both bands.
R.F.C. — Ohmite u.h.f. choke. About 50 turns of No. 30 wire on a ¼-inch bakelite rod with turns spaced to occupy 1 inch will serve. Adjustment is sometimes necessary to give freedom from "dead spots."
T — UTC Type CS1 audio transformer. "Bargain store" audio transformers are invariably a failure in this type of receiver.

World Radio History

good practice always to run ground leads to a single point on the chassis of the set. Often, attention to this one detail results in the elimination of all instability problems.

The receiver shown in Figs. 1102 and 1103 is in many ways typical of the simpler types of u.h.f. receivers and might well be examined in detail by the amateur unfamiliar with this branch of receiver design. The first and most important feature is that the components of the r.f. circuit are grouped closely around the detector tube socket so that all leads may be very short. Then it will be noted that the detector and its associated components are all mounted on a metal plate serving as a "ground" for the set. This plate, as it happens, is bent across the panel to serve also as a shield to prevent "hand-capacity" effects in tuning the receiver. This feature is made necessary by the use of a non-metallic panel. In many u.h.f. receivers metal construction is used throughout. In these cases, of course, the chassis itself is the "ground."

The chassis for the receiver under discussion is made from Tempered Masonite — a material which is proving popular particularly because of the ease with which it can be worked. The base measures 7 by 4½ inches, the panel being 7½ by 5 inches. The aluminum angle piece on which the detector assembly is mounted is the full depth of the base and the full height from the base to the top of the panel. The tuning condenser and detector tube are mounted far enough back on it to accommodate a flexible coupling between the condenser and the dial. This coupling is essential since both sides of the condenser are at high r.f. potential. The detector socket is tilted so that the grid and plate terminals come directly opposite the corresponding terminals on the tuning condenser. The total length of connecting leads is then only a fraction of an inch. The r.f. choke and by-pass condenser (which actually is two condensers in parallel to give the desired capacity) are located on the other side of the metal piece carrying the detector unit. In other respects, the receiver follows normal practice.

The circuit of the receiver, shown in Fig. 1103, appears to be very simple but, in this type of receiver requires quite careful treatment. Very erratic behavior may result from incorrect adjustment of the tap on L_1, from the use of an r.f. choke of the wrong size or from the use of long return paths to ground from the detector cathode or from the by-pass condenser C_3. The by-pass condenser C_5 happened to be an essential in this particular receiver though it is not invariably so. On the other hand, a resistor of a quarter or half megohm is often necessary across the secondary of the audio transformer to kill "fringe howl" effects which often occur.

The receiver circuit as shown is designed for the operation of a loud speaker. The heavy plate current of the pentode output tube will quickly ruin a pair of head phones unless a coupling choke and condenser or a coupling transformer is used. For head-phone work it is better to use a 6C5 in the output stage — in which case the bias resistor R_3 should be increased to 5000 ohms. No other change in the wiring is necessary since the lead to the second grid of the 6F6 will be open when the 6C5 is plugged in.

Successful operation of this receiver is dependent to a considerable degree on the type of antenna used and the manner in which it is tuned. The chief requirement is that the detector circuit be heavily loaded by the antenna.

A SELF-QUENCHED ACORN-TUBE RECEIVER

In Fig. 1104 is a somewhat similar type of circuit except in the type of detector tube used. In this case the acorn detector, because of its extremely small elements and short leads, allows operation on frequencies as high as 300 Mc. This receiver is therefore a particularly useful one in cases where experiment is to be conducted on the bands higher in frequency than 112 Mc. The circuit itself is quite similar

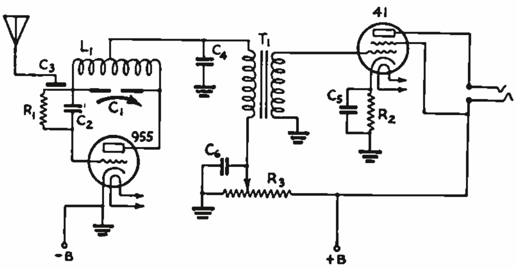


FIG. 1104 — CIRCUIT OF AN "ACORN" RECEIVER

L_1 — Five turns of No. 14 wire ¼-inch inside diameter with turns spaced diameter of wire, for 224 Mc. Five similar turns ½-inch diameter for 112 Mc. 14 turns of same diameter for 56 Mc.
C_1 — Cardwell Type ZR 15AS condenser — Special split-stator tuning condenser — two rotor and one stator plate — the latter sawed in two.
C_2 — 50 $\mu\mu$fd. midget condenser.
C_3 — Brass strip 3/16 inch wide mounted close to the exposed surface of C_2.
C_4 — 0.002 μfd. fixed condenser.
C_5 — 10 μfd. electrolytic condenser. C_6 — 1 μfd.
R_1 — 5 to 10 megohms.
R_2 — 1200 ohm, one-watt resistor.
R_3 — 100,000 ohm potentiometer. Note that this resistor is across plate supply and that, if batteries are used, the supply should therefore be disconnected when switching off set.

A 41 tube is used as the audio amplifier and allows speaker operation. A transformer or choke-condenser coupling unit must be used with this tube. For headphone work, a 37 tube would be more appropriate.

Quieter operation may sometimes be obtained by putting 0.5 megohm across the transformer secondary.

World Radio History

to that of Fig. 1103 except in minor details. The grid resistor is again connected to the coil carrying high voltage but in some instances it is preferable to run it in the conventional manner between the grid and cathode. The other important difference in this circuit is that the tuning condenser is of the split-stator type. By splitting the stator plates of the small tuning condenser used, the path through the condenser is reduced in length and extremely short connections between the coil and condenser are made possible. The suggested sizes for coils for the three bands are, of course, approximate only. Slight variation of the length of the leads within the tuned circuit will result in modification of the coils. Fortunately, small variations of the inductance can be made readily by spacing the turns until the desired tuning range is obtained.

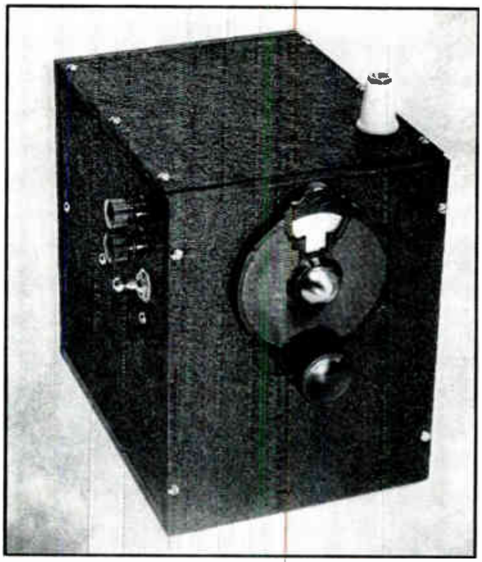


FIG. 1105 — A PORTABLE SELF-QUENCHED SUPERREGENERATIVE RECEIVER EMPLOYING AN ACORN DETECTOR AND TYPE 30 AUDIO AMPLIFIER

The dial on the panel is the only control. A quarter- or half-wave rod plugs into the jack at the top. The switch and headset terminals are at the left.

TWO-BAND PORTABLE SUPERREGENERATIVE RECEIVER

The self-quenched superregenerative receiver no doubt will soon be outmoded on the 56-Mc. band, so far as fixed station operation is concerned. However, for portable use, emergency work and operation on bands above 56 Mc., this type of receiver will long be one of the most satisfactory pieces of receiving equipment.

A simple self-quenched receiver using an acorn detector is illustrated in Figs. 1105 and 1107. The circuit is shown in Fig. 1106. It will be noticed that all parts are grouped closely around the acorn tube socket, permitting the shortest possible leads. It might well be said that this is one of the most important considerations in the building of u.h.f. receivers.

The tempered masonite case for the set is 5 inches wide, 6½ inches high and 6½ inches deep. The shelf on which the parts are mounted is located 3 inches below the top edge. There is room below the shelf for a small 45-volt "B" battery and eight flashlight cells. A series-parallel arrangement of the cells provides a fairly long-lived filament supply.

Although the superregenerative detector may be followed by an acorn audio amplifier, a Type 30 tube, which works equally well for this purpose and is inexpensive, is used in this case. The tube is horizontally mounted behind the detector on a small aluminum bracket. The limited gain of such a receiver does not justify the use of a gain control, therefore the only control on the entire set is the tuning dial, on C_2. The other components mounted on the outside of the case are the headphone binding-posts, a double-pole toggle switch and the jack-top, feed-through antenna insulator. The switch breaks the positive leads of both "A" and "B" voltage supplies.

The antenna circuit consists of a

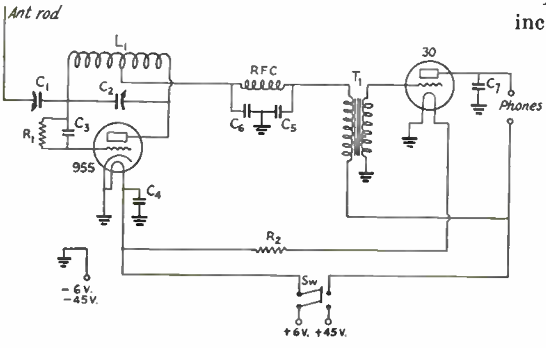


FIG. 1106 — CIRCUIT OF THE PORTABLE SELF-QUENCHED RECEIVER

C_1 — 30-μμfd. isolantite-insulated trimmer (National M-30).
C_2 — 15-μμfd. variable (National UM-15).
C_3, C_4, C_5 — 100-μμfd. mica.
C_6 — 0.005-μfd. mica.
C_7 — 0.001-μfd. mica.
R_1 — 5 megohms, ½-watt.
R_2 — 50 ohms, ½-watt.
T_1 — Audio transformer (Thordarson T-13A34).
L_1 — 112 Mc.: 3 turns No. 14, diameter ½ inch, length ½ inch. 224 Mc.: 2 turns No. 14, diameter 5/16 inch, length 5/16 inch. Each tapped at center.
RFC — 25 turns No. 20 d.s.c., diameter ¼ inch, close-wound.

World Radio History

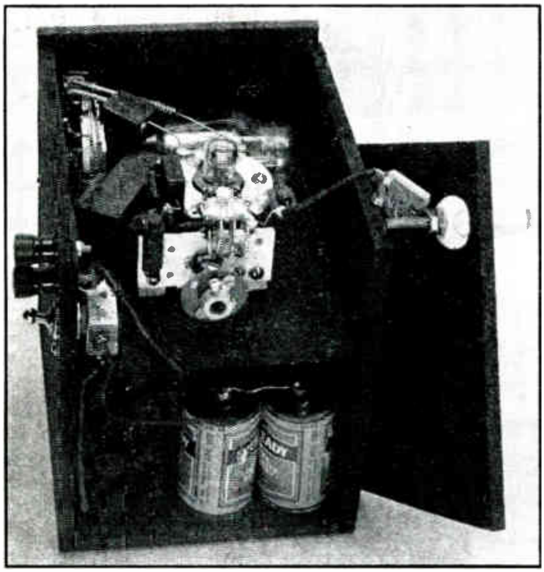
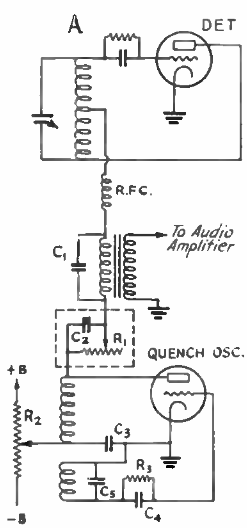


FIG. 1107 — INSIDE VIEW OF THE PORTABLE RECEIVER

Note the compactness of the detector stage. The antenna coupling condenser is mounted on the feed-through insulator in the top of the box. The battery compartment is below the receiver shelf.

quarter-wave brass rod (approximately 26 inches long) capacity coupled to the coil side of the grid condenser. C_1, the coupling condenser, is mounted on the under side of the feed-through insulator. A banana plug attached to the bottom of the antenna rod permits the unit to be a plug-in affair.

When adjusting the circuit for operation on either 112 or 224 Mc. considerable care should be given to the placement of the regeneration tap. This is probably the most critical adjustment of the receiver.



RECEIVERS WITH SEPARATE QUENCH OSCILLATORS

While the self-quenched receivers just treated are entirely satisfactory for much experimental work and have the merit of extreme simplicity, it must be admitted that a considerable improvement in performance can almost invariably be obtained by using a separate tube to produce the required quenching voltage. Innumerable circuits have been devised to provide appropriate coupling between the quench oscillator and the detector itself and it is, of course, obviously impossible to cover them all.

Fig. 1108 illustrates the detector and quench oscillator portion of two typical superregenerative circuits having separate quench oscillator tubes. The arrangement shown at "A" is probably the most effective one for use with a triode detector. The plate winding of the quench oscillator is so connected that it is able to serve the same purpose as the modulation choke in a "Heising" plate-modulated transmitter. In this case, though, the modulation is applied to both grid and plate of the detector. The condenser C_1 effectively by-passes the audio-frequency transformer primary so far as the quench voltage is concerned. Its capacity is usually between 0.002 and 0.004 μfd. — a value which does not cause serious loss of high audio frequencies yet by-passes the quench voltage. The purpose of R_1 and C_2 is to permit variation of the detector plate voltage without upsetting

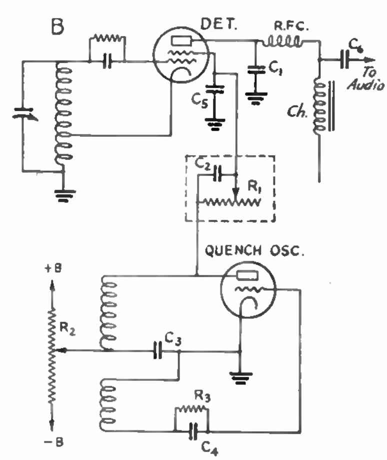


FIG. 1108 — TWO TYPICAL METHODS OF APPLYING QUENCH VOLTAGE TO THE SUPERREGENERATIVE DETECTOR

Circuit "A" is one of the most successful types using a triode detector while that at "B" shows what is probably the most satisfactory for use with a screen-grid detector. Typical values for the components marked are:

C_1 — .002 to .004 μfd.	C_5 — .002 μfd.
C_2 — .1 to .5 μfd.	R_1 — 100,000 ohms.
C_3 — .1 μfd.	R_2 — 50,000 ohms.
C_4 — .001 μfd.	R_3 — 50,000 ohms.

Circuit "B" can be understood more readily if it is noted that the screen by-pass condenser C_5 is also serving as the tuning condenser across the plate coil of the quench oscillator.

World Radio History

the voltage on the quench oscillator plate. In some cases individual adjustment of the quench oscillator and detector voltages results in an improved performance but practice indicates that in many cases the additional components required (R_1, C_2) are hardly justified.

The diagram "B" in Fig. 1108 illustrates what we believe to be the most successful method of applying the quench voltage to a screen-grid detector. In this instance the screen of the detector is modulated by the quench oscillator in the same manner as were the grid and plate in the triode circuit. Much experimental work has been done in studying the effect of applying the modulation to other grids in receivers of this general type but screen-grid modulation has so far not been excelled. In this circuit again are shown the additional components required for separate control of the detector screen voltage. They are possibly more desirable in arrangement "B" than in "A."

It should be realized that the performance of all the various circuits is very similar providing the optimum operating conditions are obtained. The important factors are the screen and plate voltages on the detector, the order of quench voltage applied to the detector and the frequency of the quench voltage. Of these factors, probably the least critical is the quench frequency, but there exists an optimum frequency for each signal frequency. The normal superregenerative receiver is very tolerant in this respect and it is usually found that a quench frequency of about 100 kc. is suitable.

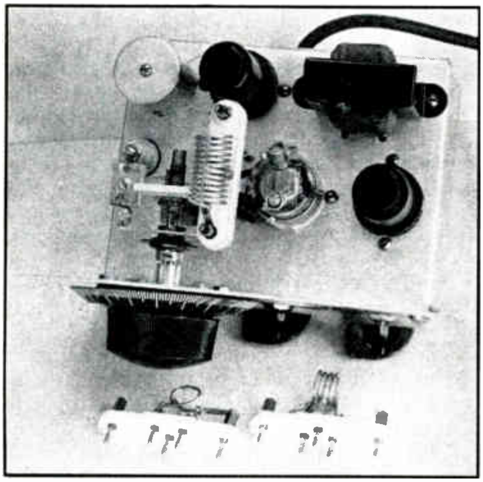


FIG. 1109 — TOP VIEW OF THE PLUG-IN COIL RECEIVER WITH THE 56-MC. COIL IN PLACE

Notice the closely grouped components of the detector circuit. The quench coil is at the left rear corner with the quench tube just to the right.

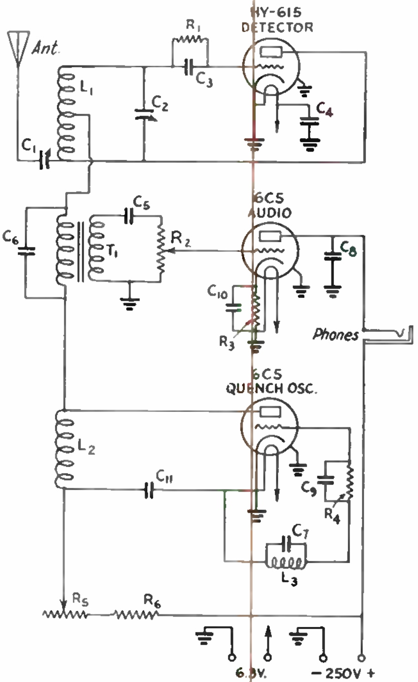


FIG. 1110 — PLUG-IN COIL RECEIVER CIRCUIT

C_1 — 30-μμfd. isolantite-insulated trimmer.
C_2 — 2-plate midget variable (National UM-15 with all but two plates removed).

C_3 — 100-μμfd. mica.	R_1 — 5 megohms, ½-watt.
C_4, C_5 — 0.01-μfd. paper.	R_2 — 500,000-ohm variable.
C_6, C_7 — 0.002-μfd. mica.	R_3 — 2000 ohms, ½-watt.
C_8, C_9 — 0.001-μfd. mica.	R_4 — 50,000 ohms, ½-watt.
C_{10} — 0.5-μfd. paper.	R_5 — 50,000-ohm variable.
C_{11} — 0.1-μfd. paper.	R_6 — 10,000 ohms, 1-watt.

L_1 — 56 Mc.: 12 turns No. 14, length 1⅛ inches, diameter ⅝ inch.
112 Mc.: 4 turns No. 14, length ⅜ inch, diameter ⅝ inch.
224 Mc.: 1 turn No. 14, diameter ½ inch.
All diameters are outside; all coils tapped at center.

A THREE-BAND SUPERREGENERATIVE RECEIVER WITH SEPARATE QUENCH TUBE

A SEPARATELY quenched plug-in coil receiver which works well on 56, 112, or 224 Mc. is shown in Figs. 1101, 1109 and 1111. The circuit is given in Fig. 1110.

As the circuit shows, the receiver employs three tubes. A Type HY-615 high-frequency triode is used as the detector, and 6C5 triodes are found in both the quench and audio stages. The set may be considered to be a "general purpose" unit, since it may be operated from battery power, as well as the usual power pack, is compact and portable, and the plug-in coils permit instantaneous operation on any of the three ultra-high frequency bands.

World Radio History

The top view, Fig. 1109, shows the compactness of the detector circuit layout. This portion of the circuit is arranged as shown on the 6 by 4½ by 2-inch aluminum base. The parts line-up across the panel side of the chassis is as follows: At the left, supported by a small stand-off insulator, is the antenna coupling condenser, C_1. To the right of C_1 is the detector circuit consisting of the tuning condenser, C_2, the plug-in-coil assembly and the detector tube. The audio tube is at the right. Across the back from right to left are the quench-coil unit, the quench tube and the audio transformer.

The coil-socket is mounted on pillars between the condenser and the tube, high enough so that its prongs are in line with the tube caps and the condenser lugs. Of the three prongs forming a small triangle at the center of the socket, the two along the side face the condenser and the single prong faces the tube. The single prong is the terminal to which the quench lead and coil tap are connected. A fourth prong, located at the panel end of the form, is connected to the grid side of C_2. The antenna-coupling condenser is connected to this point.

The bottom view, Fig. 1111, shows the placement of the by-pass condensers, resistors, switch and headphone jack, and the potentiometers. By-passing must be as direct as possible and preferably to not more than one or two points. The plate and filament voltage cable enters the chassis through a hole in the rear wall.

In the panel view, Fig. 1101, the tuning dial is at the right with the jack and switch just below. The small dial at the bottom right edge is on the volume control and the adjacent one on the regeneration control. The panel measures 5½ by 7 inches.

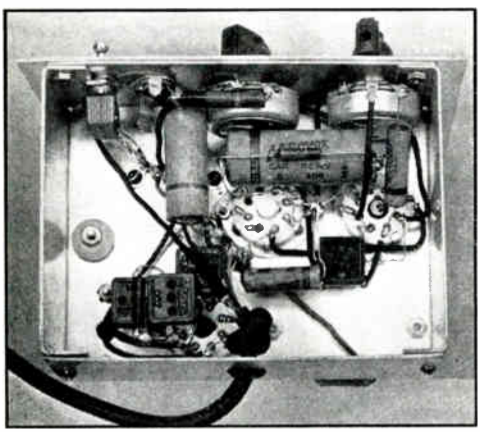


FIG. 1111—BOTTOM VIEW OF THE PLUG-IN COIL RECEIVER

Parts are arranged for the prime purpose of obtaining short ground connections.

Construction of the coils is quite simple, as indicated by Fig. 1109. Each is soldered directly to the appropriate lugs on the form. The position of the tap is not particularly critical; tapping at approximately the center of the coil should be sufficient. Each coil covers slightly more than the intended band, with the band itself spread over approximately 75 divisions of the dial.

The total current drain of the receiver is 18 milliamperes, 5 ma. each for the detector and quench tubes and 8 for the audio stage.

The antenna loading is not too critical; almost any length of wire can be coupled to the detector, through C_1, without overloading the circuit. Of course the capacity of C_1 must be varied to suit the particular band.

SUPERREGENERATIVE RECEIVERS WITH R.F. AMPLIFIERS

One important disadvantage of the simple superregenerative receivers just described is that they are capable of strong radiation. Also, as we have already stated, they are extremely unselective. Prevention of radiation and some improvement in selectivity is made possible by adding an r.f. amplifier stage ahead of the superregenerative detector. Fig. 1112 illustrates various methods of coupling the r.f. stage to the detector. All of them have been shown to be effective in practice but each has its particular points of merit. The circuit shown at "A" will be recognized as an example of conventional transformer coupling with normal wiring of the r.f. amplifier itself. The best number of turns for L_3 will usually be just slightly less than that used in L_4, but this depends upon the order of coupling between the two coils and the order of freedom with which the detector superregenerates. One of the difficulties in this arrangement is in providing a suitable mechanical arrangement for mounting the coils. L_6 may be wound on a form of some good insulating material with the turns of L_3 occupying the spaces between the turns of L_4 but many workers prefer to avoid any dielectric in the field of u.h.f. coils. Then, L_3 may be wound on a slightly smaller form pushed inside the turns of L_4. One effective alternative scheme is to make L_3 of about 30 gauge d.s.c. wire with the turns cemented to the turns of L_4 with Duco cement or its equivalent. Yet another method is to make L_3 a self-supporting coil of No. 18 wire of a diameter just sufficient to slide inside L_4. In this case, L_3 might well be mounted from small stand-off insulators.

The arrangement shown at "B" in Fig. 1112 is particularly suitable in receivers having the high voltage applied to the detector coil as in Figs. 1103 and 1104. The plate lead is merely tapped near the grid end of the detector coil

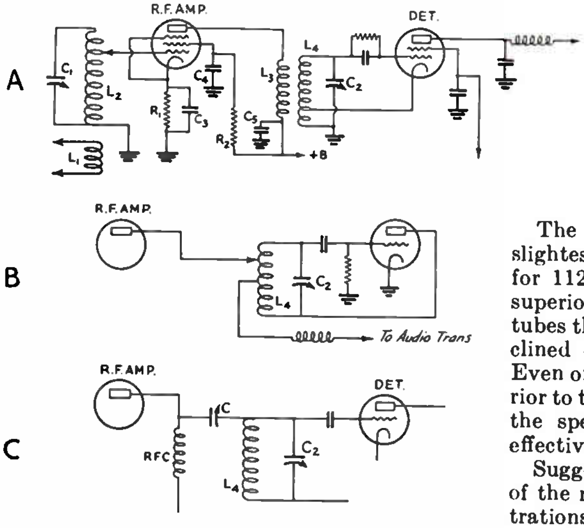


FIG. 1112—THREE EFFECTIVE METHODS OF COUPLING AN R.F. AMPLIFIER TO THE SUPER-REGENERATIVE DETECTOR

Assuming that the r.f. amplifier is a 954 acorn, suitable values for the various components marked will be:

R_1 — 1500-ohm half-watt.
R_2 — 100,000-ohm half-watt.
C_1, C_2 — 15 $\mu\mu$fd. Some difficulty may be had in making the two condensers "track" if a conventional tube is used as a detector. If single dial operation is essential, C_1 may be loaded with a 15 $\mu\mu$fd. trimmer in parallel to provide the equivalent of the higher tube capacity across L_4. A separate control for C_1 or a parallel trimmer condenser available for control from the front panel is very desirable.

L_2 will be exactly similar to L_4 — the usual detector grid coil. L_1 should comply with the specifications given for the usual antenna coil. Since variation of its coupling will have relatively little effect on the regeneration in the detector it may usually be operated closer to the grid coil than would be possible in the receiver lacking an r.f. stage.

with no other modification to the detector circuit.

Circuit "C" in the same illustration is a general-purpose affair suited for almost any receiver. In this arrangement the plate voltage is applied to the r.f. tube plate through a good u.h.f. choke, a coupling condenser of 5 to 15 $\mu\mu$fd. then being connected between the r.f. plate and the grid end of the detector coil. Coupling is varied by changing the capacity of *C*.

In all of the circuits the most important adjustment is the order of coupling between the r.f. tube and the detector. The superregenerative detector is extremely sensitive to changes of the load on its grid circuit and usually operates most effectively when heavily loaded. On the other hand, tight coupling and the consequent heavy loading of the detector will not allow the maximum possible r.f. selectivity. The coupling adjustment should therefore be varied to give the desired optimum performance considering both selectivity and sensitivity.

Suitable Tubes for R.F. Amplifiers

The Type 954 acorn pentode is, without the slightest doubt, the most effective r.f. amplifier for 112 Mc. and above. It is, indeed, so far superior to the conventional glass or metal tubes that the serious u.h.f. worker is rarely inclined even to consider using anything else. Even on 56 Mc. the 954 is incomparably superior to the normal screen-grid pentode, although the special types 1852 and 1853 are quite effective at this frequency.

Suggestions for the mechanical arrangement of the r.f. stage may be gained from the illustrations of the receiver of Fig. 1113 and of superhet converters later in this chapter. In general it will be found that quite simple shielding will serve to prevent oscillation, providing the by-passing has been done carefully. A simple baffle, such as that used in the converter shown in Fig. 1120, is probably the most practical arrangement for the 954 — the tube socket being mounted on the baffle or partition and the tube grid protruding through a small hole in the metal. The most satisfactory socket available for this type of amplifier is the National Type XMA metal socket. Excellent by-passing is possible with this particular design.

In the r.f. amplifier using conventional tubes,

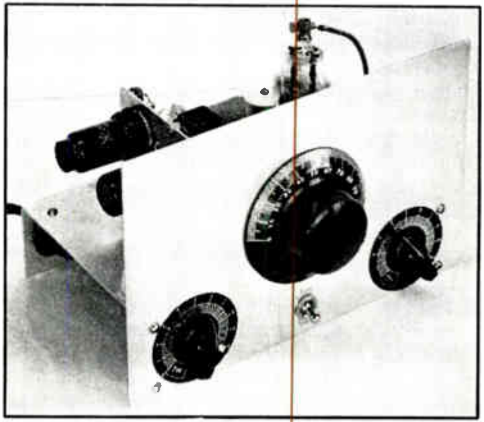


FIG. 1113—A SUPERREGENERATIVE RECEIVER WITH R.F. AMPLIFIER, SEPARATE QUENCH CIRCUIT AND TWO STAGES OF AUDIO

Regeneration and audio controls are on the front panel. An on-off switch is provided for the "B" voltage. The r.f. stage employs an 1852 tube.

World Radio History

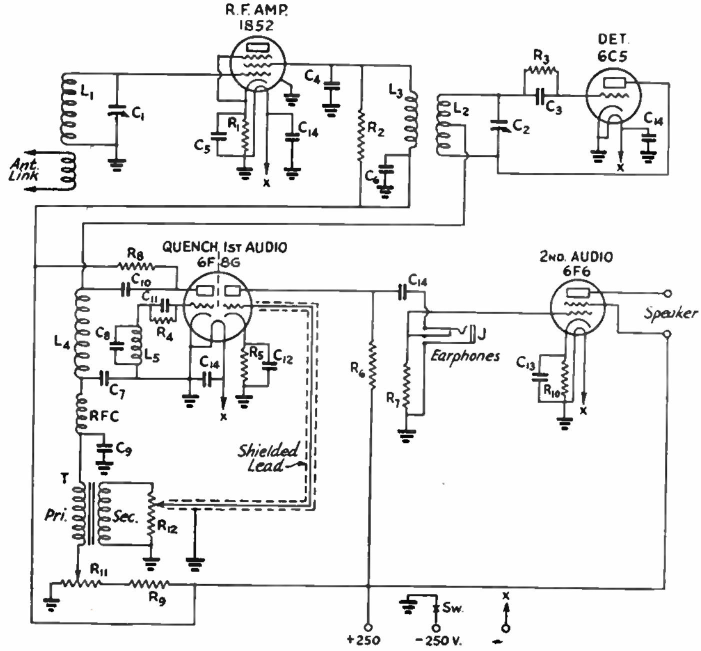


FIG. 1114 — THE T.R.F.-SUPERREGENERATIVE RECEIVER CIRCUIT

C_1, C_2 — 15-$\mu\mu$fd. variable.
C_3 — 100-$\mu\mu$fd. mica.
C_4 to C_7, inc. — 0.005-μfd. mica.
C_8, C_9 — 0.002-μfd. mica.
C_{10}, C_{11} — 0.001-μfd. mica.
C_{12} — 0.5-μfd. paper, 400-volt.
C_{13}—5-μfd. 25-volt electrolytic.
C_{14} — 0.01-μfd. paper, 400-volt.
R_1 — 300 ohms, ½-watt.
R_2 — 65,000 ohms, ½-watt.
R_3 — 5 megohms, ½-watt.
R_4 — 50,000 ohms, ½-watt.
R_5 — 2000 ohms, ½-watt.
R_6 — 50,000 ohms, ½-watt.
R_7, R_8 — 500,000 ohms, ½-watt.
R_9 — 200,000 ohms, ½-watt.
R_{10} — 500 ohms, 2-watt.
R_{11} — 50,000-ohm variable.
R_{12} — 500,000-ohm variable.
T — Audio transformer (Thordarson T-72A59).
RFC — H.f. solenoid choke (Ohmite).
J — Closed-circuit jack.
L_1 — 7 turns No. 14, length 1 inch, diameter ½ inch.
L_2 — 11 turns No. 14, length 1⅜ inches, diameter ½ inch.
L_3 — 9 turns No. 22 d.s.c., length ⅞ inch, diameter 5/16 inch.

a simple partition is again useful. The tube socket may be mounted on that side of the partition which faces the detector circuit or it may be mounted in the base in the usual manner.

SEPARATELY QUENCHED SUPER-REGENERATIVE RECEIVER WITH R.F. AMPLIFIER

The practical t.r.f.-superregenerative receiver illustrated in Figs. 1113, 1115 and 1116 is about as complete and advanced as the present-day 56-Mc. superregenerative set can be made. Besides the r.f. amplifier to prevent radiation and to increase sensitivity and selectivity, there are also included a separate quench oscillator and two stages of audio, one for headphone reception and one for speaker operation. Capacities and inductances are proportioned so as to spread the 56-Mc. band over the greater portion of the tuning dial.

As shown by the circuit diagram, Fig. 1114, an 1852 is used as an r.f. amplifier. The 1852, primarily intended for television work, is also well suited to the r.f. stages of ultra-high-frequency receivers. The second tube is a 6C5 triode detector. The quench tube is one section of a 6F8G dual triode; the 6F8G, which is equipped with two separate cathodes, is particularly suitable since the construction permits operating the quench section with grounded cathode. The second section is used as a cathode-biased first audio stage. Resistors R_8 and R_9 drop the plate-supply voltage to approximately 30 volts, the voltage at which best operation is secured. A standard 6F6 audio circuit at the output end of the receiver provides loud-speaker reception.

Fig. 1115 shows the arrangement of the r.f. amplifier and the detector. The amplifier is the unit closest to the panel and the detector is the one to the rear. The tubes for these two stages are mounted on a 2¾-by-4-inch aluminum partition to the right of the tuned circuits. It is important that the 1852 tube be mounted with the filament pins in line vertically. Filament pins for both tubes should face toward the rear of the chassis.

Shielding between the r.f. and detector stages is provided by a second aluminum partition measuring 2¾ by 2¼ inches. The tuning condensers, ganged together through the medium of an insulated flexible coupling, have their respective coils soldered directly to the condenser lugs. The amplifier plate coil is inside the detector coil. The antenna link is supported on standoff insulators just below the amplifier coil. A second pair of insulators carries the link leads to the left-hand edge of the chassis, where the antenna terminals are located. Leads for the detector-quench voltage and amplifier plate voltage are brought up through holes at the rear of the chassis. By-passing, always important, is done directly to the grounded aluminum partitions.

Fig. 1115 also shows the quench coil, located at the rear of the chassis, and the 6F8G and

World Radio History

6F6 which are toward the front edge. The headphone jack may be seen at the left of the rear wall with the speaker terminals to the right. The power cable enters at the right.

A bottom photograph, Fig. 1116, shows the resistors and condensers, stacked together to obtain the shortest possible leads. The transformer T_1 is mounted slightly to the rear of the chassis center. Although the r.f. amplifier is a rather broad tuning circuit, peak performance will be secured only when the two circuits are made to tune over the same range simultaneously. To do this the flexible coupling between the two tuning condensers should be loosened so that the condensers may be tuned separately. Then, with the detector condenser, C_2, set near minimum capacity, tune C_1 for maximum response to a steady signal or to auto ignition noise. If resonance occurs at higher capacity on C_1 than on C_2, the turns of L_1 should be spread until the two condenser settings are identical; if at minimum on C_1, the turns should be squeezed closer together. Then set C_2 at maximum capacity and again tune C_1 to resonance. Should there again be a discrepancy, it will be necessary to make similar adjustments to L_2 until satisfactory tracking is secured.

The next adjustment is that of the coupling between L_2 and L_3. With the set oscillating, L_3 is placed inside the detector coil and its position varied until the maximum response is reached. Ignition and background noise again will be useful in determining the gain. It may be found that these adjustments have slightly upset the original frequency range of the circuit. If so, the spacing of coil turns must again be varied until the proper frequency coverage is obtained.

Coupling to the antenna may also require some experimentation, and calls for a coil of the proper number of turns suitably spaced in relation to L_1. Although depending somewhat on the antenna used, two or three turns similar to L_1 probably will be close to the correct value. Alternatively, capacity coupling may be used.

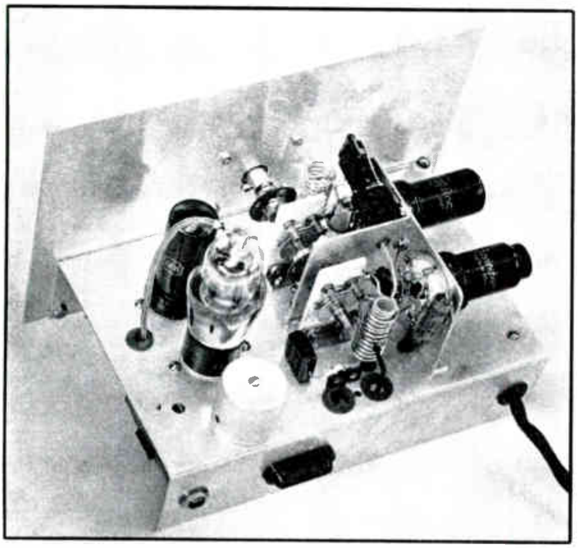


FIG. 1115 — CHASSIS LAYOUT OF THE FOUR-TUBE RECEIVER

Care should be used to follow the arrangement of the r.f. amplifier and the detector.

THE SUPERHETERODYNE RECEIVER

While the superregenerative receiver has unique and unparalleled advantages in the matter of discrimination against ignition and similar noises, a.v.c. action and extreme sensitivity, it does suffer from severe lack of selectivity. R.f. amplifiers ahead of the superregenerative detector provide an improvement in selectivity but the improvement is naturally very slight.

The present necessity, under the F.C.C. regulations, for high stability in amateur u.h.f. transmitters has made it possible to advance the receiving technique by using the superhet type receiver. With the superhet it is immediately possible to provide a high order of selectivity and, in the more advanced superhets, a signal-noise ratio more favorable than that obtained in the superregenerative receiver. The superhet receiver is though, more complex and costly than the superregenerative type.

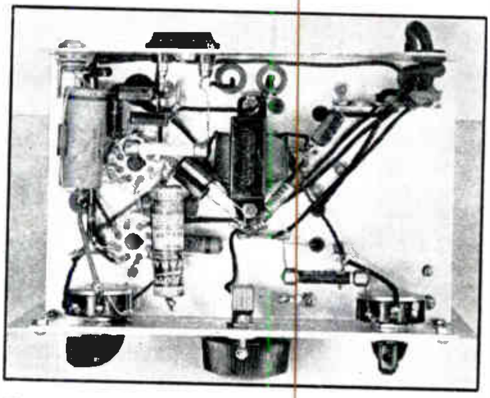


FIG. 1116 — BELOW THE BASE OF THE FOUR-TUBE RECEIVER

By-pass condensers are placed to give short ground connections.

World Radio History

Since a great many amateurs already own superhet high frequency receivers (or possibly a broadcast receiver of good sensitivity) and since these receivers serve admirably as the i.f. amplifiers for u.h.f. receivers, many workers will prefer to build their u.h.f. superhets in two sections — a converter unit serving to change the signal frequency to a much lower one, and their normal receiver serving as the i.f. amplifier. A receiver built in this fashion and using a good high-frequency or broadcast-frequency receiver as the i.f. will, of course, have high selectivity.

Probably the most serious weakness of the conventional superhet is its high response to damped interference such as that caused by the ignition system of automobiles. There are two practical methods of reducing this trouble. One is in the use of a high-frequency i.f. amplifier having a superregenerative final detector (such an amplifier is outlined later in this chapter). The other alternative is in the use of one of the noise silencer methods described in Chapter Seven. The latter procedure is very much to be preferred in a receiver having a high-gain and high-selectivity i.f. amplifier.

The designs for u.h.f. superhet converters which follow are presented with the intention of giving a general idea of present practice. They may be used in conjunction with some existing receiver as the i.f. or they may be combined on the same chassis with a special i.f. amplifier. The converter units will remain the same in either case.

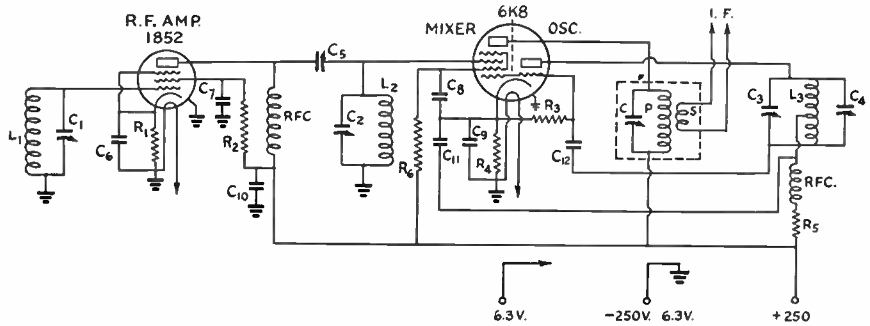


FIG. 1118 — THE 1852-6K8 CONVERTER CIRCUIT

C_1, C_2 — 15-$\mu\mu$fd. midget variable (National UM-15).
C_3 — Same as C_1 with two rotor and one stator plate removed.
C_4, C_5 — 30-$\mu\mu$fd. compression-type padders.
C_6 to C_9, inc. — 0.005-μfd. mica.
C_{10} — 0.002-μfd. mica.
C_{11} — 250-$\mu\mu$fd. mica.
C_{12} — 100-$\mu\mu$fd. mica.
R_1 — 200 ohms, ½-watt.
R_2 — 65,000 ohms ½-watt.
R_3 — 50,000 ohms, ½-watt.
R_4 — 300 ohms, ½-watt.
R_5 — 20,000 ohms, ½-watt.
R_6 — 20,000 ohms, 2-watt.
RFC — In 1852 plate circuit, 2.5-mh. pie-wound; in oscillator circuit, solenoid type (Ohmite).
L_1 — 6 turns No. 14, diameter ½ inch, length 1 inch.
L_2 — 6 turns No. 14, diameter ½ inch, length ⅝ inch.
L_3 — 10 turns No. 14, diameter ½ inch, length 1¼ inches, tapped 4th turn from grid end.
I.F. Output Transformer — *P*, 30 turns No. 28 d.s.c. close-wound on half-inch form; *S*, 6 turns wound over *P* at bottom; *C*, 35-$\mu\mu$fd. midget variable.

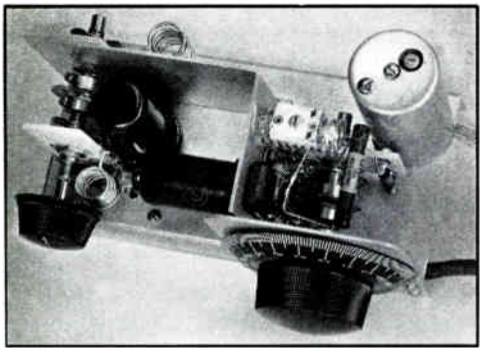


FIG. 1117 — A SUPERHET CONVERTER FOR 56-MC. RECEPTION

Designed for use with a communications-type receiver, this converter has an 1852 r.f. stage and a 6K8 mixer-oscillator. It uses a high-frequency i.f. (10 Mc.) for image reduction, and is suitable for reception of crystal-controlled 'phone or c.w. signals.

A METAL-TUBE CONVERTER FOR 55 MC.

Figs. 1117 and 1119 show a 56-Mc. converter which may be used in conjunction with any high-frequency receiver, preferably of the superheterodyne type, capable of tuning in the vicinity of 10,000 kc., the i.f. for which the unit is designed. Construction is simple, and the circuit employs only two tubes, both of which are modern types especially suited for the purpose. The circuit, Fig. 1118, shows that an 1852 is used as an r.f. amplifier or preselector, and that a triode-hexode converter

World Radio History

tube, the 6K8, is used in the mixer and oscillator circuits. The 10-Mc. intermediate-frequency is chosen to give a good image ratio on the 56-Mc. band.

The aluminum chassis measures 1 by 3½ by 7 inches. Shielding between stages is provided by the right-angle partition shown in the photograph. This partition is 2¾ inches high, and the side parallel to the front edge of the chassis is 4 inches long. The portion that supports the 6K8 is 2½ inches long. The 6K8 is mounted at the bottom of the shield, with the grid-cap facing the left end of the base.

The 1852 grid tuning condenser, C_1, and coil, L_1, are mounted to the rear of the 4-inch section of the shield. The 1852, condenser C_2, and coil L_2 are mounted in front of the partition, with C_2 directly in line with C_1. A hole through the shield permits the two shafts to be connected by a flexible coupling. Both of the coils, and also coil L_3, have their terminals soldered directly to the appropriate condenser lugs.

The oscillator-mixer section of the circuit is to the right of the 2½-inch partition, with the tube socket mounted on the same side. C_3, also mounted on the partition, is located at the rear of the tube socket. The i.f. transformer, T_1, is mounted at the right-rear corner of the chassis. The output leads from this transformer are shielded to prevent stray pick-up between the converter and the receiver. By-pass condensers and resistors are closely grouped around the tube socket, assuring short leads. A trimmer condenser, C_4, soldered across L_3, allows a small variable capacity to be used as the tuning element and at the same time makes the circuit fairly high-C in the interests of good stability.

A small panel is used to mount a vernier dial for the oscillator condenser. Since the r.f. tuning is not critical and, indeed, is broad enough to cover a good portion of the band with one setting, a small knob gives sufficient control.

The output line may be connected to the antenna and ground terminals of the standard receiver used as an i.f. amplifier, or to the "doublet" terminals, if provided. The exact i.f. chosen is not particularly important, so long as it is in the vicinity of 10 Mc. Choose a frequency which is free from signals, if possible, so that there will be no unnecessary interference from this source.

Tuning of the converter is as follows: With the r.f. and oscillator condensers at about half

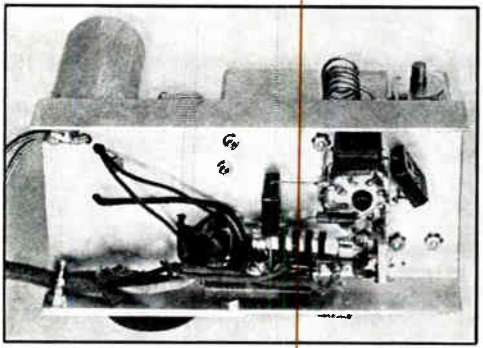


FIG. 1119 — BELOW-CHASSIS WIRING OF THE METAL-TUBE CONVERTER

The 1852 socket may be seen at the right. A shielded output cable is used to prevent signal pick-up at the intermediate frequency used (10 Mc.).

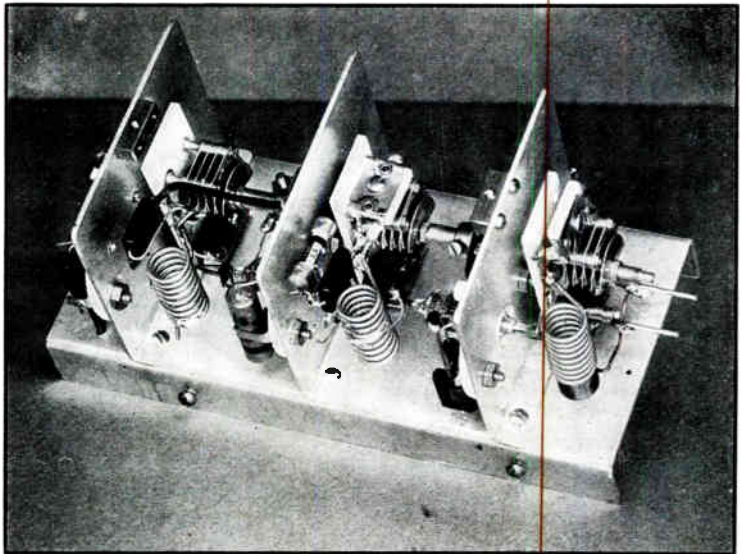


FIG. 1120 — A TYPICAL EXAMPLE OF AN ULTRA-HIGH-FREQUENCY CONVERTER USING ACORN TUBES

A unit of this type, operated in conjunction with a good standard high-frequency receiver, allows excellent reception performance on frequencies up to about 200 Mc. providing the transmitted signal is substantially free from frequency instability. Should the receiver be fitted with a modern noise silencer, the complete outfit is then about the last word in u.h.f. receiving equipment. A special i.f. amplifier with a lower order of selectivity is necessary to allow reception from transmitters using modulated oscillators.

World Radio History

capacity, the padder, C_4, is adjusted until 56-Mc. stations of known frequency are heard. After this the padder may be set to bring the high-frequency end of the band near minimum capacity on C_3. The i.f. transformers should then be tuned for maximum signal strength. The 56–60-Mc. band will occupy approximately 60 to 70 divisions on the dial. The r.f. and mixer input circuits, L_1C_1 and L_2C_2, may be made to track by using the system described in connection with the t.r.f.-superregenerative receiver.

Any type of antenna may be used, so long as

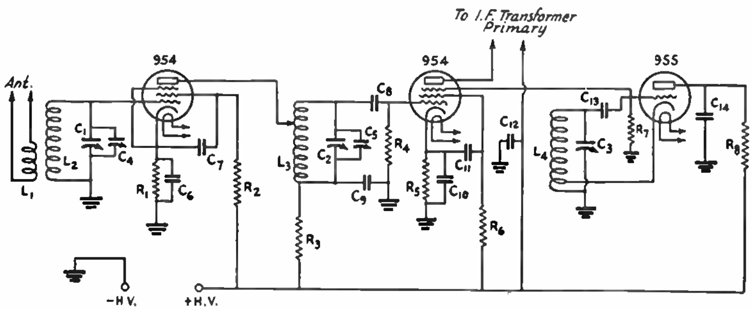


FIG. 1121 — WIRING OF THE ACORN CONVERTER

L_1 — Seven turns of No. 16 enamelled wire ½-inch inside diameter. Very slight spacing between turns.
$L_{2,\,3,\,4}$ — Each eight turns of No. 14 bare or tinned wire ½-inch inside diameter with turns spaced to occupy one inch. The best position for the plate tap on L_3 is usually 3 or 4 turns down from the grid end of the coil. Cathode tap on L_4 at 1½ or 2 turns from the grounded end of coil. These coils are for 56-Mc. operation.
$C_{1,\,2,\,3}$ — National Type UMA condensers with four stator and five rotor plates. These are unnecessarily large for the 56- to 60-Mc. band but give convenient coverage of about 4 Mc. on each side of the amateur band.
$C_{4,\,5}$ — National Type M30 padding condensers (Max. capacity 30 μμfds.).
$C_{6,\,7}$ — 500 μμfd. fixed midget condensers.
C_8 — 100 μμfd. fixed midget condenser.
C_9 — 500 μμfd. fixed midget condenser.
$C_{10,\,11,\,12}$ — 0.01 μfd. 400-volt paper-type condensers. C_{10} may be low-voltage type.
C_{13} — 100 μμfd. fixed midget condenser.
C_{14} — 1000 μμfd. fixed midget condenser.
R_1 — 1500-ohm half-watt fixed resistor.
R_2 — 100,000-ohm half-watt fixed resistor.
R_3 — 2000-ohm half-watt fixed resistor.
R_4 — 1-megohm half-watt fixed resistor.
R_5 — 2000-ohm half-watt fixed resistor.
R_6 — 100,000-ohm half-watt fixed resistor.
R_7 — 50,000-ohm half-watt fixed resistor.
R_8 — 100,000-ohm half-watt fixed resistor.

it loads the r.f. grid circuit quite heavily. Optimum operation will result under these conditions. A single-wire antenna may be capacity-coupled, while a two-wire feeder system preferably should be inductively coupled. The coupling coil should be slightly smaller than the r.f. coil, L_1.

The converter is suitable for the reception of c.w. signals, since the oscillator stability is quite high. The beat is provided by the standard receiver's beat oscillator, just as in normal reception.

A CONVERTER USING ACORN TUBES

THE converter just described is satisfactory for the 56-Mc. band but quite limited in its performance on the higher frequencies. The amateur who plans to build a superhet for 112 Mc. and higher should therefore think only in terms of the acorn tube for the converter unit. The unit shown in Figs. 1120 and 1121 may therefore be considered as the last word in superhet converter practice for operation on several u.h.f. bands.

The circuit used is quite straightforward, with a 954 r.f. stage, 954 mixer with suppressor injection, and a 955 oscillator. Parallel trimmer condensers are used across the r.f. and mixer grid circuits to allow adjustment for good tracking of the condenser gang.

The unit is assembled on a folded aluminum chassis 7¾ by 3 by 1 inch, the partitions on which the tube sockets are mounted being 3 by 3 inches. In the converter illustrated, normal isolantite tube sockets are used. It is suggested, however, that the metal National XMA socket be used for the r.f. and mixer tubes, since by-passing may be made much more effective. In assembling the unit it will be found that there is very little room to spare and that the relative placement of tube sockets, tuning condensers and other components must be given careful consideration. This compact type of assembly, while making construction slightly more difficult, is of great advantage in allowing very short leads throughout the r.f. circuits. All condensers in the circuit except C_{12} are mounted above the base and directly connected to the various socket terminals concerned.

It will be found that complete freedom from oscillation in the r.f. stage may be had even with no shielding other than the vertical partitions. This only applies, of course, when the antenna is connected. On the other hand, an additional shield cover over the whole unit is desirable if only to protect it from dust.

Adjusting the U.H.F. Converter

Amateurs unfamiliar with normal procedure in aligning superhet receivers will doubtless

World Radio History

have some difficulty with the u.h.f. converters. The process is greatly simplified if an i.f. amplifier in the form of a broadcast or high frequency superhet is already available. For the moment we will assume this to be the case. The first step is to set the i.f. amplifier at the frequency chosen and connect to it the output transformer from the mixer in the converter. The connecting leads may be of twisted pair but should run in a piece of flexible cable shield grounded to both the chassis of the converter and the ground terminal of the receiver serving as i.f. amplifier. Now the tuning condenser in the output transformer from the mixer should be tuned until the noise output from the receiver rises to a peak. This may be done even though the converter is not yet lined up. At this stage, the oscillator tuning condenser should be freed from the two others, if ganged, and with the latter condensers set at about half scale the oscillator condenser should be rotated until there is a sudden increase in noise output. With fairly wide oscillator-frequency range and a rather low intermediate frequency (5000 kc. or lower) two settings should be found at which the noise increases — each one differing in frequency from the resonant point of the r.f. amplifier circuits by an amount equal to the i.f. frequency. In the converter just described, the higher of these two oscillator frequencies should be chosen. At this point the trimmers across the first two tuning condensers should be adjusted so that the three tuning condensers come into line. The adjustment may be repeated at both ends of the scale to make certain that the three circuits stay in line across the full tuning range. The procedure is greatly facilitated if a modulated u.h.f. test oscillator is available. Even by using background noise alone, however, quite accurate alignment is possible.

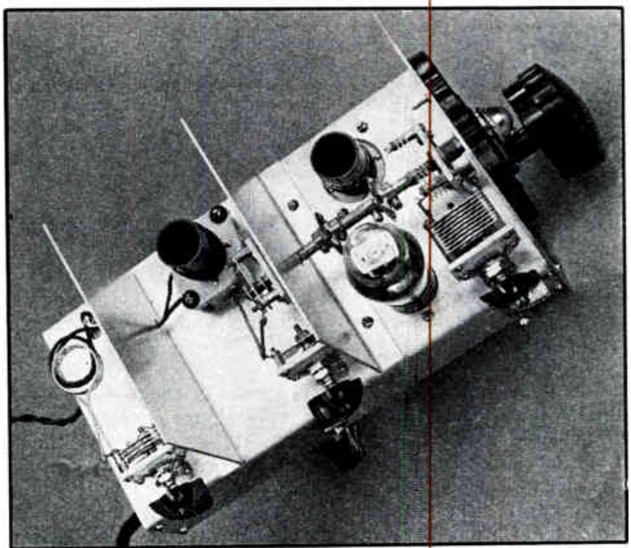
A CONVERTER FOR C.W. WORK

The converters already described may be used for c.w. reception providing the i.f. amplifier with which they are used is fitted with a beat oscillator. The present trend towards the use of c.w. on the 56-Mc. band (particularly for attempts at long-distance work but also for short hauls) has led to development of more than ordinarily stable receivers. The converter shown in Figs. 1122 to 1124 has the merit of excellent stability and has the further advantage of being virtually free from image or harmonic troubles — a matter of extreme importance when one is trying to establish the identity of weak signals believed to be propagated on 56 Mc.

In this converter, the stability problem and that of image interference are solved by using the very high i.f. frequency of 20.5 Mc. and putting the oscillator on the low-frequency side of the signal. Stability is further aided and the ganging problem solved by using a large parallel padding condenser on the oscillator and a padding condenser across the detector circuit of large capacity with respect to the very small tuning capacity. Other features include the use of regeneration in the detector and cathode coupling between oscillator and detector. It will be noted from Fig. 1123 that the coupling coil in the detector cathode circuit serves also as the impedance in the cathode circuit responsible for regeneration. Screen voltage variation is used to control regeneration.

FIG. 1122 — TOP VIEW OF THE 56-MC. CONVERTER DESIGNED FOR C.W. WORK

The front portion contains the oscillator tuning condenser and padding condenser, oscillator tube, and coil. The middle portion houses the detector tuning condenser and padding condenser, and detector coil. The acorn-tube detector is mounted directly under the detector coil socket, permitting a very short grid lead. The antenna tuning unit at the rear is link-coupled to the detector coil, and the antenna is clipped directly on to the coil. The output transformer is adjusted through the small hole under the link to the antenna coil.



World Radio History

The chassis for the converter is made by bending over 2 inches of each side of a 9 by 10 inch piece of aluminum, resulting in a U-shaped channel 5 by 10 inches. The front panel is made of a 5½ by 7 inch piece, fastened to the base by tapped ¼-inch square brass rod, and the rear end is made by bending over the ends of a small piece of aluminum so that it will fit tightly and bolting it to the chassis. The shield can for the output coupling transformer is made by bending thin aluminum to form a box 2½ by 3½ inches, with mounting tabs on the bottom, and another piece is bent to form a tight-fitting cover.

The general layout of parts is shown in the illustrations, and requires no special mention. The detector tube, a 954, has its socket mounted directly under the detector coil socket. It will be necessary to make two mounting pillars for the coil socket by tapping two 1-inch lengths of brass rod, since the acorn-tube socket partially covers the mounting holes for the pillars. Flat-head screws must be used. An acorn-tube socket similar to the one shown must be used, because it is necessary to keep the capacity between cathode and ground low.

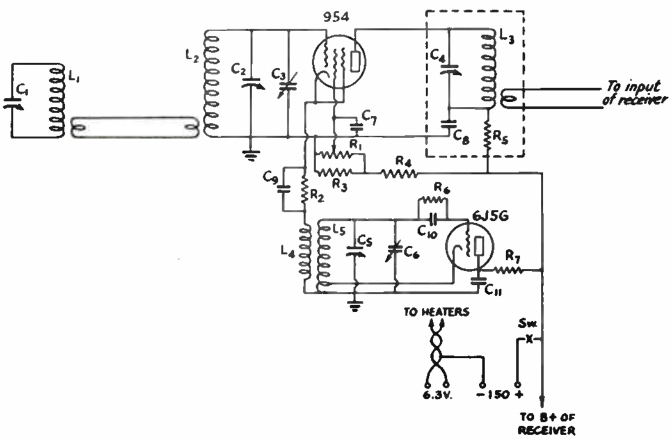


FIG. 1123 — CIRCUIT DIAGRAM OF THE 56-MC. CONVERTER

C_1, C_5 — 25-μμfd. midget variable (Cardwell ZR-25-AS).
C_2 — 2.5-μμfd. midget variable (Cardwell Z-4SS with one stator and one rotor plate removed).
C_3 — 10-μμfd. midget variable (Cardwell ZR-10-AS).
C_4 — 50-μμfd. midget variable (National UM-50).
C_6 — 100-μμfd. midget variable (Cardwell ZU-100-AS).
C_7, C_8, C_{11} — 0.006-μfd. postage-stamp mica condenser.
C_9 — 250-μμfd. postage-stamp mica condenser.
C_{10} — 100-μμfd. postage-stamp mica condenser.
R_1 — 50,000-ohm wire-wound potentiometer.
R_2 — 2000-ohm, ½-watt carbon.
R_3, R_4 — 15,000-ohm, 10-watt wire-wound.
R_5 — 2500-ohm, ½-watt carbon.
R_6 — 15,000-ohm, ½-watt carbon.
R_7 — 5000-ohm, 1-watt carbon.
L_1 — 4 turns No. 14, 1-inch diameter, ¾″ long.
L_2 — 4½ turns No. 18 enamelled, ¾″ long.
L_3 — 12 turns No. 14, 1″ diameter, 1⅛″ long, with 5 turns No. 26 d.c.c. wound inside for output coupling.
L_4 — 2¾ turns No. 18 enamelled close wound at low-potential end of L_5.
L_5 — 1⅓ turns No. 18, ¾″ long, tapped ½ turn up for cathode; L_2, L_4, L_5 are wound on 1″ diameter forms (National XR-1). The coupling coils for L_1 and L_2 are two turns each.
The link between L_1 and L_2 has its wires separated about half an inch — not twisted.

The simplest sort of 20.5-Mc. i.f. amplifier for this converter is a t.r.f. receiver covering that range. A superhet could be used, but there is a good chance of trouble from oscillator harmonics from the receiver used as the i.f. A National SW-3 served as the i.f. with the converter described, but any stable t.r.f. set will work quite well.

Probably the most difficult task in the construction of the receiver is that of trimming the coils to the proper inductance. The first thing to do is to couple the output transformer to the receiver to be used as the i.f. amplifier. Couple the output of a modulated oscillator set at 20.5 Mc. to the 954 grid and tune in the signal on the receiver. Then tune the trimming condenser on the output transformer for maximum response. The i.f. amplifier is now lined up.

Set the test oscillator at 28 Mc. and set the tuning dial at 90. Rotating the oscillator padding condenser, the signal (second harmonic of the test oscillator) should be heard with the oscillator padder at almost exactly half scale. Then set the test oscillator at 30 Mc. and see where the signal comes in on the tuning dial. If it's at about 5 on the dial, the tuning range is adequate. If not, a little trimming of the oscillator coil, about a quarter turn at a time, will soon give the proper range.

Loosely couple the test oscillator to the antenna circuit and trim the detector coil. The detector padding condenser should be set at about ⅓ scale to give exact tracking, but the antenna tuning will interlock slightly so it is not necessary to trim down to the last sixteenth of an inch of wire. If car noises peak up with the detector padder set at half scale or so the coil is adjusted closely enough.

Running the regeneration control up, the detector should oscillate at about ⅔ scale. If it oscillates too soon, space the turns slightly on

World Radio History

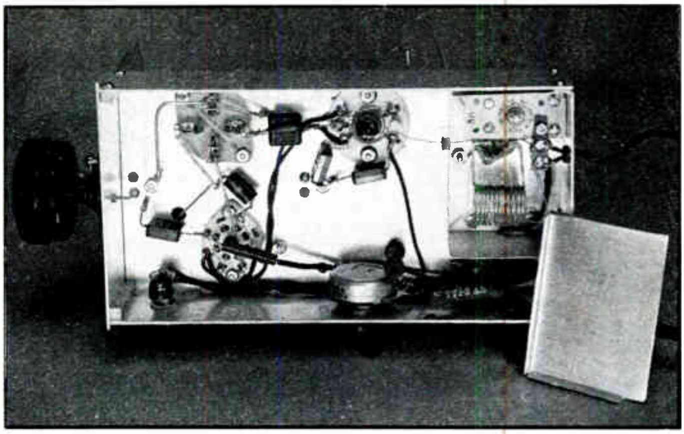


FIG. 1124 — THE BOTTOM VIEW SHOWS THE OUTPUT TRANSFORMER WITH COVER REMOVED

Heavy leads are used in the oscillator circuit to maintain stability. The output is taken through the twisted pair at the rear of the set.

L_3, the cathode impedance, until the regeneration works the way it should. It will be found that ⅛ of a turn here will make quite a difference in performance, so it is well to spend some time with the cathode coil.

With the set lined up properly, it will be possible to run across the band for c.w. signals with all of the ease customary on other bands. Any crystal-controlled signal will have the same stability that is obtained on 14 and 28 Mc. Using the SW-3 as the i.f. amplifier, the regeneration control of the SW-3 is set in the sensitive position normally used for weak-signal reception, and held there for c.w. reception. It is backed off slightly for 'phone reception, in the usual manner.

When the receiver is in operation, try changing the number of turns that link the output transformer to the receiver being used as the i.f. amplifier. Different receivers have different input impedances, and some adjustment of the coupling coil may be necessary if maximum sensitivity is to be secured.

This converter was originally described in *QST*, August, 1937.

THE I.F. AMPLIFIER PROBLEM

As we have already stated, a conventional high frequency superhet or broadcast receiver is eminently satisfactory as the i.f. amplifier if high selectivity can be tolerated. One satisfactory frequency on which to operate is somewhere in the neighborhood of 1500 kc. At this frequency, trouble from image interference will not be very severe on 56 Mc. if the r.f. stage in the converter is adjusted correctly. The ideal set-up is, of course, one in which the receiver used as i.f. amplifier is fitted with an effective noise silencer as well as effective a.v.c. Details of both of these features will be found in Chapter Seven.

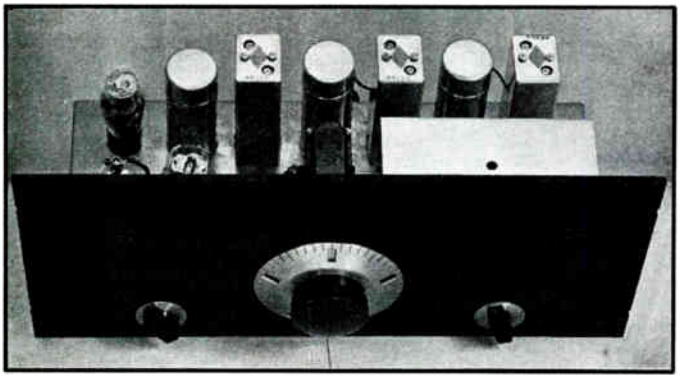


FIG. 1125 — A GENERAL-PURPOSE U.H.F. SUPERHET USING A 5000-KC. I.F. AMPLIFIER

The input converter section is similar to that shown in Fig. 1120, a shield-cover enclosing the three acorns and their associated components. This section may readily be removed and replaced by one designed for still higher frequency operation.

In instances where the selectivity of the complete superhet must be of a low order to allow reception of frequency modulated or generally unstable transmissions, as on 112 Mc., some other sort of i.f. amplifier is essential. One solution, as already suggested, is to use a good receiver of the r.f.-detector-audio type. An SW3 or its equivalent, makes a quite satisfactory amplifier. With the detector regeneration control set for highest sensitivity, the overall gain is quite respectable. An alternative is an old-time tuned r.f. broadcast receiver. Such receivers can be picked up for a few dollars at most radio

World Radio History

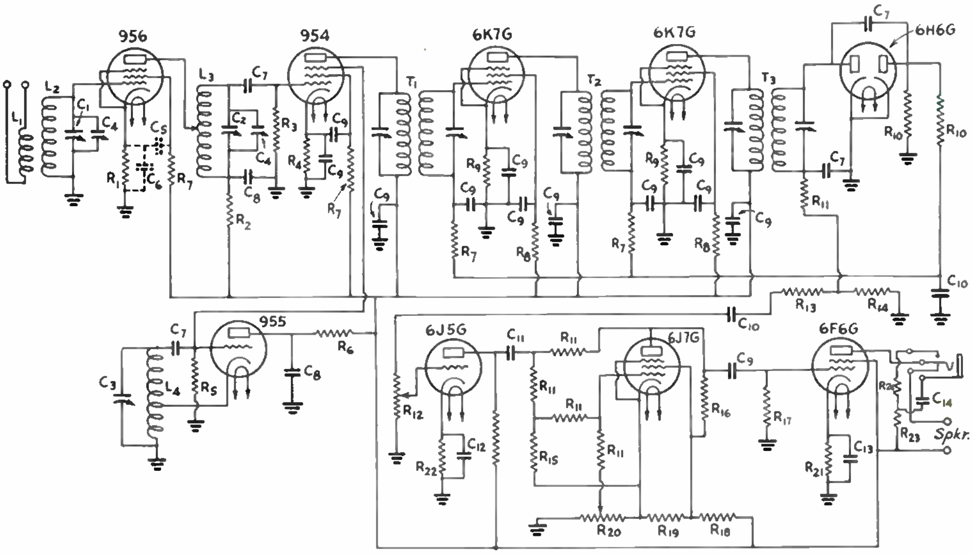


FIG. 1126 — THE CIRCUIT OF THE GENERAL-PURPOSE SUPERHET

C1, C2, C3 — National UM-15 variable condensers.
C4 — National M30 padding condensers.
C5 — Capacity built into National Type XMA acorn socket.
C6 — Socket to chassis capacity of Type XMA socket.
C7 — 100 μμfd. midget condensers.
C8 — 500 μμfd. midget condensers.
C9 — .01 μfd. paper condenser.
C10 — .1 μfd. paper condenser.
C11 — 1 μfd. paper condenser.
C12 — 10 μfd. 25-volt electrolytic.
C13 — 25 μfd. 25-volt electrolytic.
R1 — 1500-ohm half-watt resistor.
R2 — 100,000-ohm half-watt.
R3 — 1-megohm half-watt.
R4 — 2000-ohm half-watt.
R5 — 50,000-ohm half-watt.
R6 — 100,000-ohm half-watt.
R7 — 100,000-ohm half-watt.
R8 — 65,000-ohm half-watt.
R9 — 350-ohm half-watt.
R10 — 1 megohm half-watt.
R11 — 50,000 ohm half-watt.
R12 — 1 megohm potentiometer.
R13 — 100,000-ohm half-watt.
R14 — 500,000-ohm half-watt.
R15 — 20,000-ohm half-watt.
R16 — 10-megohm.
R17 — 2-megohm half-watt.
R18 — 20,000-ohm one-watt.
R19 — 2500-ohm one-watt.
R20 — 1000-ohm potentiometer.
R21 — 450-ohm five-watt.
R22 — 1000-ohm half-watt.
R23 — 2000-ohm five-watt.
R24 — 500-ohm one-watt.
L1 — Seven turns No. 16 wire ½-inch diameter.
L2, L3, L4 — Each eight turns No. 14 wire ½-inch inside diameter with turns spaced to occupy one inch.
T1, T2, T3 — Sickles 5000 kc. transformers.

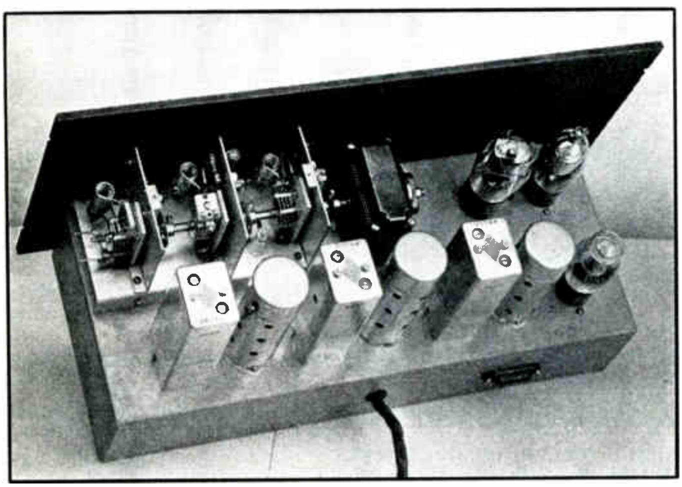


FIG. 1127 — ANOTHER VIEW OF THE SUPERHET SHOWING THE LOCATION OF THE COMPONENTS ABOVE THE CHASSIS

stores and work out well. The remaining alternative is to build a special i.f. amplifier with i.f. transformers operating at 5000 kc. or higher. Such transformers are now available. The general design of a receiver fitted with such an i.f. amplifier follows.

GENERAL PURPOSE SUPERHET

Figs. 1125 to 1128 illustrate a superhet of modern design and good performance based on the use of a specially built 5000-kc. i.f. amplifier. Its performance is inferior to a receiver using the same input converter section with a high-selectivity i.f. amplifier but the set serves as a good example of the compromise design

World Radio History

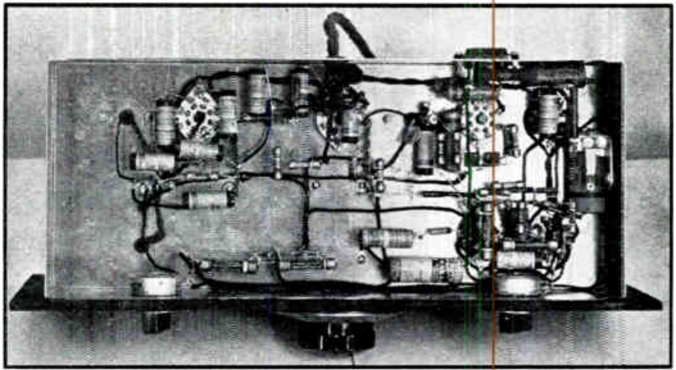


FIG. 1128 — THE UNDERSIDE OF THE GENERAL-PURPOSE SUPERHET

that must result when one demands the ability to receive the signals from transmitters suffering from frequency modulation.

Fig. 1126 reveals that the converter section employs acorn tubes arranged in almost exactly similar fashion to those of Fig. 1121. This section is followed by a two-stage i.f. amplifier operating on 5000 kc. and feeding the two diodes of a 6H6 — one supplying the audio signal and the other a.v.c. voltage. A feature of the audio amplifier is the use of an RCA type audio noise suppressor, the design principles of which are treated in Chapter Seven. This type of noise suppressor was chosen in this case in the attempt to avoid the complications which ordinarily result from the use of the usual r.f. type suppressor in an i.f. amplifier of relatively low gain. It will be noted that the use of this system calls for connection of the phone jack in the output tube circuit.

The photographs of the receiver show that the converter unit is located at the right of the National type PWO dial, the rest of the components being arranged in the same sequence as in the circuit, starting from the right rear corner of the chassis, proceeding across the rear and then doubling back toward the dial. In this fashion feedback troubles are minimized and ample space is provided under the tube sockets for the necessary by-pass condensers and resistors. The circuit itself is quite conventional and the only precaution found necessary in practice was the provision of extremely short by-pass leads throughout the i.f. circuit.

Successful alignment of the i.f. amplifier and of the converter section calls for the use of a test oscillator and involves the principles already outlined. No special padding condensers were found essential in the first oscillator circuit to give satisfactory tracking across the 56–60-Mc. band providing care was taken to get similar inductance values in L_2, L_3 and L_4.

This particular receiver has ample sensitivity for normal weak-signal reception and passes a sufficiently wide band to allow substantially undistorted reception of the usual modulated oscillator transmitter on 112 Mc. However, it is doubtful if sufficient sensitivity could be had with conventional tubes in the converter section.

AN I.F. AMPLIFIER WITH SUPER-REGENERATION

An unconventional solution of the i.f. amplifier problem is that described in *QST* for November and December, 1935. The complete receiver incorporating this type of i.f. amplifier, known as the Superinfragenerator, has since shown its merit in practice and is still deserving of consideration.

In this receiver the incoming ultra-high-frequency signal frequency is converted in the first detector (or mixer) to an appropriate low first intermediate frequency. This permits the immediate establishment of a desirable order of selectivity. The second detector, instead of giving audio-frequency output converts the i.f. signal to a very much higher frequency suited for thoroughly effective superregenerative action. This second high-intermediate frequency is tremendously amplified and its audio-frequency components made audible by the superregenerative 3rd detector. It is then amplified with the conventional audio-frequency tube. The receiver therefore consists primarily of three detectors operating on three widely separated frequencies and interconnected with nothing more than appropriate tuned circuits.

FUTURE DEVELOPMENTS

In describing these odd pieces of representative ultra-high-frequency receiving equipment, the idea has been to sketch the requirements for effective working. None of the apparatus can be considered as the ultimate. We would emphasize that the entire field of ultra-high-frequency working is in a state of flux. New developments are appearing frequently, and equipment which is now modern is likely to be superseded in the very early future.

World Radio History

CHAPTER TWELVE

ULTRA-HIGH-FREQUENCY TRANSMITTERS

Simple Circuits — Frequency Stability Considerations — Linear Oscillators — Short-Line-Controlled Oscillators — Oscillator-Amplifier Transmitters — Crystal Control

Transmitter practice on the ultra-high frequencies often differs considerably from that followed on the lower frequencies. Indeed, u.h.f. practice itself can be subdivided. One important reason for this is that most modern amateur transmitting tubes, while quite effective as amplifiers and oscillators in the 56-Mc. band, usually are rather poor performers at 112 Mc. and above. Coupled with the fact that in the 56–60-Mc. region the amateur regulations impose the same stability requirements as on the lower-frequency bands, this means that a rather sharp change in technique is characteristic on going from 56 Mc. to 112 Mc.

On 56-Mc., transmitter design principles are much the same as on the lower frequencies, with certain modifications made necessary by the very short wavelength. On 112 and 224 Mc., however, simple oscillator transmitters, usually with special u.h.f. tubes, are the order of the day. These "ultra-ultra-high" frequencies will be given first attention in this chapter. It must be realized that there is no settled mode of operation on these bands — new circuits and ideas are constantly in development, and the near future may see radical changes. The field is a promising one for the serious experimenter.

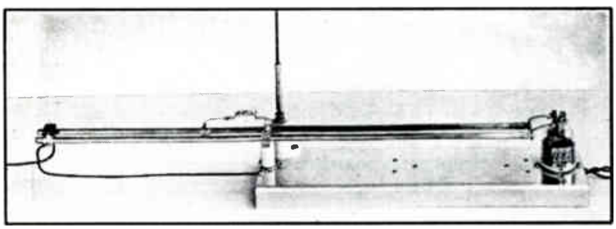


FIG. 1201 — THIS LOW-POWER TRANSMITTER ILLUSTRATES THE SIMPLICITY OF CONSTRUCTION ON THE 112- AND 224-MC. BANDS

The circuit diagram is given in Fig. 1204.

On the ultra-high frequencies the amateur has available the territory from 56 to 60 Mc., 112 to 118 Mc., 224 to 230 Mc., and also all the frequencies higher than 300 Mc.

In mentioning these bands we have so far adhered to the usual practice of stating the frequencies involved. This practice, however, is prone to be very inconvenient when speaking of and working with the ultra-high frequencies. Antennas, linear tuning rods, reflectors and directors are all to be measured in terms of wavelength and it is most inconvenient to be obliged to convert frequency to wavelength before proceeding with such measurements. Then, the most practical means of frequency determination on the ultra-high frequencies is by actually measuring the wavelength directly from a standing wave on wires as explained in Chapter Sixteen. It is obviously a handicap to be obliged to convert direct measurements so obtained back to frequency.

For these reasons we will find it desirable to make use of wavelength very frequently in this chapter and can only hope that the reader will find it reasonably simple to acquire the habit of thinking in terms of frequency and wavelength simultaneously.

The 56-Mc. band covers from 5.357 to 5 meters. The semi-harmonically related 112-Mc. band will be from 2.678 to 2.541 meters while the next band down — the 224-Mc. band — will be from 1.339 to 1.304 meters.

SIMPLE OSCILLATOR CIRCUITS

Four circuits which have stood the test of time are given in Fig. 1202. They are by no means the only possible u.h.f. oscillator circuits but they may be considered the standard ones. That shown at

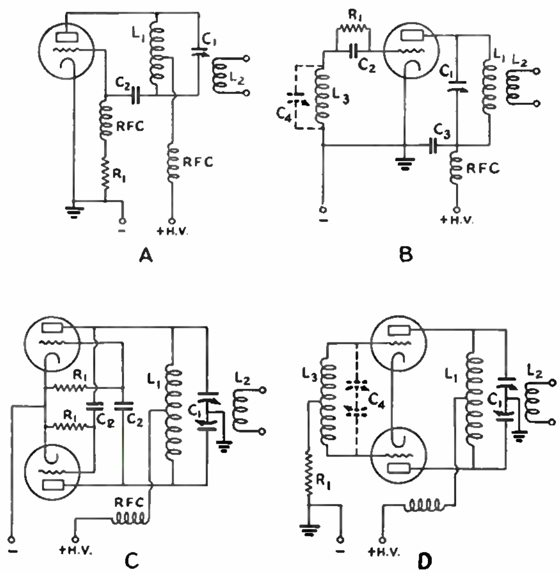


FIG. 1202 — FOUR STANDARD OSCILLATOR CIRCUITS FOR U.H.F. WORK

These arrangements are all subject to frequency modulation when modulated directly but are still valued for special applications.

Typical values for the various components (subject, of course, to considerable variation) follow:

C_1 — 15 $\mu\mu$fd. maximum capacity (30 $\mu\mu$fd. per section of the split-stator condensers).
C_2 — 100 $\mu\mu$fd.
C_3 — 500 $\mu\mu$fd.
C_4 — 15 $\mu\mu$fd.
L_1 — 2 or 3 turns of No. 12 wire or small copper tubing 2 inches in diameter. The size depends considerably on the type of tube or tubes used.
L_2 — 1 or 2 turns of similar diameter to L_1.
L_3 — Same as L_1 if tuned. Approximately 10 turns of No. 16 wire if untuned. In this case the size is greatly dependent upon the type of tube used and it will be essential to vary the turn spacing and possibly the number of turns until the oscillator plate current (unloaded) is lowest at the desired frequency.
R_1 — Between 5000 and 50,000 ohms depending on the tube and plate voltage used.
RFC — Approximately 30 turns of No. 30 wire on a ¼-inch former. Most of the standard r.f. chokes are perfectly satisfactory.

"A" is a Colpitts circuit of extreme simplicity. The tuned circuit is connected between grid and plate of the tube with a fixed condenser serving the double purpose of grid condenser and plate blocking condenser. The circuit at "B" is the popular tuned-grid tuned-plate. The grid tuning condenser is often omitted — the grid coil turns being adjusted in number and spacing until the desired resonant frequency is obtained.

Circuit "C" is a useful push-pull circuit when a considerable frequency range must be covered with a single tuning adjustment. The tuned-grid tuned-plate arrangement at "D" is a push-pull version of "B." This particular circuit probably enjoys the greatest popularity of all.

These four circuits and all others similar to them are suited only for the pure c.w. work in the 56- to 60-Mc. band, where with careful adjustment and a well-filtered d.c. plate supply they can be made to comply satisfactorily with the F.C.C. regulations. They are not suitable for modulated transmission on this band, however. They could be used on 112 Mc. with special u.h.f. tubes, but at this and still higher frequencies the necessary inductances would be of such small values as to be almost non-existent. For the very high frequencies it is usually far better to use linear tank circuits in the manner to be described.

Frequency Modulation

Any simple oscillators of the type described have a very low order of frequency stability. When modulation is applied the output frequency will change in accordance with the modulation voltage and, as a result, the signal will sweep across a wide band of frequencies. Such circuits are therefore not recommended for u.h.f. 'phone communication except in instances where circumstances demand that the gear should be as compact and light in weight as possible. Used with any appreciable amount of power in populous areas they are the curse of the ultra-high frequencies. On the 56-Mc. band their use is effectively prohibited because of their inability to comply with the regulation governing elimination of frequency modulation.

LINEAR OSCILLATOR CIRCUITS

INSTEAD of using lumped inductance and capacity in the tank circuits of u.h.f. oscillators it is possible and often very desirable to use resonant linear circuits consisting of copper pipes or rods adjusted to have an electrical length of some multiple of a quarter wave. Such linear tanks are very simple to build and adjust and usually result in higher operating efficiency. At the outset it should be realized that while a simple resonant line, unconnected to anything else, will have a physical length almost exactly equal to a quarter wave or its multiple, this will no longer hold when the elements of a tube or tubes are connected to it. The same applies to the Q of the circuit. The line itself may have an exceedingly high Q and may appear to be capable of producing a high order of frequency stability. The connection of a tube or tubes across the open end, however immediately results in a serious reduction of

World Radio History

the effective Q. It is with the idea of reducing this effect that the tubes are connected down toward the shorted end of the line in circuits where the line is expected to do an effective job of frequency control. Such circuits will be discussed later.

In Fig. 1203 are shown three typical linear oscillators, very simple in construction and eminently suited for experiment on frequencies of 112 Mc. and above. As we have already indicated, these circuits give slightly better frequency stability than the simple circuits with coils and condensers but are still subject to serious frequency modulation.

The circuit at "A" is perhaps the simplest form of linear oscillator. The line in this case is slightly less than a quarter wave long (its actual length depending on the loading effect of the tube) the supply leads being connected at the voltage node point and the tube elements at the "hot" ends. The filament chokes are usually, but not always, necessary. Circuit "B" is made somewhat more effective and convenient by using a half-wave line with the tube connected at one end. It will be noticed that the node does not come in the physical center of the line because of the loading effect of the tube on the quarter-wave portion to which it is connected. In adjusting the circuit the supply leads may be connected near the center and then adjusted until they can be touched with an insulated screw driver without change in the plate current. A neon bulb could also be used to find the node if sufficient power is available to light it at off-center points.

Circuit "C" is a logical development of "B" for push-pull operation. In this case the line itself is symmetrical.

Several methods of coupling the antenna to these transmitters are available. At "A" a single-wire feeder is suggested. An alternative would be to use a "hair-pin" shaped antenna "coil" inductively coupled near the node end of the line. The other two circuits lend themselves to the use of a two-wire transmission line connected across a section of the line near the node. The spacing of the clips on the line is varied to give the desired order of coupling. The simplicity of the resonant-line type transmitters is illustrated by the low-power unit shown in Fig. 1201. The circuit diagram is that of Fig. 1204. It is intended for operation on the 112- and 224-Mc. bands.

The tube used is the HY-615 high-frequency triode, which has extremely short internal leads and is rated at a power input of five watts.

Fig. 1201 shows how the various components are located and mounted on the 3-by-12-by-

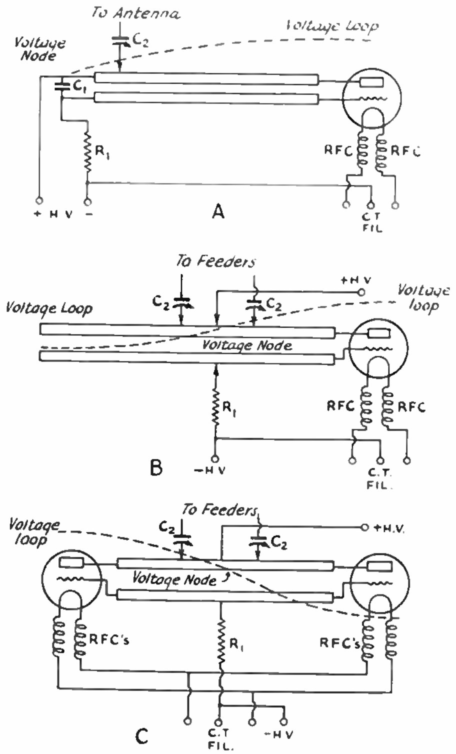


FIG. 1203 — THREE LINEAR OSCILLATOR CIRCUITS SUITABLE FOR EXPERIMENT, PARTICULARLY ON THE BANDS ABOVE 60 MC.

The applications of these circuits and their adjustment are matters treated in the text. Suitable conductors for the lines are ½-inch diameter copper pipes but larger and smaller sizes are also suitable. The spacing between centers should be approximately four times the radius of the pipes. A satisfactory value for C_1 is 500 $\mu\mu$fd., C_2 being the usual feeder condenser of 35 or 50 $\mu\mu$fd. R_1 will be between 5000 and 50,000 ohms depending on the type of tubes used. The filament chokes should be approximately 25 turns of No. 14 wire ⅝-inch diameter with the turns spaced the wire diameter. Tuned lines are desirable in their place when operation on the very high n.h. frequencies is desired.

Almost any of the usual triodes will serve in these circuits on 112 Mc. The low-capacity tubes are almost essential for operation on higher frequencies.

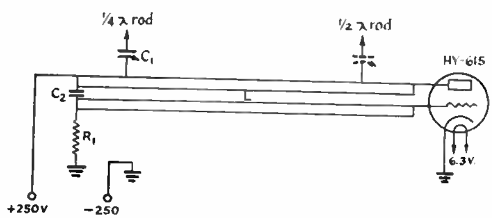


FIG. 1204 — CIRCUIT OF THE LOW-POWER OSCILLATOR SHOWN IN FIG. 1201

C_1 — 30-$\mu\mu$fd. isolantite-insulated compression-type trimmer.
C_2 — 100-$\mu\mu$fd. midget mica.
R_1 — 50,000 to 75,000 ohms, ½-watt.
L — Linear tank circuit; see text.

World Radio History

1-inch chassis. The only hidden part is the grid-leak resistor, R_1, mounted beneath the chassis between the common ground point and one of the spare tube-socket prongs. The line is made from ¼-inch diameter, soft-drawn copper tubing and is 20 inches long. The spacing between tubes is approximately ¼ inch. A standoff insulator at the left end of the base is the main support for the line. At the opposite end, support is furnished by the heavy wire used to make contact between the open ends of the line and the tube caps.

C_2, the mica condenser across the low-potential line, is held in place by two metal-tube grid-clips. This condenser isolates the grid circuit from the plate voltage. The grid clips act not only as the condenser support but also permit sliding the condenser along the line, thus furnishing a means of frequency variation.

The picture shows one method of antenna coupling, this particular setup being used in connection with a quarter-wave rod antenna (26 inches for the 112-Mc. band). The rod plugs into the jack-top insulator and is capacity coupled to the plate rod through C_1. An antenna of this type readily will load the oscillator to the maximum plate-current value of 20 ma. for the tube. Incidentally, the no-load plate current should be 6 to 8 ma. at 250 volts. This type of antenna should be coupled near

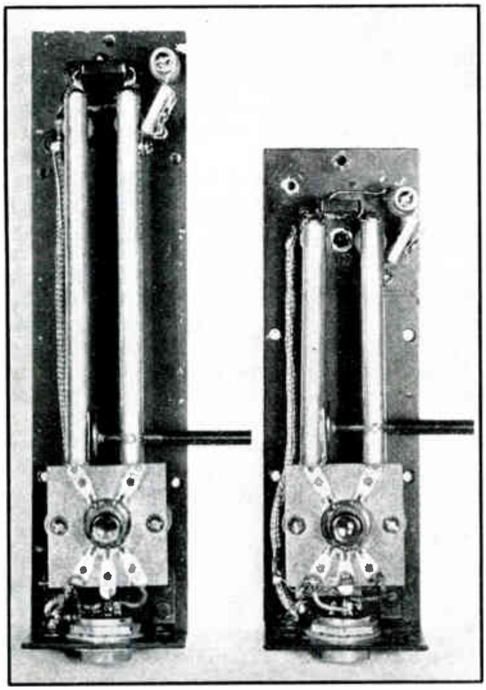


FIG. 1205 — TYPICAL RESONANT-LINE OSCILLATORS

Both use 955 acorn tubes for portable work. The oscillator at the left is tuned approximately to 200 Mc.; that at the right to 300 Mc. Power connections are plugged into 4-prong sockets at the bottoms of each unit (W9YNJ, March, 1938, *QST*.)

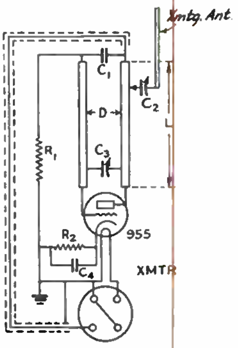


FIG. 1206 — CIRCUIT DIAGRAM OF THE ACORN RESONANT-LINE OSCILLATORS

C_1 — 100-μμfd. (Cornell-Dubilier with low-loss case).
C_2 — 30-μμfd. padder (National M-30).
C_3 — Tuning condenser. (See text and photos.)
C_4 — 0.01-μfd. paper.
L — ⅜-inch brass rods, length 3¾ inches for 300 Mc., 5 inches for 224 Mc., spaced ¾ inch.
R_1 — 5000 ohms, ½-watt.
R_2 — 450 ohms, 1-watt.

the shorted end of the line. A grid-clip, as a sliding contact, affords an easy form of coupling adjustment. The approximate position of the tap will be 6 inches in from the shorted end.

If a half-wave rod is used as the radiator, it should be coupled close to the open end of the plate rod. A third type of antenna would be one coupled to the shorted end of the line through a hairpin link of the type shown later in this chapter.

For work on the 224-Mc. band the condenser "bridge" is placed approximately at the center of the line. The frequency may be checked by the Lecher wire method as explained in Chapter Sixteen.

Fig. 1205 shows typical linear oscillators using acorn tubes, which are excellent for "pack" transmitters, intended to be carried while in operation, since the battery drain is quite small and therefore can be supplied by light-weight "A" and "B" batteries. The circuit is given in Fig. 1206. The frequency can be changed by means of the condenser at the tube end of the line; this is simply two small discs, one soldered to a machine screw so that the spacing can be varied, and fitted with a bakelite-rod extension handle. The antenna-coupling condenser, an isolantite-mounted compression-type trimmer, is in the upper right-hand corner of each unit. The coupling point is correct for a quarter-wave rod antenna.

World Radio History

The Filament Circuit

It will be noticed that in the circuits of Fig. 1203 chokes are included in the filament leads. These are made necessary on very high frequencies, with filament-type tubes, by the fact that the filament and its leads within the tube are often a considerable portion of a wavelength and so prevent normal circuit operation. Chokes, as suggested, provide one solution. Another scheme — the preferred one — is to use a tuned line in the filament circuit, adjusting its length so that the electrical length of the line plus the filaments is a half wave. Fig. 1207 shows a typical arrangement for a push-pull oscillator. The pipes constitute one side of the filament circuit, the wires threaded through them being the other. The jumper is adjusted, just as soon as the circuit is oscillating, to give minimum plate current.

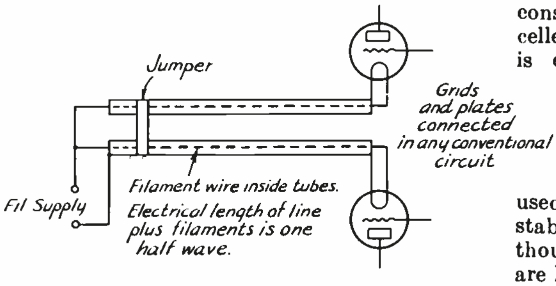


FIG. 1207 — ILLUSTRATING THE USE OF A HALF-WAVE LINE IN THE FILAMENT CIRCUIT OF THE U.H.F. OSCILLATOR

Copper tubing of ¼- or ½-inch diameter would serve for the line, the inner conductor being any heavy insulated wire.

In the single-ended oscillator it is often convenient to use a separate concentric line in each filament lead.

SHORT LINE CONTROL

In the circuits just discussed, somewhat improved stability is made possible by the use of resonant-line or linear circuits. However, since the tube or tubes in the circuit are attached to the free end of the line, the Q of the complete circuit is considerably less than that of the line by itself. A large family of circuits has been devised in which a very high-Q line is used as the frequency-controlling element, so connected into the tube circuit as to avoid any really serious reduction in effectiveness.

The basis of the scheme can best be explained by comparing it with crystal control. In the normal crystal oscillator, the grid circuit consists of the crystal itself, serving as the frequency controlling element. In the short-line controlled oscillator, the crystal is displaced by a high-Q resonant line along which the grid or grids of the oscillator tube or tubes are tapped. The grid connection is made as near to the voltage node of the line as possible, in order to reduce the influence of variations in the tube circuit on the characteristics on the line. Circuits of this general type are quite simple in construction and are capable of providing excellent frequency stability when the line itself is correctly designed. Assuming that the optimum spacing is used between the conductors of the line, the Q of the line is proportional to the diameter of the conductor used. In many commercial installations lines of 18-inch diameter or more are used to the tune of a very high Q and excellent stability. Tubing of such dimensions is, though, quite expensive, and most amateurs are limited to sizes of 3 or 4 inches. Such lines do not provide the highest possible order of stability, but allow quite a tremendous improvement over oscillators not fitted with this type of frequency control.

Constructing Resonant Lines

The lines used for frequency control are of two general types. First there is the open line, consisting of two parallel copper pipes connected together with a heavy jumper at one end and open at the other. The length of the line from jumper to open end is slightly less than a quarter wave — it would be exactly a quarter wave if it were not for the loading offered by the capacity of the vacuum-tube elements.

The second and much more effective type of line is of the concentric type, a small copper pipe or rod being mounted inside a larger pipe and the two connected together at one end. The usual practice is to make the outer conductor slightly longer than a quarter wave and the inner line considerably shorter. A sliding sleeve over the inner conductor is then used to vary its length and so to tune the circuit. In its original form, this line is rather difficult to handle in practice since free access to the inner conductor cannot be had. Further, large diameter copper tubing or pipe is quite expensive. Both of the problems have been solved in a design for the concentric line suggested by Paul Zottu and detailed in *QST* for September, 1936. In this design the inner conductor is the usual rod or pipe but the outer element is a square-section trough of folded sheet copper. The inner conductor is, of course, readily available for adjustment through the open side of the trough. The use of a square section for the outer conductor and opening one of its sides does not measurably affect the performance.

Line Spacing

In determining the spacing of the conductors in both the open and concentric resonant

World Radio History

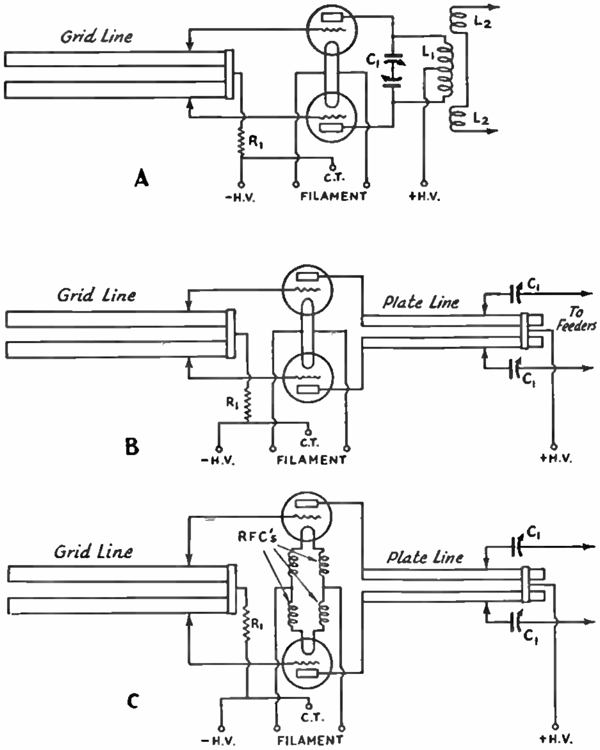


FIG. 1208 — THREE BASIC CIRCUITS FOR THE SHORT-LINE-CONTROLLED OSCILLATOR

The pipes in the grid circuit play the major part in providing frequency stability and the greater their diameter the better. They should be of hard-drawn copper and particular attention should be given to the method of making contact between them at the shorted end.

L_1 — One turn of ⅛-inch copper tubing, turns 2 inches diameter for 112 Mc. Actual coil size will depend greatly on type of tubes used, arrangement of wiring and type of tuning condenser.

L_2 — Each a single turn 2 inches in diameter. They must be wound so that the two turns, though separated, are in the same direction.

C_1 — at "A" — split-stator condenser of voltage rating to suit supply used. 15 to 35 μμfd. total effective capacity suitable.

C_1 — at "B" and "C" — 15 to 75 μμfd. receiving type condensers. The smaller order of capacity suitable for the highest frequency bands.

R_1 — 10,000 to 50,000 ohms depending on type of tubes used.

RFC — Approximately 15 turns of No. 14 wire ½-inch inside diameter for 112 Mc. Seven similar turns of 224 Mc. Careful adjustment of these chokes in each individual layout is usually necessary. Allowance must be made for the filament voltage drop in these chokes, especially when the more powerful tubes are used.

It is as well to start out with the grid line a full quarter-wave long, then moving up the bridge and adjusting grid taps until desired frequency is reached. One quarter-wave is approximately two feet for 112-Mc. band and one foot for 224-Mc. band. The plate lines will be considerably shorter because of the loading effect of the tubes. The same full quarter-wave might well be used at the start, however.

lines, the following ratio should be observed

$$\frac{b}{a} = 3.6$$

when

b=inner radius of outer conductor in concentric lines, or the spacing between tube centers in open lines.

a=outer radius of inner conductor in concentric lines, or the tube radius in an open line.

This figure of 3.6 is, in practice, not extremely critical. Practical considerations will often require using a figure nearer 3 or 4. In the case of the open line this is the equivalent of saying that the pipes should be spaced slightly less than their own diameter.

In the trough-type line it is sufficient to consider the side dimension as the diameter in the above relationship.

PRACTICAL OPEN-LINE CIRCUITS

FIG. 1208 illustrates three practical arrangements of push-pull oscillators employing short-line frequency control with open-type lines. The controlling element, marked "grid line" on the diagram, consists of a pair of copper pipes slightly less than a quarter wavelength long and with the pipes spaced approximately their own diameter. The bridge across the voltage-node end of the line must be given careful consideration. At this point very large r.f. currents are flowing and it is readily possible to destroy the effectiveness of the line if poor electrical contact exists at this point. For experimental work this bridge may consist of copper strips clamped in place with machine screws (to permit adjustment of the effective length of the line) but a much more satisfactory scheme for the permanent transmitter is to solder or braze the pipes at this point into a copper plate, then providing sliding extension pieces in the free ends of the pipes to allow adjustment of the length.

In setting up the type of transmitter shown in "A" of Fig. 1208, it is as well to start out with the resonant line a full quarter-wave long. Then, with the grid connected about one-third the line length from the shorted end, the plate tank is tuned until the plate current takes a sharp drop — indicating oscillation. The bridge on the line and the grid taps are then varied until oscillation is obtained at the desired frequency with the lowest possible value of plate current. The oscillator is then coupled to the antenna circuit in the usual manner. The closer

World Radio History

the grid taps approach the bridge the greater will be the stability and the longer will the line be for a given frequency. High stability can only be obtained by very careful adjustment of these grid taps.

Considerable improvement in the overall efficiency of this type transmitter can be obtained by replacing the conventional plate tank with a second resonant line. In this case, it is usually convenient to connect the plates directly to the free end of the line, then coupling the antenna to the bridge end of the line. The antenna may be coupled in the manner shown in Fig. 1208 at "B" and "C" or it may be coupled inductively with a "hairpin" antenna coil such as that illustrated in Fig. 1209.

This type of circuit will usually operate satisfactorily on the 56-Mc. band without any attention being given to the filament circuit. However, on the higher frequency bands it will usually be found necessary to include chokes in the filament lead in the manner indicated at "C" of Fig. 1208. A still better scheme, to be detailed later, is to use a tuned line in the filament circuit so adjusted that the electrical length of the path from the center of the filament to the grounded end of the line is a half wave.

It will be noted that in all these circuits the grids are tapped on the grid line down toward the closed end of the line. This procedure has a definite influence on the performance of the line as a stabilizing device and care must be taken to make the grid connections as near to the closed end of the line as is consistent with reasonable efficiency in the oscillator.

The chief limitation of these circuits is in the open type of line used. Radiation losses make it difficult to obtain a very high Q even when pipes two or three inches in diameter are used. Hence when excellent frequency stability is hoped for it is better to use the closed or concentric type of line. The construction of lines of this type has already been discussed.

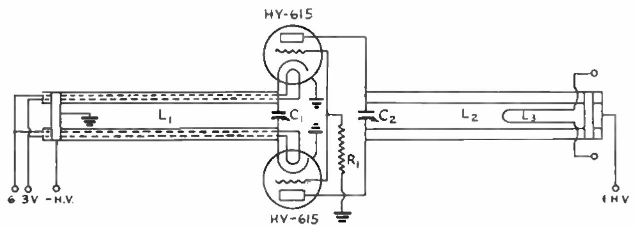


FIG. 1210 — CIRCUIT DIAGRAM OF THE LOW-POWER TUNED-PLATE TUNED-FILAMENT OSCILLATOR

C_1 — 15-μμfd. variable (National UM-15).
C_2 — See text.
R_1 — 20,000 ohms, 1-watt.
L_1 — Filament line, ¼-inch o.d. copper tubing, length 10 inches, spacing ⅝ inch.
L_2 — Plate line; for 112 Mc., 7/16-inch o.d. copper tubing, length 14 inches; spacing diameter of tubing; for 224 Mc., ¼-inch o.d. copper tubing, length 6 inches, spacing diameter of tubing.
L_3 — Hairpin link for antenna coupling; length approximately 4½ inches.

A LOW-POWER RESONANT-LINE OSCILLATOR

A LOW-POWER oscillator using linear tank circuits is shown in Fig. 1210. This might be called a "tuned-plate tuned-filament" oscillator, since it employs tuned lines in both the plate and filament circuits. It gives good stability and an unusually high order of efficiency for u.h.f. oscillators.

Photographs of the transmitter using this circuit are shown in Figs. 1209 and 1211. The push-pull HY-615 tubes are capable of about five watts output at 2½ meters and somewhat less at 1¼ meters.

The aluminum chassis measures 3¼ by 16 by 1½ inches; at one end are the tube sockets, mounted with the filament prongs facing the front edge. A soldering lug is placed under one of the socket mounting screws so that all grounds at this end of the chassis may be made to this one point.

The top view, Fig. 1209, shows the tubes mounted closely together at the left with the tuned plate line extending to the right. A home-made condenser across the tube end of the pipes permits adjusting the frequency over a fairly large range. The grids, which should be as nearly as possible at zero r.f. potential, are tied together and grounded to the chassis through the

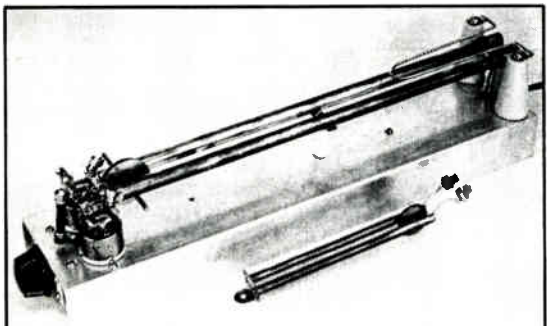


FIG. 1209 — A LOW-POWER TUNED-PLATE TUNED-FILAMENT OSCILLATOR

For operation on 112 and 224 Mc. The small line in front is for 224 Mc.

World Radio History

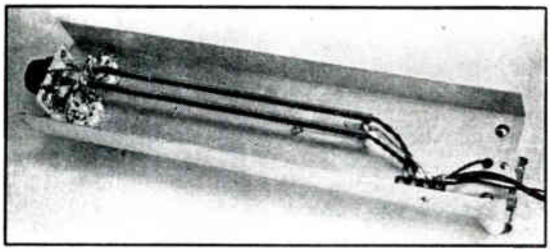


FIG. 1211 — FILAMENT-CIRCUIT VIEW OF THE LOW-POWER PUSH-PULL OSCILLATOR

The tuned filament line is grounded at one end and soldered directly to the cathode prongs of the tube sockets at the other. Filament leads run inside the tubes.

grid leak, R_1. The antenna link is mounted on two standoff insulators at the right end of the base.

The plate-pipe assembly is supported by standoff insulators, the center of the pipes resting on one and the shorted end of the line on the other (between the two cones). Plate voltage is fed through a hole in the chassis to this latter point. The stand-offs are of sufficient height to permit the shortest possible connections between the line and the tube plates. A strip of the best obtainable r.f. insulating material should be used as the spacer and mounting support across the center of the line.

The plate tuning condenser is made from two 1½-inch diameter copper discs, to each of which is soldered a machine screw. The pipes are drilled and tapped so that one plate can be mounted on each pipe.

Construction of the 1¼-meter line may be similar, but the light weight of the line suggests that only one supporting insulator be used. This may be accomplished by soldering a right-angle bracket to the shorted end of the line and attaching the assembly to the insulator used to support the center of the 112-Mc. pipes. The condenser plates for this frequency are 1 inch in diameter.

Beneath the chassis is the tuned cathode circuit, connected to the cathode prongs of the tube sockets by short lengths of No. 12 wire. The pipes are shorted and grounded to the chassis at the far end. C_1, the tuning condenser, is insulated from the chassis and connected directly across the open end of the line. Each tube has a separate set of twisted pair filament leads running through its cathode pipe; they are connected in parallel for the heater power, of course.

In tuning to the 2½-meter band, first set the plate condenser C_2 so that the spacing between plates is approximately 3/16 inch. Then apply power and rotate the filament condenser, C_1, until oscillation starts, indicated by a drop in plate current. The oscillating plate current should be about 20 ma., rising, when the antenna is coupled, to about 40 ma. A reliable frequency checking system should then be used to make sure that the transmitter is tuned to the desired frequency. The frequency is lowered by increasing the plate condenser capacity and retuning the filament circuit. Decreasing the plate capacity increases the frequency.

For 1¼-meter operation, in addition to replacing the larger plate pipes by smaller ones, a section of the cathode line may be shorted by a metal slider, the position of which should be adjusted so that C_1 is effective in tuning. It should, however, be possible to find resonance on this band simply by tuning C_1 carefully in the region near minimum capacity, since the line is rather short for 2½ meters.

HIGH-POWER TUNED-PLATE TUNED-FILAMENT TRANSMITTER

Figs. 1212 to 1214 show the construction and circuit of a second tuned-plate tuned-filament 2½-meter transmitter. This set has much in common with the one just described, but conventional tubes of the medium-power class are employed. Fundamentally the circuit of Fig. 1213 is the same as that of Fig. 1210, with slight changes made necessary by the directly heated type of tube used. This arrangement, even with conventional tubes, operates with an efficiency of better than 50 per cent.

A glance at Fig. 1212 will show the arrangement of the plate circuit, supported on top of the chassis. The chassis is 4½ inches wide, 15 inches long and 2½ inches deep. There is no

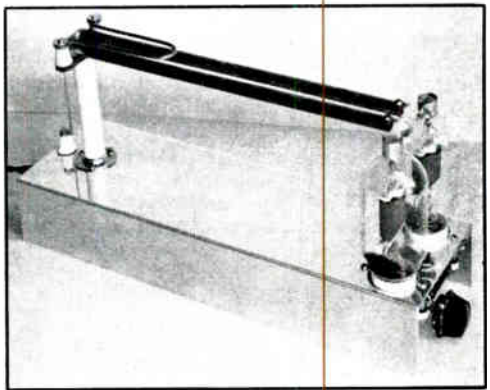


FIG. 1212 — THIS TRANSMITTER OPERATES EFFICIENTLY WITH CONVENTIONAL TUBES AT 224 MC.

To reduce losses, the plate lines are not condenser tuned. A slider is used for frequency adjustment. The hairpin coupling link is at the left.

World Radio History

tuning condenser for the plate line; a condenser may be used, if desired, but for best efficiency it should be omitted. The line is relatively short for the frequency, the reason being that the internal tube leads make a considerable addition to the actual length of the line, plus the loading effect of the tube plate-grid capacity.

The high-voltage connection, brought through an insulator in the chassis, is shown just to the left of the supporting insulator in Fig. 1212. The antenna-coupling link, L_3, is made from small-diameter copper tubing; its length should be adjusted to give the desired loading, with the antenna used.

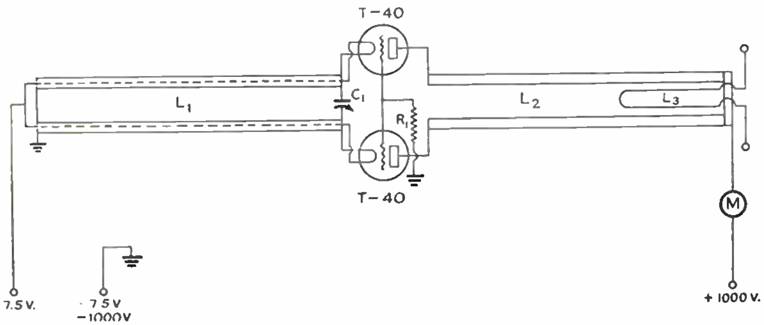


FIG. 1213 — CIRCUIT DIAGRAM OF THE MEDIUM-POWER 112-MC. OSCILLATOR

C_1 — 15-μμfd. variable.
R_1 — 5000 ohms, 10-watt.
L_1, L_2 — Filament and plate lines; 7/16-inch o.d. copper tubing, length 12 inches, spaced diameter of tubing.
L_3 — Hairpin link for antenna coupling; length approximately 3 inches.

Fig. 1214 is a view of the tuned filament circuit underneath the chassis. Each pipe is soldered to and partly supported by a filament prong on each tube socket. The shorted end of the line is held in place by a metal pillar which also makes the connection to the chassis ground. A wire is fed through each pipe and connected to the other filament prong on the appropriate socket. These wires are connected together at the shorted end and filament voltage applied between this common connection and ground.

C_1, the filament-line tuning condenser, rests on the insulated portions of the sockets and is securely mounted by two small aluminum brackets which fit under the socket mounting screws. Care must be taken to prevent grounding of the condenser plates. A short connection is made between the two grid prongs, and the grid resistor, R_1, runs from the center of this connection to ground.

Tuning is similar to that already described for the low-power transmitter. The setting of C_1 which gives minimum plate current is not, however, the adjustment at which the circuit delivers maximum output. A lamp dummy antenna coupled to the pipes will show that as the condenser setting is slightly altered the plate current will rise and the output will increase. The current should not be allowed to exceed 200 ma. at full load.

Other tubes than the T-40's shown have been used successfully in this circuit, including Types 809, T-20, RK-11, RK-12, and TZ-40. Still others of similar construction and ratings undoubtedly also would function satisfactorily.

CONCENTRIC-LINE-CONTROLLED TRANSMITTERS

Fig. 1215 shows a simple circuit in which a concentric line is used in the grid circuit. The drawing itself shows the various components well separated, but in the actual transmitter the tube would be located immediately alongside the line to allow short leads from the grid to the inner conductor and from the filament circuit through C_2 to the outer conductor. It is very important, also, that the plate tank be so mounted that the return path through C_3 is short. In this particular circuit the plate tank is self-resonant — the turn spacing in the relatively large coil used being varied until minimum plate current is had at the desired frequency (with the oscillator unloaded). While a cylindrical line is indicated on this diagram, it is obviously possible to replace it with the trough type of line.

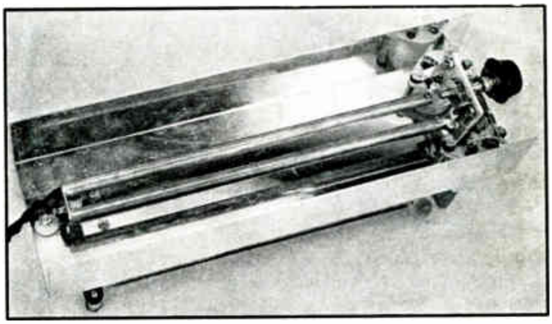


FIG. 1214 — BELOW-CHASSIS VIEW OF THE MEDIUM-POWER OSCILLATOR

The arrangement is described in the text.

World Radio History

Fig 1217 shows an alternative circuit of the same general type. In this case, the filament and plate circuits are by-passed directly to the outer conductor, the gridleak being connected between the negative high-voltage lead and ground. It is the circuit used in the 224-Mc. transmitter illustrated in Fig. 1216 In this "trough line" oscillator the filament circuit is by-passed to the wall of the line by two 1-inch by 1½-inch copper strips which serve also as the supports for the tubes. These strips are insulated from the wall of the line with thin mica. The plate by-pass condenser is treated in similar fashion and consists of a 1- by 2-inch copper strip mounted on the upper surface of the line. The plate circuit consists of a "hairpin" of No. 14 bare wire about 3 inches long and 1 inch wide. It is supported from the plate terminal of the tube by an appropriately drilled and tapped section of ¼-inch square brass rod.

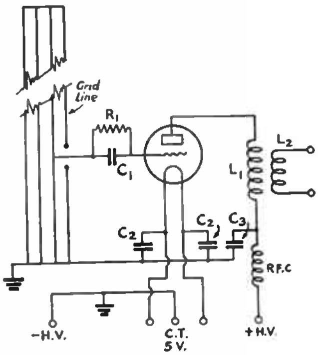


FIG. 1215 — THE CIRCUIT OF A CONCENTRIC-LINE-CONTROLLED TRANSMITTER

C_1 — 100-μμfd. receiving type condenser.
C_2 — 500-μμfd. receiving type condensers.
C_3 — 500-μμfd. high-voltage condenser.
R_1 — 10,000 to 50,000 ohms depending on tube used.
L_1 — Size will depend greatly on tube used and careful adjustment of turn spacing will be essential.
L_2 — Two turns of similar diameter to L_1.

The concentric line may be built either of copper tubing or folded from copper sheet into a trough-type line. The inner conductor will be a few inches less than 2 feet long for 112 Mc.

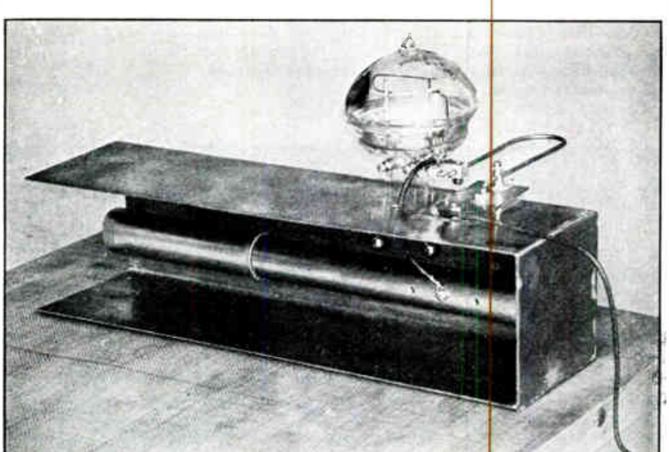
The line itself is made of fairly heavy copper sheet folded to form a trough 2½ inches wide and 2¾ inches high. The end plate is soldered into position and the inner conductor, of ¾-inch outside diameter copper pipe, is soldered to it. The trough, for 1¼-meter operation, should be approximately 10 inches long. The inner conductor is only 8 inches long but is fitted with an extension piece of rolled copper sheet at the free end. This extension piece, about 3½ inches long, permits adjustment of the resonant frequency of the grid circuit. The grid is tapped about ¼ the length of the inner conductor from its closed end.

Adjustment of this transmitter is the acme of simplicity. The tube will oscillate with a wide range of plate circuit adjustments and it is merely necessary to vary the length of wire in the plate circuit until the plate current, with the oscillator unloaded, is a minimum at the desired operating frequency. The frequency is adjusted, of course, by variation of the position of the extension piece on the inner conductor of the line.

This type of circuit is equally suitable for use in transmitters using other types of tubes and operating on lower frequencies. The special by-pass condensers used in the 224-Mc. transmitter could be replaced with conventional fixed condensers when the circuit is used on the lower frequencies. Also, the "hairpin" tank circuit could be replaced with a conventional coil and condenser for 2½-meter operation.

FIG. 1216 — A CONCENTRIC-LINE-CONTROLLED TRANSMITTER USING THE TROUGH-TYPE LINE AND THE W.E.316-A TUBE

The reasonant line serves as the chassis for the transmitter with the tube mounted to it by means of the filament by-pass condensers. This same method of assembly might well be used on the lower frequencies in transmitters using other types of tubes.



World Radio History

The plate tank should be mounted close to the resonant line so that by-passing may be accomplished without any long leads.

CRYSTAL-CONTROLLED TRANSMITTERS

IMPROVEMENTS in tube and circuit design and the constant demand for absolute freedom from frequency modulation on the ultra-high frequencies have led to the development of thoroughly practical crystal-controlled transmitters for the 56–60-Mc. band. These transmitters are more complex than the types already described but their performance is, of course, incomparably better.

Since the crystal-controlled transmitters follow so closely the general principles discussed for lower frequency working in Chapter Eight, no attempt will be made to describe them in full detail at this point. Their planning. construction and adjustment comprise an extension of the technique developed for the lower frequencies. Amateurs unfamiliar with that technique would be ill-advised to dive headlong into the complex field of crystal control on the ultra-high frequencies.

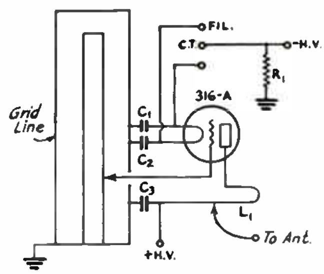


FIG. 1217 — THE CIRCUIT OF THE TROUGH-LINE CONTROLLED TRANSMITTER

L_1 — Hairpin-shaped loop of No. 14 bare wire 3¼ inches long and 1 inch wide.
$C_{1,2}$ — Filament by-pass condensers made of copper strip, see text.
C_3 — Plate by-pass condenser made in similar fashion.
R_1 — 30,000-ohm 10-watt resistor.

The outer conductor of the grid line is one quarter-wave long (about 12 inches at 1¼ meters). The inner conductor is 8 inches long and fitted with a sliding extension piece made of copper sheet rolled into tube form.

The antenna used with this experimental transmitter is a half-wave affair with a single wire transmission line connected to the antenna terminal shown on the diagram. This antenna is set up and adjusted in accordance with the principles explained in Chapter Thirteen.

In Figs. 1218 and 1219 are shown a typical low-powered crystal-controlled transmitter using receiving-type tubes but capable of an output of 10 to 15 watts. The similarity between this and conventional circuits used on the lower frequencies will be seen at once. In this arrangement, the first section of a 6A6 serves as the crystal oscillator on 14 Mc., while the second section doubles to the 28-Mc. band. The following 6L6 doubles to the 56-Mc.band and drives the final 6L6. The transmitter is normally operated with 300 volts on the 6A6 and the 6L6 doubler, these tubes taking 60 and 40 ma. respectively. The final tube is supplied with 400 volts, the plate current under load being 80 ma. These values are all rather high for u.h.f. operation, but in cases where the tubes are relatively inexpensive and where a long tube life is not demanded, it is often convenient to run tubes slightly beyond their normal ratings.

It will be noted that two meters are provided to adjust the transmitter. The 100-ma. meter may be plugged in to read the plate current of any one of the three tubes, while the second meter, of 25-ma. range, is permanently connected in the grid circuit of the final amplifier. The 6L6, like most pentodes, is rather critical as to its excitation requirements. If it is driven too hard, the output falls off, and too little excitation will cause downward modulation. A happy compromise in this transmitter seems to come at a d.c. grid current of 4 or 5 ma.

This transmitter was described in detail by W2IP in *QST*, March, 1937.

An alternative arrangement of receiving

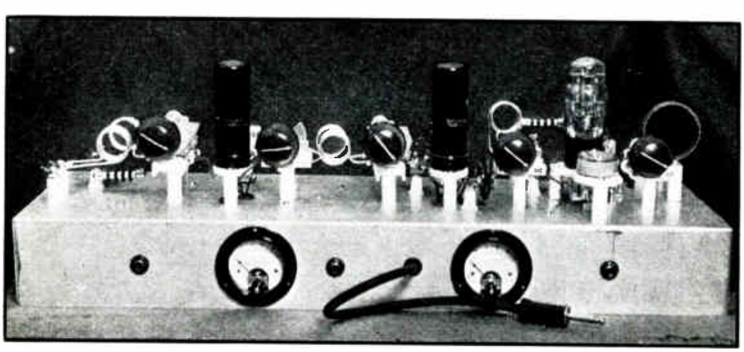


FIG. 1218 — A SIMPLE CRYSTAL-CONTROLLED U.H.F. TRANSMITTER USING RECEIVING TUBES

World Radio History

tubes in a crystal-controlled u.h.f. transmitter is that shown in Fig. 1220. In this rig the second doubler stage is a 6A6 with the sections arranged as a push-push doubler — the grid circuit being push-pull and the plates being con- a combination 14-Mc. crystal oscillator and 28-Mc. doubler. It is followed by a 6L6 56-Mc. doubler, which drives push-pull 807's on the same frequency. The output of this unit is amplified by the push-pull 35T's shown sche-

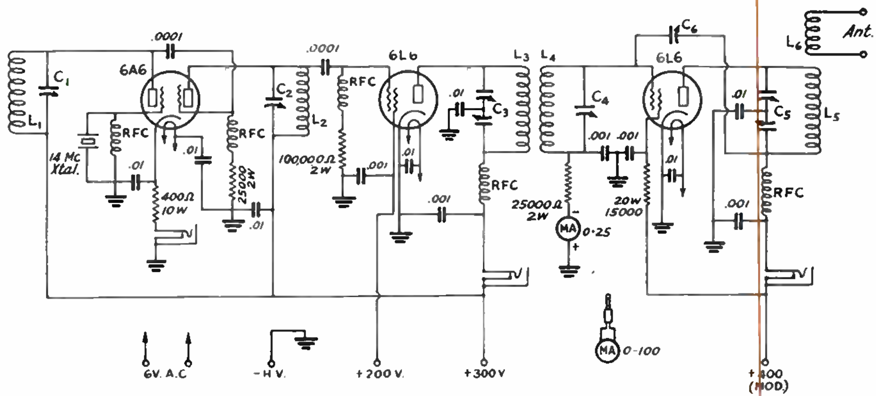


FIG. 1219 — THE R.F. CIRCUIT OF THE SIMPLE CRYSTAL-CONTROLLED TRANSMITTER

L_1 — 5 turns No. 16 d.s.c. wire, spaced diameter of wire, on celluloid coil form 2 inches in diameter.
L_2 — 7 turns No. 12 bare copper wire, 1-inch diameter.
L_3 — 5 turns, same as L_1.
L_4 — 3 turns, same as L_1.
L_5 — 5 turns, same as L_1.
L_6 — 4 turns, same as L_1.
C_1 — 100 $\mu\mu$fd. (Hammarlund MC 100S).
C_2 — 50 $\mu\mu$fd. (Hammarlund MC 50S).
C_3 and C_5 — 35 $\mu\mu$fd. each section (Hammarlund MCD 35X).
C_4 — 20 $\mu\mu$fd. (Hammarlund MC 20S).
C_6 — 5 $\mu\mu$fd. (Cardwell ZV5TS).
RFC — 2.5-millihenry r.f. choke (National Type 100).

nected in parallel. The output stage is a 6A6 with the elements in push-pull. Using 220 volts on the first two tubes and 280 to 300 on the final stage an output of 10 watts or so may be expected.

The original transmitter was described by W1EHT in *QST*, July, 1937.

High Power with Crystal Control

Conventional circuit practice can be augmented by the use of linear tank circuits for 56-Mc. work, the resulting increase in efficiency being considered well worth while. The transmitter shown in Figs. 1221–1224 is an illustration. It consists of two units, one suitable for low-power work, the other being a high-power neutralized amplifier.

As shown in Fig. 1222, a 6A6 is used as

matically in Fig 1224. The output delivered by the 35T's is over 100 watts.

The driver section, Fig. 1223, is built on a chassis measuring 5 by 14 by 2½ inches. The 6A6 oscillator-doubler is at the left end with

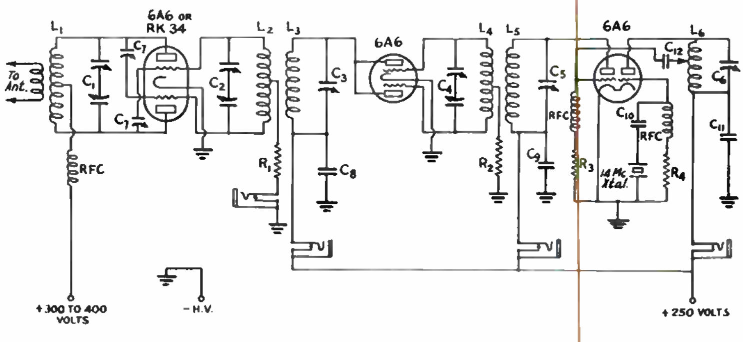


FIG. 1220 — ANOTHER CIRCUIT FOR A SIMPLE CRYSTAL 56-MC. TRANSMITTER

L_1 — 4 turns ⅜″ copper tubing.
L_2 — 3 turns No. 14 wire.
L_3 — 3 turns No. 14 wire.
L_4 — 6 turns No. 14 wire, tap 3 turns.
L_5 — 6 turns No. 14 wire.
L_6 — 8 turns No. 14 wire on 1¼ inch Isolantite form, tap 3 turns from plate end.
C_1 — Split-stator, 50-$\mu\mu$fd. per section.
C_2 — Split-stator, 35-$\mu\mu$fd. per section.
C_3 — 15 $\mu\mu$fd.
C_4 — Split-stator, 35-$\mu\mu$fd. per section.
C_5 — 50 $\mu\mu$fd.
C_6 — 100 $\mu\mu$fd.
C_7 — 2-stator 1-rotor, double-spaced.
C_8, C_9, C_{11} — 0.01-μfd. fixed.
C_{10}, C_{12} — 0.001-μfd. fixed.
R_1 — 2000-ohm.
R_2 — 10,000-ohm.
R_3 — 20,000-ohm.
R_4 — 5000-ohm.

the 6L6 doubler located slightly to the left side of the center. The 807 amplifier, minus its plate circuit, is at the right.

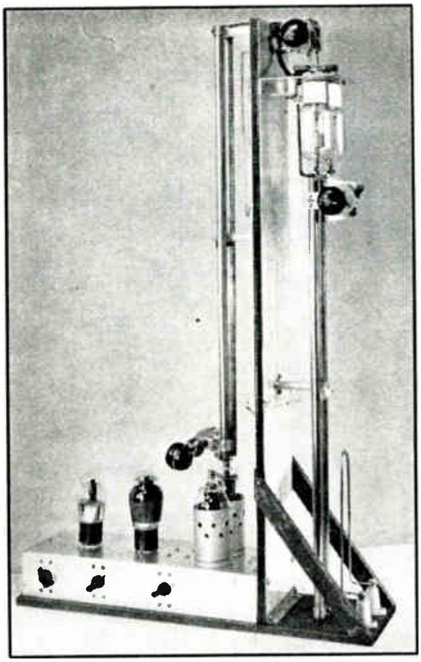


FIG. 1221 — HIGH-POWER CRYSTAL-CONTROLLED 56-MC. TRANSMITTER

Linear tank circuits are used to give maximum efficiency in the driver and amplifier stages. The exciter, with push-pull 807 output, is constructed on the aluminum chassis.

Wiring, up to the 807 grids, is below the chassis; the circuits are perfectly conventional. Condensers C_1, C_2 and C_3 are mounted as shown, with the proper coils soldered directly to the condenser lugs. The crystal socket is mounted on the back wall of the chassis to the rear of the 6A6. Four jacks are provided to facilitate reading of plate currents and the 807 grid current. Filament voltages for all four tubes and plate voltage for the 6A6 are brought to a four-screw terminal strip. Plate voltage leads for the 6L6 and 807's, and filament leads for the 35T's, are brought through a hole also located on the back wall.

The rack used to support the two units consists of two ½-inch boards; one, measuring 20½ by 5¾ inches, is utilized as a base. The second, measuring 32 by 5 inches, is fastened vertically to the base, centered 6 inches in from the left end. Both sides of the standing section are covered with thin aluminum sheet, which acts as a shield and ground plate.

The plate lines, constructed in the usual fashion, are mounted on stand-off insulators, that at the left being the 807 plate circuit. C_4, mounted across the open end of the line, is used both for tuning and to reduce the pipe length. Plate voltage is brought to the shorted end through a lead which lies in a groove cut in the wooden vertical member. A groove is also cut on the opposite side to contain the 35T filament wires. The wires and grooves are underneath the aluminum sheets.

Coupling between the 807's and the 35T's is through a tuned circuit, L_1C_1, Fig. 1224. The inductance is a hairpin link which runs, from

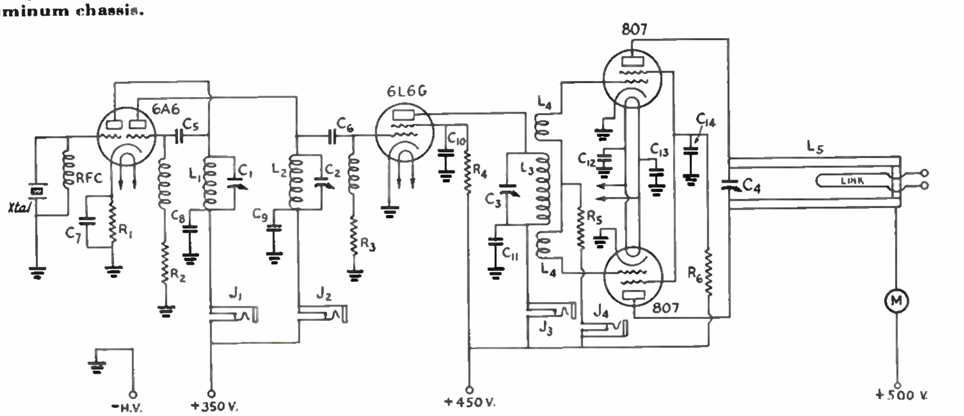


FIG. 1222 — CIRCUIT DIAGRAM OF THE EXCITER SECTION OF THE CRYSTAL-CONTROLLED TRANSMITTER

C_1 — 75-μμfd. variable.
C_2 — 50-μμfd. variable.
C_3, C_4 — 15-μμfd. variable.
C_5, C_6 — 100-μμfd. mica.
C_7 to C_{14}, inc. — 0.001-μfd. mica.
R_1 — 400 ohms, 1-watt.
R_2 — 20,000 ohms, 1-watt.
R_3 — 150,000 ohms, 1-watt.
R_4 — 30,000 ohms, 2-watt.
R_5 — 10,000 ohms, 2-watt.
R_6 — 15,000 ohms, 10-watt.
RFC — 2.5-mh. sectional chokes.
L_1 — 7 turns No. 20 d.c.c., diameter 1 inch, close-wound.
L_2 — 7 turns No. 12, diameter 1 inch, length ⅞ inch.
L_3 — 4 turns No. 12, diameter ¾ inch, length ¾ inch.
L_4 — 3 turns No. 12 each side L_3, diameter 1 inch, double-spaced.
L_5 — ⅞-inch o.d. copper tubing line, 24 inches long, spaced diameter of tubing.

World Radio History

C_1, through holes in the vertical board and down along the 807 plate line for about 9 inches. The grid resistor, R_L, is soldered between the center of the link and grid jack. The jack is mounted on a small bracket to the rear of the link. Fig. 1222 shows the link coupled to the 807 tank circuit.

In the amplifier, C_1, Fig. 1224, is mounted on an aluminum bracket as close to the top as possible. The tubes, mounted upside down, are supported by an aluminum shelf, which also holds the neutralizing condensers. These condensers are made from aluminum plates mounted on standoff insulators; the plate-spacing is approximately ⅛ inch.

L_2, the 35T plate line, is supported with the shorted end at the bottom. The plate voltage is tapped in at this point. The antenna link is 10 or so inches long and is mounted on two standoff insulators. C_2, across the open end of the line, resonates the circuit at various frequencies in the band.

The transmitter is tuned the same as any lower-frequency set. Approximate current readings are as follows: 6A6 oscillator section, 30 ma.; doubler section, 25 ma.; 6L6 doubler, 75 to 85 ma.; 807 grid current, 7 ma.; screen current, 25 to 35 ma.; plate current, 150 ma. Grid current to the 35T's is 60 ma. and the plate current 175 ma. at full load.

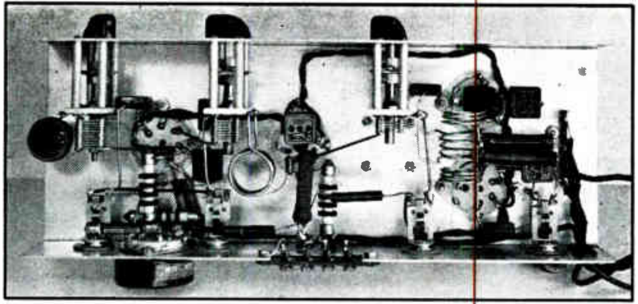


FIG. 1223 — BOTTOM-OF-CHASSIS VIEW OF THE CRYSTAL-CONTROLLED EXCITER SHOWN IN FIG. 1221

The tuning condensers, left to right, are for the oscillator, first doubler (second section of 6A6 tube), and second doubler.

28-Mc. Crystals

All of the crystal-controlled circuits shown have been based on the use of 14-Mc. crystals. There is no reason, however, why lower-frequency crystals cannot be used, providing additional doubler stages are incorporated. In fact, if the station is equipped with an "all-band" exciter of one of the types described in Chapter Eight, the addition of one doubler and a final amplifier will be all that is needed to extend the range to the 56-Mc. band.

Alternatively, the 56-Mc. crystal-controlled transmitter can be simplified by the use of the relatively new 28-Mc. crystals. Their use is convenient, especially for portable-mobile work, where the power available definitely limits the number of stages which can be used. Crystals for the 28-Mc. band require somewhat more care in circuit design than do those for

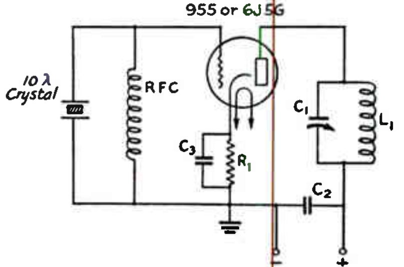


FIG. 1225 — TRIODE CRYSTAL OSCILLATOR CIRCUIT RECOMMENDED FOR 28-MC. CRYSTALS

L_1 — 8 turns No. 12 wire, ¾-inch diameter, turns spaced diameter of wire.
C_1 — 75-μμfd. variable.
C_2, C_3 — 0.005-μfd. mica.
R_1 — 200-ohm carbon.
RFC — 2.5-mh. r.f. choke.
Plate voltage should be 180 for the 955, 220 for the 6J5G.

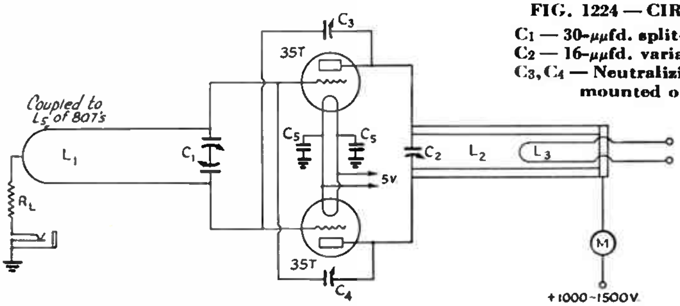


FIG. 1224 — CIRCUIT OF THE 35T AMPLIFIER

C_1 — 30-μμfd. split-stator (Cardwell ET-30-AD).
C_2 — 16-μμfd. variable (Cardwell Na-16-AS).
C_3, C_4 — Neutralizing condensers; 1-inch square plates mounted on standoff insulators, one plate of each condenser movable for adjustment.
C_5 — 0.005-μfd. mica.
R_L — 5000 ohms, 25-watt.
L_1 — Coupling link; see text.
L_2 — ⅞-inch o.d. copper tubing line, length 24 inches, spaced diameter of tubing.
L_3 — Antenna-coupling link, app. 10 inches long.

World Radio History

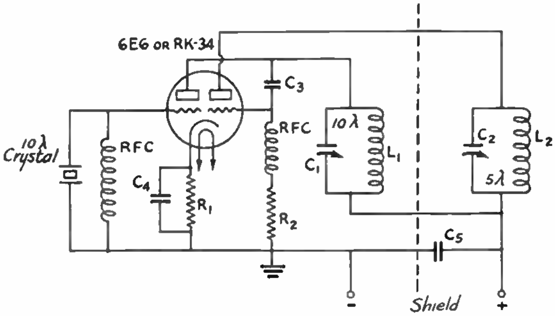


FIG. 1226 — DUAL-TRIODE OSCILLATOR-DOUBLER FOR 56-MC. OUTPUT

L_1 — 6 turns No. 12, diameter ¾ inch; spacing equal to wire thickness.
L_2 — 4 turns No. 12, diameter ¾ inch; spacing twice wire diameter.
C_1 — 75-μμfd. variable.
C_2 — 35-μμfd. variable.
C_3 — 100-μμfd. mica.
C_4, C_5 — 0.005-μfd. mica.
R_1 — 400 ohms.
R_2 — 30,000 ohms.
RFC — 2.5-mh. r.f. choke.
Plate voltage for 6E6, 300; for RK34, 325.

the lower frequencies, and the circuits of Figs. 1225 and 1226 are especially recommended. With the 6J5G in Fig. 1225, sufficient output can be secured at 220 volts on the plate to drive tubes such as the 6L6 and 807 as 56-Mc. doublers. With the dual-triode-circuit of Fig. 1226, outputs of the order of 3 watts can be secured on 56 Mc. from the doubler section.

The usual precautions as to short leads and compact construction apply.

THE MODULATOR PROBLEM

The subject of modulator design for the u.h.f. transmitter is, of course, of very wide scope. However, since it differs in no way from the same problem as it applies to lower frequency transmitters, we are not justified in offering any detailed extension of the design principles appearing in Chapter Ten. A study of that

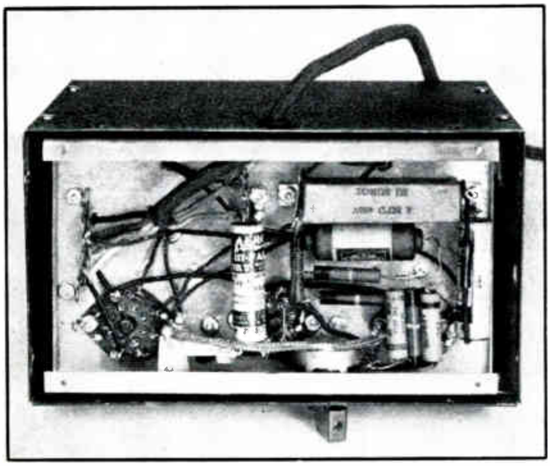


FIG. 1228 — SHOWING THE SIMPLE CONSTRUCTION ON THE UNDERSIDE OF THE 10-WATT MODULATOR

FIG. 1229 — A PLAN VIEW OF THE 10-WATT MODULATOR

In spite of the compact assembly, this modulator has sufficient gain to allow operation from a standard crystal microphone. It was originally planned as a companion piece for the transmitter illustrated in Fig. 1215.

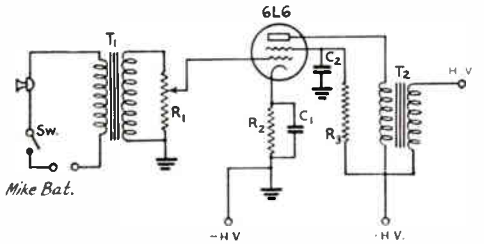
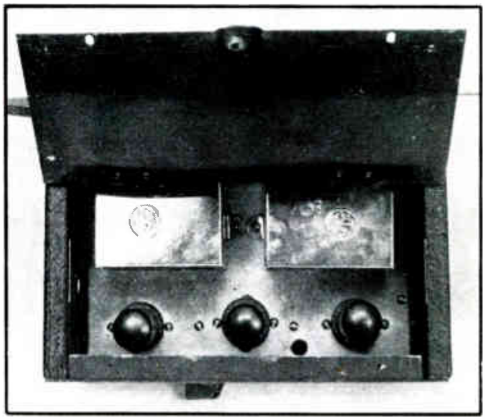


FIG. 1227 — THE SIMPLE MODULATOR USED WITH THE MOBILE TRANSMITTER

T_1 — UTC Type CS103 microphone transformer.
T_2 — UTC Type CS34 used back-to-front to give a step-up turn ratio of 1 to 1.2.
R_1 — 500,000-ohm potentiometer.
R_2 — 350-ohm 5-watt resistor.
R_3 — 25,000-ohm 1-watt fixed resistor.
C_1 — 25 μfd. 50-volt electrolytic condenser.
C_2 — .5 μfd. tubular-type condenser.



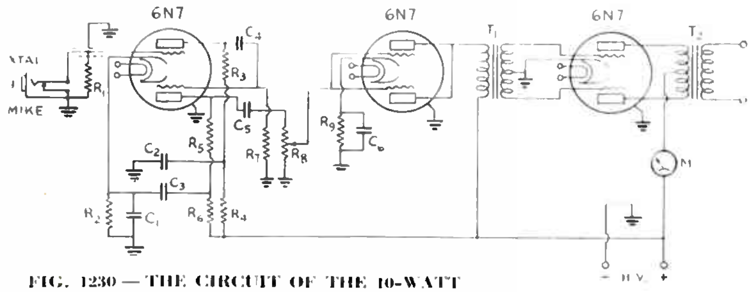


FIG. 1230 — THE CIRCUIT OF THE 10-WATT MODULATOR

C_1 — 5 μfd., 25-volt electrolytic condenser.
C_2, C_3 — 8 μfd., 500-volt electrolytic.
C_4, C_5 — .01 μfd., 600-volt paper condensers.
C_6 — 5 μfd., 25-volt electrolytic.
R_1 — 2 megohm half-watt resistor.
R_2 — 1750 ohm one-watt resistor.
R_3, R_5 — 100,000 ohm one-watt resistors.
R_4, R_6 — 20,000 ohm one-watt resistors.
R_7 — 500,000 ohm half-watt resistor.
R_8 — 500,000 ohm potentiometer.
R_9 — 1200 ohm one-watt resistor.
T_1 — Class B input (UTC Type CS-22).
T_2 — Class B output (UTC Type CS33).

chapter will quickly reveal the fundamental principles involved in choosing modulator tubes and their companion speech amplifiers.

We will, however, present two typical examples of simple low-powered modulators of the type suitable for use with the smaller u.h.f. sets. The modulators for the more powerful transmitters may well be modeled along the lines of those shown in Chapter Ten.

Fig. 1227 is the circuit of a very simple Class A modulator suitable for modulating the output of a transmitter operated with an input of 10 or 12 watts. It will be seen that in the interests of simplicity a single-button microphone is used to drive the 6L6 directly. This means that the modulator can be driven to full output only by using a high voice level. Such operation is, however, usually the rule with mobile installations, particularly in airplane work. The output transformer is made necessary since the load impedance of the modulator usually is considerably higher than that required for the modulator tube.

A 10-Watt Modulator

A more advanced type of modulator suitable for use with a crystal microphone and capable of modulating a final amplifier running at 20 watts of input is illustrated in Figs. 1228 to 1230. Three 6N7 tubes are used, the first as a two-stage resistance-coupled amplifier, the second as a parallel-connected driver and the third as a conventional Class-B modulator.

The unit is built in a standard 9-by-5-by-6 metal box with the three tubes in a row and the transformers behind them. Notwithstanding the compact assembly, no trouble has been had from any form of instability. The plate meter in the modulator (shown on the diagram) is convenient as a means of checking operation, but would require a larger container for the set than that illustrated.

THE TRANSCEIVER

For portable work, a reduction in weight and general simplification of equipment can be made by using the same tubes for transmission as for reception. In the early days of u.h.f. work this idea was carried out very thoroughly, but with present conditions the simpler types of transceivers cannot comply with the regulations respecting stability of transmission, and are undesirable for reception because of severe radiation from the super-regenerative receiver operated at relatively high plate voltage. At the present time the "transceiver" normally uses only the audio equipment for both transmitting and receiving, the r.f. sections being entirely separate.

A transceiver of the latter type is shown in Figs. 1231 and 1232. The transmitter circuit will be recognized as that of Fig. 1226. The receiver section consists of a super-regenerative detector preceded by an r.f. stage to prevent radiation. The 6F6 is used as a speaker amplifier with the switch in the "receive" position,

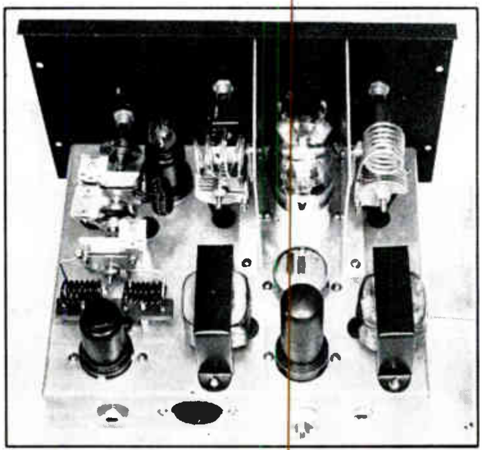


FIG. 1231 — A 56-MC. CRYSTAL-CONTROLLED TRANSCEIVER FOR PORTABLE AND PORTABLE-MOBILE WORK

The 6F6 and its input transformer and output choke are in the foreground. The crystal is between the 6F6 and RK-34. (W3VR, April, 1938, *QST*.)

World Radio History

and as a modulator with the switch in the "send" position. The circuit and construction follow the practice already outlined, and need no special comment. A unit of this type may be used for low-power fixed station work as well as for portable and portable-mobile operation.

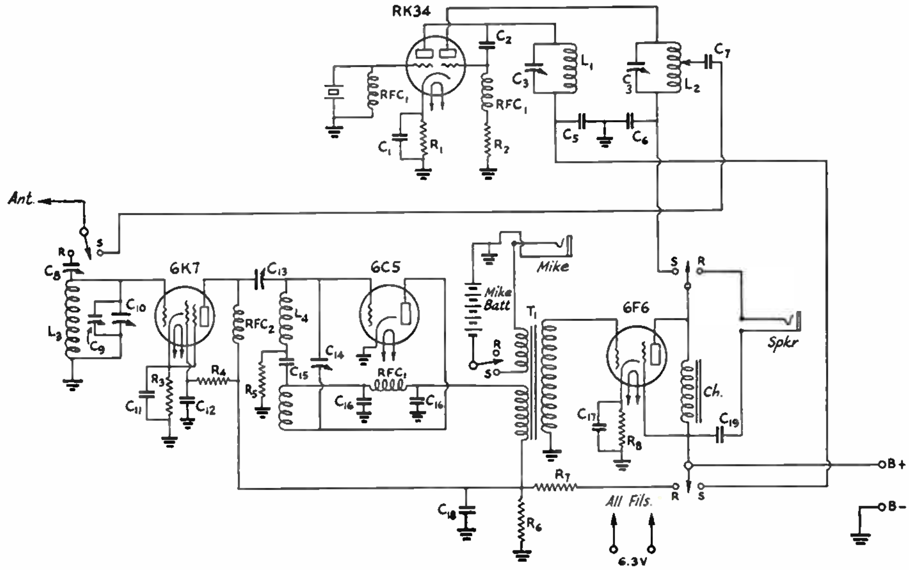


FIG. 1232 — CIRCUIT DIAGRAM OF THE CRYSTAL-CONTROLLED TRANSCEIVER

C_1, C_5, C_6 — 0.005-μfd. midget mica.
C_2 — 0.002-μfd. midget mica.
C_3 — 75-$\mu\mu$fd. midget variable (Cardwell ZR-75-AS).
C_4 — 35-$\mu\mu$fd. midget variable (Cardwell ZR-35-AS).
C_7 — 0.001-μfd. midget mica.
C_8, C_{10}, C_{13} — 3-30-$\mu\mu$fd. trimmers (National M-30).
C_9, C_{14} — 15-$\mu\mu$fd. midget variable (Cardwell ZR-15-AS).
C_{11}, C_{12} — 500-$\mu\mu$fd. midget mica.
C_{15} — 100-$\mu\mu$fd. midget mica.
C_{16} — 0.001-μfd. midget mica.
C_{17} — 10-μfd. 25-volt electrolytic.
C_{18} — 0.25-μfd. 400-volt paper.
C_{19} — 0.01-μfd. 400-volt paper.
RFC_1 — 2.5-mh. r.f. choke.
RFC_2 — R100 choke (National).
R_1 — 400 ohms, 10-watt.
R_2 — 30,000 ohms, 2-watt.
R_3 — 1500 ohms, ½-watt.
R_4, R_5 — 100,000 ohms, ½-watt.
R_6, R_7 — 50,000 ohms, 1-watt.
R_8 — 450 ohms, 10-watt.
L_1 — 6 turns No. 12, diameter ¾ inch, spaced wire diameter.
L_2 — 4 turns same as L_1.
L_3 — 7 turns No. 14, diameter ½ inch, spaced wire diameter.
L_4 — 56-Mc. receiver coil (Sickles No. 1203).
T_1 — Transceiver input transformer (Kenyon KA-114-M).
CH — 30-henry, 70-ma. choke.
Switch — 4-pole double-throw (Yaxley 3242J).

World Radio History

CHAPTER THIRTEEN

ANTENNAS

Propagation of Radio Waves — Types of Antennas — Their Radiation Characteristics — Feeder Systems for Simple Antennas — Methods of Coupling — Directive Arrays

Too often an amateur erects an antenna system without a clear understanding of the characteristics possessed by the particular type chosen and, consequently, with little regard for the all-important question of whether or not those characteristics are suited to the purpose for which the antenna is intended. Before one can select the right tool for a job he must know what that job is. The antenna's job is that of radiating electro-magnetic waves in such a way that they will reach a desired receiving point with maximum intensity. Obviously, then, we must know something about the nature of radio waves and how they travel before we can consider how most effectively to start them on their way.

THE NATURE OF RADIO WAVES

Radio waves are of the same nature as light waves, traveling with the same velocity of 186,000 miles or 300,000 kilometers per second. They are *electro-magnetic* waves, having an electric component and an accompanying magnetic component, the two being at right angles to each other in space. The waves are *plane waves:* the plane of the electric and magnetic components is always at right angles to the line along which the waves are traveling. The waves are said to be *vertically polarized* when the wave travels with its electric component perpendicular to the earth, and are said to be *horizontally polarized* when the electric component is parallel to the earth. The polarization at transmission will correspond to the position of the antenna which radiates the waves, vertical or horizontal, although the polarization may shift as the wave travels through space or encounters incidental conductors in its path. The polarization of the waves at the receiving point is of practical importance because the voltage induced in the receiving antenna will be greatest when the antenna is placed to suit the particular polarization of the wave — vertical for vertically-polarized waves and horizontal for horizontally-polarized waves.

Radio waves, like light waves, can be *reflected* and *refracted.* Reflection occurs when the wave strikes a conductor, such as a wire. A current is set up in the wire, and in turn causes the wire to radiate an electro-magnetic wave of its own. Reflection also can occur in the upper atmosphere, as described in the following paragraphs.

The Ionosphere

Radio waves not only travel along the surface of the earth in the lower atmosphere, for short-distance communication; they also travel through the upper regions far above the earth for long-distance communication.

The general idea of the paths followed by radio waves for both direct-ray and indirect-ray communication is illustrated in Fig. 1301-A. As would be expected, a direct ray travels out from the transmitter along the surface of the earth and will be received strongly at a relatively near-by point. This part of the radiation is commonly called the *ground wave.* It is rapidly weakened or *attenuated* as it progresses, until finally it is no longer of useful strength. Moreover, the rapidity with which the ground wave is attenuated is greater as its frequency is higher (or as its wavelength is shorter).

But not all the energy radiated by the antenna is in waves along the surface. The greater part is likely to be at angles considerably above the horizontal, in fact. These higher-angle *sky waves* would travel on outward into space indefinitely, and would be of no practical use for communication, if they were not bent back to earth again. This bending action is explained by the existence of a region of ionized atmosphere, known as the *ionosphere,* surrounding the earth. The possibility of radio waves being returned from such an ionized region was proposed almost simultaneously by A. E. Kennelly in America and by Oliver Heaviside in England in 1902, many years before long-distance short-wave communication demonstrated its proof. In honor of these two scientists, the ionosphere has been long known also as the *Kennelly-Heaviside layer.*

World Radio History

The ionosphere is not strictly a single layer, however. Dr. Kennelly suggested this in his original proposal and investigations have shown that there are several distinct layers, as will be explained in the following paragraphs.

How Sky Waves Are Bent by Refraction

The ionization of air molecules mentioned above is the result of bombardment by cosmic and solar radiation, breaking them into free electrons and positive ions. This ionization is inappreciable in the air near the earth's surface, to which the ionizing radiations penetrate to only a slight extent, and in which the electrons and ions recombine so quickly as to permit the electrons practically no free path. It is considerable in the thin atmosphere at heights extending between approximately 40 and 250 miles (70 to 400 kilometers). It is the presence of the free electrons resulting from ionization in this region, and the relatively long free path there allowed the electron before recombination, which is principally responsible for bending of the sky waves.

For the amateur frequencies between 7000 kc. (40-meter band) and 30,000 kc. (10-meter band), the bending is practically all *refraction.* That is, a wave entering the increasingly ionized region from the lower atmosphere has its velocity increased by the increased conductivity due to the presence of the free electrons, and more or less gradually has its course turned away from the ionized region, back towards the earth. One way of visualizing this is to consider the wave as two adjacent rays, one above the other. The upper ray travels faster than the lower ray as it progresses into the ionosphere because it is in the denser electron atmosphere. Hence, it tends to gain on the lower ray, with the consequence that the path of the wave is curved downward to earth — somewhat as the left wheel of a vehicle turning faster than the right will cause a change of direction to the right. A suggestion of this refracting action is given for sky waves in Fig. 1301.

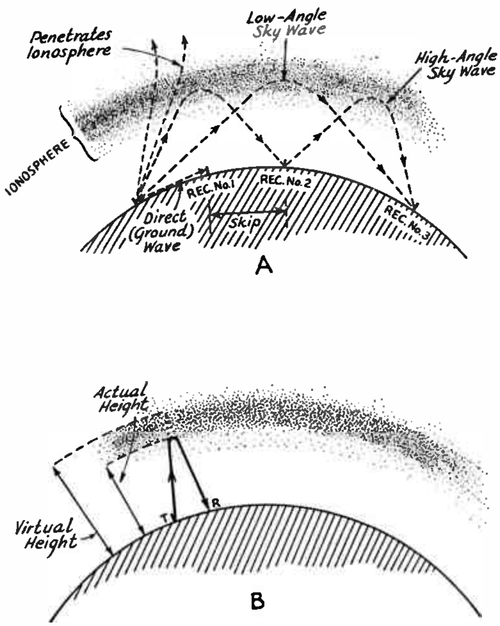


FIG. 1301 — ILLUSTRATING GROUND-WAVE AND SKY-WAVE TRANSMISSION OF RADIO WAVES

The density of the dots indicates that the electron density in the ionosphere increases and then decreases as the altitude becomes greater. This is a simplified representation; actually there are other ionized layers which affect different frequencies in different ways.

Skip Distance and Layer Height

The sharpness with which this bending occurs is the greater as the frequency of the wave is lower. At 3500 kc. and lower frequencies the sky wave usually will return quite close to the transmitting point, within the range covered by the ground wave, as well as at greater distances. At 7000 kc., however, the sky wave often will not return this close to the transmitter, and there will be a zone of silence from the farther limit of the ground wave to the closest point at which the sky wave returns. This no-signal interval is known as the *skip distance,* from the fact that the signals seem to skip over. The skip distance increases with frequency, until at frequencies in the 28-Mc. band it becomes so great that the returning signal is likely to miss the earth and not to be heard under ionosphere conditions prevailing much of the time.

As shown by Fig. 1301-A, the bending at a given frequency is also determined by the angle at which the wave strikes the ionized region. Waves entering the ionosphere at grazing incidence are much more readily refracted than those which approach it nearly perpendicularly. At the higher frequencies, in fact, waves which strike the ionosphere at relatively high angles with respect to the horizon are not refracted sufficiently to be returned to earth, and hence are not useful for communication. Under all except very abnormal conditions, 56-Mc. waves, for instance, are not refracted by the ionosphere even though the angle is very low.

The degree of bending is a function of the intensity of ionization. This varies with the time of day, as the portion of the earth under consideration receives more or less radiation from the sun, so that transmission conditions go through daily cycles. The ionization also is influenced by cyclic changes in the condition of the sun itself, so that similar variations fol-

World Radio History

low the 27-day and 11- or 22-year sun-spot activity cycles. The effect of the latter variations is more apparent on the higher frequencies — 14 and 28 Mc. — where conditions for refraction are most critical.

Measurements have shown that there are three ionized regions or layers of a major nature, with others occasionally making an appearance. The three are called the *E layer*, the *F_1 layer* and the *F_2 layer*. Measurements made at Washington, D. C., by the U. S. Bureau of Standards show that the *E* layer has a virtual height of approximately 70 miles for the lower frequencies in this range during daytime. At mid-frequencies the waves penetrate this layer and are returned from the F_1 layer at a height of approximately 125 miles. At the higher frequencies the waves penetrate both the *E* and F_1 layers and are returned from the F_2 layer at a height of approximately 180 miles. Towards evening the F_1 and F_2 layers appear to merge, leaving only the one layer in the *F* region at a virtual height of approximately 150 miles or higher during the night.

The layer principally effective for long-distance communication at night is the *F* layer, while any one of the three may be effective for sky-wave transmission during the daytime, depending on the frequency and degree of ionization.

Ultra-High Frequency Waves

Although waves of ultra-high frequency (above 30 Mc.) are only rarely bent back to earth by the ionosphere, studies in reception of 56-Mc. transmissions over distances of 100 miles or so, which are greater than the ground wave or optical range, have shown evidence of bending in the lower atmosphere. Investigations by the A.R.R.L. technical staff during 1934 and 1935 showed that this bending accompanies the presence below 10,000-foot altitude of warmer air layers over cooler surface air, or that it accompanies the occurrence of temperature inversions in the lower atmosphere. Apparently there is cause for sufficient refraction at 56 Mc., and at 112 Mc., to give "air-wave" communication at distances greater than would be possible with only ground wave transmission. Communication on these frequencies is treated more fully in Chapters Eleven and Twelve.

Wave Propagation in Relation to Antenna Design

An important practical lesson to be learned from these peculiarities of radio wave travel is that transmission will be most effective when the energy radiated from the antenna is concentrated on the ionosphere at an angle which will put the best signal down at the receiving point. For long-distance communication this means that the maximum radiation should be more nearly horizontal than vertical; that is, *low-angle* radiation is desirable, especially on the 14- and 28-Mc. bands.

Available data indicate that under most conditions, 28-Mc. waves traveling at an angle of more than 15 degrees or so with the horizon seldom are returned to earth by the ionosphere; on the average, the optimum angle lies between 5 and 10 degrees. On 14 Mc. the normal upper limit is about 30 degrees, with angles up to 15 or 20 degrees being most effective. On 7 and 3.5 Mc. purely vertical radiation often is returned; angles up to at least 45 degrees are effective under most conditions on the former band, and to a still higher figure on the latter. In the discussion of antenna radiation characteristics in this chapter, angles of 9 degrees for 28 Mc., 15 degrees for 14 Mc., and 30 degrees for 7 and 3.5 Mc. have been assumed as representing average conditions for comparative purposes. Purely horizontal radiation over any considerable distance is practically unattainable at the higher frequencies because of rapid absorption of energy by the ground.

The question of polarization also deserves some consideration. Experimental data show that at 7 Mc. and higher the waves usually are horizontally polarized at the receiving point regardless of the polarization of the transmitting antenna. It is thought that this "ironing-out" of the polarization occurs when the wave is refracted in the ionosphere, perhaps also as the result of influence of the ground near the receiving antenna. On 3.5 Mc. the polarization is variable, and on 1.75 Mc. is chiefly vertical. The conclusion to be drawn is that on the 3.5-Mc. and higher-frequency bands little consideration need be given polarization at the *transmitting* antenna. For receiving, however, a horizontal antenna is preferable not only because it will give greatest output from the horizontally polarized waves, but also because most local electrical interference (from machines, automobile ignition, etc.) prevalent on the higher frequencies is vertically polarized, hence the response to such interference will be minimized. On 1.75 Mc. vertical polarization is to be preferred from the standpoint of effective transmission, but may lead to interference with near-by broadcast receivers, the antennas for which also respond well to vertically-polarized waves.

THE HALF-WAVE ANTENNA

The fundamental form of antenna, and the one in widest practical use for short-wave work, is a single wire whose length is approximately equal to half the transmitting wave-length. It is important to understand its properties be-

World Radio History

cause the half-wave antenna is the unit from which many more complex forms of antennas are constructed. It is sometimes known as a *Hertz* or *doublet* antenna.

It was explained in Chapter Four that when power is fed to such an antenna the current and voltage vary along its length. The distribution, which is practically the form of a sine curve, is shown in Fig. 1302. The current is maximum at the center (a point of maximum is known as a *loop* or *antinode*) and nearly zero at the ends, while the opposite is true of the r.f. voltage. The current does not actually reach zero at the current *nodes,* or minimum points, because of the effect of capacitance at the ends of the wire (*end effect*); similarly, the voltage is not zero at its node because of the resistance of the antenna, which consists of both the r.f. resistance of the wire (*ohmic resistance*) and the *radiation resistance.* Usually the ohmic resistance of a half-wave antenna is small enough, in comparison with the radiation resistance, to be neglected for all practical purposes. Radiation resistance has been defined in Chapter Four.

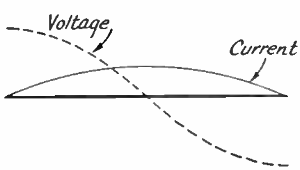


FIG. 1302 — CURRENT AND VOLTAGE DISTRIBUTION ON A HALF-WAVE ANTENNA

Antenna Impedance

The radiation resistance of a half-wave antenna in free space — that is, sufficiently removed from surrounding objects so that they do not affect the antenna's characteristics — is 73 ohms, approximately. The value under practical conditions will vary with the height of the antenna, but is commonly taken to be in the neighborhood of 70 ohms. It is a pure resistance, and is measured at the center of the antenna. The antenna impedance at any point will be equal to the voltage divided by the current at the point. The impedance is minimum at the center, where it is equal to the radiation resistance, and increases toward the ends. The end value will depend on a number of factors such as the height and physical construction, but a representative value for a half-wave antenna is about 12,000 ohms.

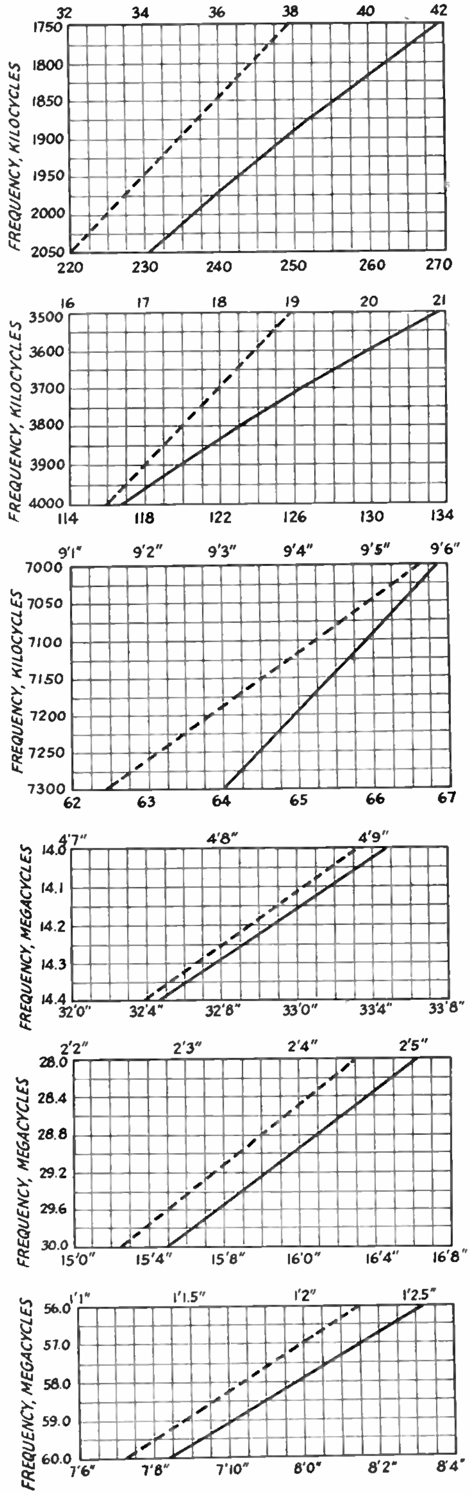


FIG. 1303 — CHARTS FOR DETERMINING THE LENGTH OF HALF-WAVE ANTENNAS FOR USE ON VARIOUS AMATEUR BANDS

Solid lines indicate antenna length (lower scale); dotted lines point of connection for single-wire feeder (upper scale). (See section on single-wire feed.)

World Radio History

The impedance is an important quantity which must be taken into account when methods of feeding power to the antenna are under consideration.

Physical Length

The actual length of a half-wave antenna will not be exactly equal to the half wavelength in space but is usually about 5% less, because of end effects. The reduction factor increases slightly as the frequency is increased. Under average conditions, the following formula will give the length of a half-wave antenna to sufficient accuracy:

$$\text{Length of half-wave antenna (feet)} = \frac{468}{\text{Freq. (Mc.)}} \quad (1)$$

This equation is shown in chart form in Fig. 1303. Differences of a few per cent in length will make no appreciable difference in the radiation characteristics of the antenna, but may have an effect on the operation of the feeder system used. This will be considered in a later section.

Radiation Characteristics

The radiation from a half-wave antenna is not uniform in all directions but varies with the angle with respect to the axis of the wire. It is most intense in directions at right-angles to the wire, and zero along the direction of the wire itself, with intermediate values at intermediate angles. This is shown by the sketch of Fig. 1304, which represents the radiation pattern in free space. The relative intensity of radiation is proportional to the length of a line drawn from the center of the figure to the perimeter. If the antenna is vertical, as shown in the figure, then the *field strength*, the measure of signal intensity, will be uniform in all horizontal directions; if the antenna is horizontal, the relative field strength will depend upon the direction of the receiving point with respect to the direction of the antenna wire.

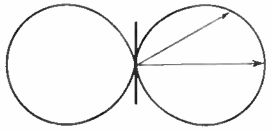


FIG. 1304 — FREE-SPACE RADIATION PATTERN OF HALF-WAVE ANTENNA

The antenna is shown in the vertical position. This is a cross-section of the solid pattern described by the figure when rotated on its axis (the antenna). The "doughnut" form of the solid pattern can easily be visualized by imagining the drawing glued to cardboard, with a short length of wire fastened on to represent the antenna. Then twirling the wire will give a visual representation of the solid pattern.

Ground Effects

When the antenna is near the ground, as all amateur antennas are, the free-space pattern of Fig. 1304 is modified by reflection of radiated waves from the ground, so that the actual pattern is the resultant of the free-space pattern and ground reflections. This resultant is dependent upon the height of the antenna and its position or orientation with respect to the surface of the ground. The reflected waves may be in such phase relationship to the directly-radiated waves that the two completely reinforce each other, or the phase relationship may be such that complete cancellation takes place. All intermediate values also are possible. In other words, the effect of a perfectly-reflecting ground is such that the original free-space field strength may be multiplied by a factor which has a maximum value of 2, for complete reinforcement, and having all intermediate values to zero, for complete cancellation. Since waves are always reflected upward from the ground (assuming that the surface is fairly level) these reflections only affect the radiation pattern in the vertical plane — that is, in directions upward from the earth's surface — and not in the horizontal plane, or the usual geographical directions.

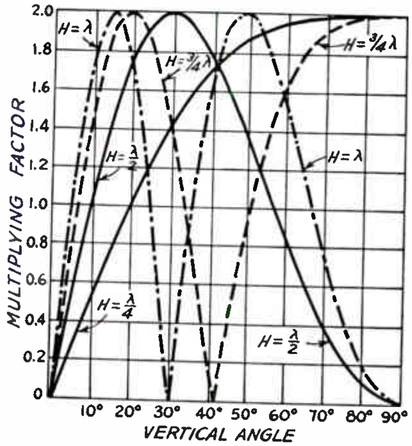


FIG. 1305 — EFFECT OF GROUND ON RADIATION AT VERTICAL ANGLES FOR FOUR ANTENNA HEIGHTS

This chart applies only to horizontal antennas, and is based on perfectly conducting ground.

Fig. 1305 shows how the multiplying factor varies with the vertical angle for several representative heights for horizontal antennas. The maximum value (2) comes at a vertical angle of 90 degrees (directly upward) for an antenna height of ¼ wavelength. As the height is increased the angle at which complete reinforcement takes place is lowered until it occurs

World Radio History

at a vertical angle of 15 degrees for a height equal to one wavelength. Note that the factor is zero for an angle of 30 degrees when the antenna is one wavelength high, is zero at slightly over 40 degrees for a height of ¾ wavelength, and is zero at 90 degrees for a height of ½ wavelength. This means that there can be no radiation at these vertical angles for the heights given, from a horizontal antenna above perfectly-conducting ground.

We have already seen that the vertical angle, or "angle of radiation" is of primary importance, especially at the higher frequencies. It is therefore advantageous to erect the antenna at a height which will take advantage of ground reflection in such a way as to reinforce the space radiation at the most desirable angle. Generally speaking, this simply means that the antenna should be as high as possible: at least ½ wavelength at 14 Mc. and preferably ¾ or 1 wavelength; at least 1 wavelength and preferably higher at 28 Mc. Fortunately the wavelength is shorter as the frequency is increased so that good heights are not impracticable; a half wavelength at 14 Mc. is only 35 feet, approximately, and the same height represents a full wavelength at 28 Mc. At 7 Mc. and lower, the higher radiation angles are effective so that again a reasonable antenna height is not difficult of attainment. Heights between 35 and 70 feet are suitable for all bands, the higher figures being preferable if circumstances permit their use.

When the half-wave antenna is vertical the maximum and minimum points in the curves of Fig. 1305 exchange positions, so that the nulls become maxima, and vice versa. In this case, the height is taken as the distance from ground to the center of the antenna.

Fig. 1305 is based on a ground having perfect conductivity, a thing which is not met with in practice. The principal effect of actual ground is to make the curves inaccurate at the lowest angles; appreciable high-frequency radiation at angles smaller than about 5 degrees is practically impossible to obtain. Above 15 degrees, however, the curves are accurate enough for all practical purposes, and may be taken as indicative of the sort of result to be expected at angles between 5 and 15 degrees.

Vertical or Horizontal?

Although polarization is generally unimportant in high-frequency communication, the question of whether the antenna should be installed in a horizontal or vertical position deserves consideration on other counts. As Fig. 1304 shows, a vertical half-wave antenna will radiate equally well in all *horizontal* directions, so that it is substantially non-directional in the usual sense of the word. If installed horizontally, however, the antenna will tend to show directional effects, and will radiate best in the direction at right-angles, or broadside, to the wire. The radiation in such case will be least in the direction toward which the wire points. This can be seen readily by imagining that Fig. 1304 is lying on the ground and that the pattern is looked at from above.

The vertical angle of radiation also will be affected by the position of the antenna. If it were not for ground losses at high frequencies, the vertical half-wave antenna would be preferred because it would concentrate the radiation horizontally. Practically, this theoretical advantage over the horizontal antenna is of little or no consequence; in fact, at certain heights the vertical antenna may actually not be as good a low-angle radiator as the horizontal since, as previously explained, the positions of the maxima and mimima of Fig. 1305 are interchanged when the antenna is vertical.

For the same pole height, a horizontal antenna usually will be more "in the clear" than a vertical, so that energy losses in near-by objects usually will be less. The horizontal position is desirable if the antenna is used for receiving, as previously explained. Also, the horizontally-polarized transmissions are less likely to cause interference with near-by broadcast receivers.

Effective Radiation Patterns

In determining the effective radiation pattern of an antenna it is necessary to consider radiation in both the horizontal and vertical planes. When the half-wave antenna is vertical, the vertical angle of radiation chosen does not affect the *shape* of the horizontal pattern, but only its relative amplitude. When the antenna is horizontal, however, both the shape and amplitude are dependent upon the angle of radiation chosen.

Fig. 1306 should make this clear. The "free-space" pattern of the horizontal antenna

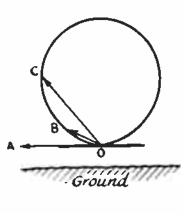


FIG. 1306 — ILLUSTRATING THE IMPORTANCE OF VERTICAL ANGLE OF RADIATION IN DETERMINING ANTENNA DIRECTIONAL EFFECTS

Ground reflection is neglected in this drawing. As previously explained, reflection from the ground will reinforce or cancel radiation at certain vertical angles, depending upon the height.

shown is a section cut vertically through the solid pattern. In the direction *OA*, horizontally along the wire axis, the radiation is zero. At some vertical angle represented by the line *OB*, however, the radiation is appreciable, despite the fact that this line runs *in the same geographical direction* as *OA*. At some higher

World Radio History

angle OC the radiation, *still in the same geographical direction,* is still more intense. The effective radiation pattern therefore depends upon the angle of radiation most useful. The factors influencing the selection of these angles were considered earlier in this chapter. It must be remembered, however, that they represent only average or near-average conditions, and that the effective pattern is dependent upon the conditions existing in the ionosphere. These conditions may vary not only from day to day and hour to hour, but even from minute to minute. Obviously, then, the effective directivity of the antenna will change along with transmission conditions.

Theoretical horizontal-directivity patterns for half-wave horizontal antennas at vertical angles of 9, 15 and 30 degrees are given in Fig. 1307. At intermediate angles the values in the

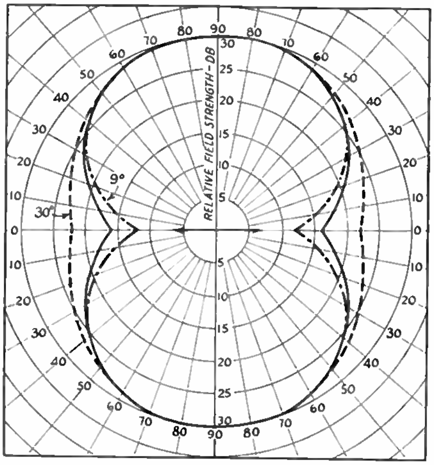


FIG. 1307 — HORIZONTAL PATTERN OF A HORIZONTAL HALF-WAVE ANTENNA AT THREE VERTICAL RADIATION ANGLES

Solid line is relative radiation at 15 degrees. Dotted lines show deviation from the 15-degree pattern, for angles of 9 and 30 degrees. The patterns are useful for shape only, since the amplitude will depend upon the height of the antenna above ground and the vertical angle considered. The patterns for all three angles have been proportioned to the same scale, but this does not mean that the maximum amplitudes necessarily are the same. These statements also apply to Figs. 1329, 1330, and 1331. The arrow indicates the direction of the antenna wire.

affected regions also will be intermediate. Relative field strengths are plotted on a decibel scale (see Appendix) so that they represent as nearly as possible the actual aural effect at the receiving station. If the signal in the direction of maximum intensity is S9, the smallest value on the scale should be about S1.

The considerations discussed here in connection with half-wave antennas also apply to the more complicated types described later.

FEEDING POWER TO THE ANTENNA

ALL THAT has been said in the preceding sections is true of *any* half-wave antenna, regardless of the method used to feed radio-frequency power to it. The various names applied to half-wave antennas with different types of feed

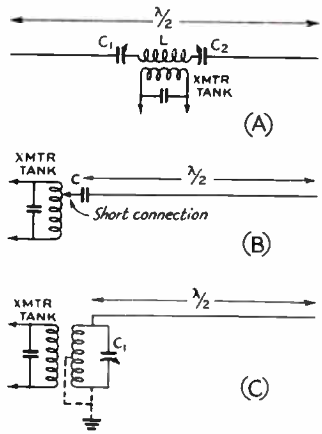


FIG. 1308 — METHODS OF DIRECT FEED TO THE HALF-WAVE ANTENNA

***A*, current feed, series tuning; *B*, voltage feed, capacity coupling; *C*, voltage feed with inductively coupled antenna tank. In *A*, the coupling apparatus is not included in the antenna length.**

systems — "Zepp," "current-fed," "end-fed," "Q," "matched-impedance," and so on, often lead to misunderstandings in that they are interpreted to be "different" antenna systems. If the *antenna* (as distinguished from the feeder) is a half-wave element the *performance is identical with that just described,* despite any distinctive name. The only qualification to this statement is the condition that the feeder, if used, should not itself radiate appreciably and thus take an unintentional part in the operation of the radiating system; well-designed feeder systems easily meet this requirement.

Power may be applied to the antenna directly or through a feed line. Three methods of direct excitation are shown in Fig. 1308. In *A* the antenna is cut at the center and a small coil inserted. The coil is coupled to the output tank circuit of the transmitter, with adjustable coupling so that the transmitter loading can be controlled. Since the addition of the coil "loads" the antenna, or increases its effective length because of the additional inductance, the series condensers C_1 and C_2 are put in the circuit to provide electrical means for reducing the length to its original unloaded value. This method of feeding is known as *current feed,* because power is inserted at a high-current point.

World Radio History

The methods of *B* and *C* are called *voltage-feed* systems because the power is introduced into the antenna at a point of high voltage. In *B* the end of the antenna is coupled to the output tank circuit through a small condenser; in *C* a separate tank, connected directly to the antenna, is used. This tank is tuned to the transmitter frequency and may be ungrounded, grounded at one end as shown, or grounded at the center of the coil. Practical considerations and methods of adjustment of all three systems will be discussed in a later section.

Direct excitation is seldom used except on the lowest amateur frequencies. It involves bringing the antenna proper into the operating room and hence into close relationship with the house and electric wiring, which usually means that some of the power is wasted in heating poor conductors in the field of the antenna. Also, it usually means that the shape of the antenna must be distorted so that the expected directional effects are not realized, and likewise means that the height is limited. For these reasons, in high-frequency work practically all amateurs use feeder systems which permit putting the antenna in a desirable location. The feeders do not radiate or dissipate themselves any substantial proportion of the power supplied by the transmitter, provided good design practice is followed.

Much of the confusion that surrounds antenna systems in the mind of the average amateur is associated with the various types of feeder systems. These will therefore be given attention in detail before the more complicated antenna systems are discussed.

Transmission Lines

The most generally applicable form of feeder or transmission is the resonant line described in Chapter Four. It may be used directly, or as a coupling link between the antenna and other types of transmissions lines, finding employment in the latter capacity because of its impedance-transforming properties.

THE RESONANT TWO-WIRE LINE

As explained in Chapter Four, the resonant line is simply an antenna folded back on itself so that the radiation from one half is cancelled by the out-of-phase radiation from the other half. Such a line may be any whole-number multiple of a quarter-wave in length; in other words any total wire length which will accommodate a whole number of standing waves. (The "length", however, of a two-wire line is always taken as the length of one of the wires.)

Quarter- and half-wave resonant lines are shown in Fig. 1309, together with the current and voltage distribution. These two are important practical cases. It will be noted that the quarter-wave line has maximum current at the closed end and minimum current at the open end; the reverse is true of the voltage. The half-wave line, however, has the same current and voltage values at both ends; if the line is closed at one end, the current is maximum at both ends and the voltage minimum, while if both ends are open the current is minimum and the voltage maximum at the ends. The terms "open" and "closed" as used here do not mean necessarily that nothing is connected to the line, or that the line is short-circuited. Actually, of course, something must be connected to the line for it to function; the "open" end would be connected to a high-voltage low-current circuit and the "closed" end to a low-voltage high-current circuit.

Such lines are ideally suited to connection to a resonant antenna. As shown in Fig. 1302, the end of a half-wave antenna is a point of high-voltage and low current. If directly excited, it would be coupled, preferably, to the transmitter through the separate antenna tank circuit of Fig. 1308-C. However, if instead we connect a quarter-wave line to the end of the antenna as shown in Fig. 1310-A, then at the transmitter end of the line we shall have high current and low voltage, so that current feed (Fig. 1308-A) with a coil and series condensers (*series tuning*) can be used. Should the line be a half-wave long, as at 1310-B, current will be minimum at the transmitter end of the line, just as it is at the end of the antenna. Voltage

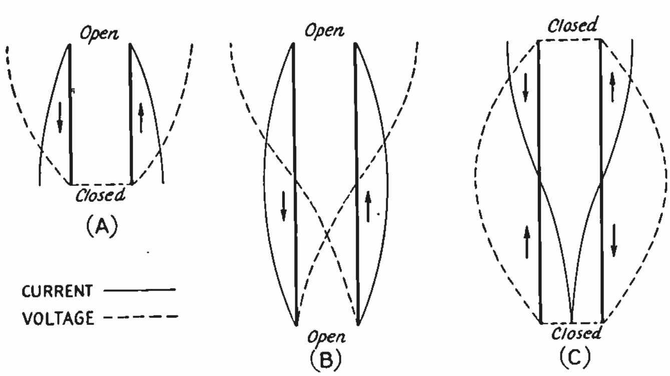


FIG. 1309 — CURRENT AND VOLTAGE DISTRIBUTION ON RESONANT LINES

***A*, quarter-wave line; *B*, half-wave line open (high voltage) at both ends; *C*, half-wave line closed (high-current) at both ends. Note that with the quarter-wave line one end is "closed" and the other "open."**

World Radio History

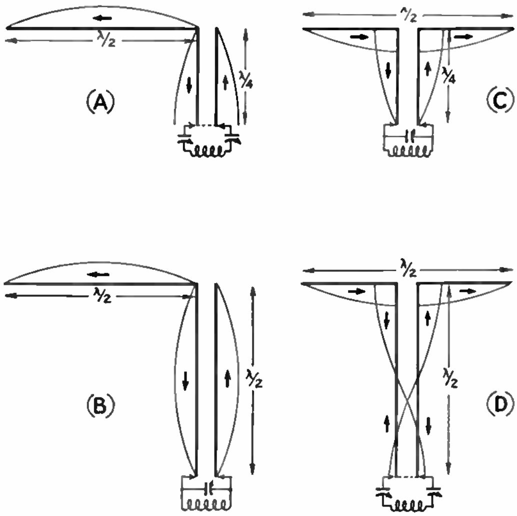


FIG. 1310 — HALF-WAVE ANTENNAS FED FROM RESONANT LINES

A and B, and feed with quarter- and half-wave lines; C and D, center feed. The current distribution is shown for all four cases.

feed therefore is required and the parallel-resonant tuned circuit (Fig. 1308-C) (*parallel-tuning*) must be used. (Parenthetically, it may be said that the line could be coupled to a balanced final tank through small condensers, as in Fig. 1308-B, but the inductively-coupled circuit is preferable for a number of reasons.) An end-fed antenna with resonant feeders, as in 1310-A and *B* is known as the "Zeppelin," or "Zepp," antenna.

The line also may be inserted at the center of the antenna at the maximum-current point. Quarter- and half-wave lines used in this way are shown at Fig. 1310-C and *D*. In *C*, the antenna end of the line is "closed," hence at the transmitter end the current is low and the voltage high. Parallel tuning therefore is used. The half-wave line at *D* has high current and low voltage at both ends, so that series tuning is used at the transmitter end.

A significant point to be noted is that the *antenna* determines the distribution of voltage and current, and that nothing can be done at the transmitter end of the line to affect it. In Fig. 1310-C, for instance, series tuning (current feed to the feeders) cannot be used because there *must* be high current at the center of the half-wave antenna if it is to operate; consequently the voltage must be high at the transmitter end of the quarter-wave feeder. If we attempt to make this end of the feeder carry high current we should have to have high voltage at the center of the antenna. Logically it follows that, since each end of the antenna is one-quarter wave from the center, we should have to have high current at the antenna ends. This of course is impossible. If series tuning is used in the arrangement of Fig. 1310-C it will be found that the combination "will not tune"; in other words, the antenna will not take power from the transmitter.

Line Length

As in the case of the antenna, the line length is not exactly the same as the length of the wave in space. Provided the wires are not too close and do not have insulating spacers at too-close intervals, the actual length will be only about 2.5 per cent less than the wavelength. A half-wave open-wire line therefore will be slightly longer than a half-wave antenna. Its length is given by the formula

$$\text{Length of two-wire half-wave line (feet)} = \frac{480}{\text{Freq. (Mc.)}}$$
$$\text{Length of two-wire } \tfrac{1}{4}\text{-wave line (feet)} = \frac{240}{\text{Freq. (Mc.)}} \qquad (2)$$

Lines of greater length can be calculated by multiplying the value given by the formula by the appropriate factor.

The formula given above applies only to open-wire lines. With other types of construction, to be considered later, the reduction factor is greater.

Line Spacing

For effective cancellation of radiation, the spacing between the two wires must be small in comparison to the wavelength; a separation of 0.01 wavelength or less is desirable. For 14 Mc. and lower, the wires need not be closer than six inches, the length of the popular "feeder spreaders" manufactured for this purpose. Even at 28 Mc. a separation of 6 inches is fairly satisfactory, but for the ultra-high frequencies the wires should be closer together.

From the practical standpoint, too-close spacing is undesirable, especially with long sections of line. The wires inevitably swing with respect to each other when there is wind; if the spacing is close, this means that insulating spreaders must be installed at frequent intervals to prevent the wires from touching, and this in turn increases the weight of the line. Swinging also causes a varying detuning effect, since the change in spacing represents a change in capacity which reacts on the transmitter, and is evidenced by periodic variations in loading.

For work on communication frequencies, the 6-inch spacing represents a compromise which works out well in practice.

World Radio History

Practical Antennas Using Resonant-Line Feed

The four arrangements shown in Fig. 1310 are thoroughly useful antenna systems, and are shown in more practical form in Fig. 1311. In each case the antenna is a half-wavelength long, the exact length being calculated from Equation (1) or taken from the charts of Fig. 1303. The line length should be an integral (whole-number) multiple of a quarter wavelength, and may be calculated from Equation (2) the result being multiplied by any whole number which gives a total length convenient for reaching from the antenna to the transmitter. If there is an *odd* number of quarter waves on the line in the case of the end-fed antenna, series tuning will be used at the transmitter end; if an *even* number of quarter waves, then parallel tuning is used. With the center-fed antenna the reverse is true.

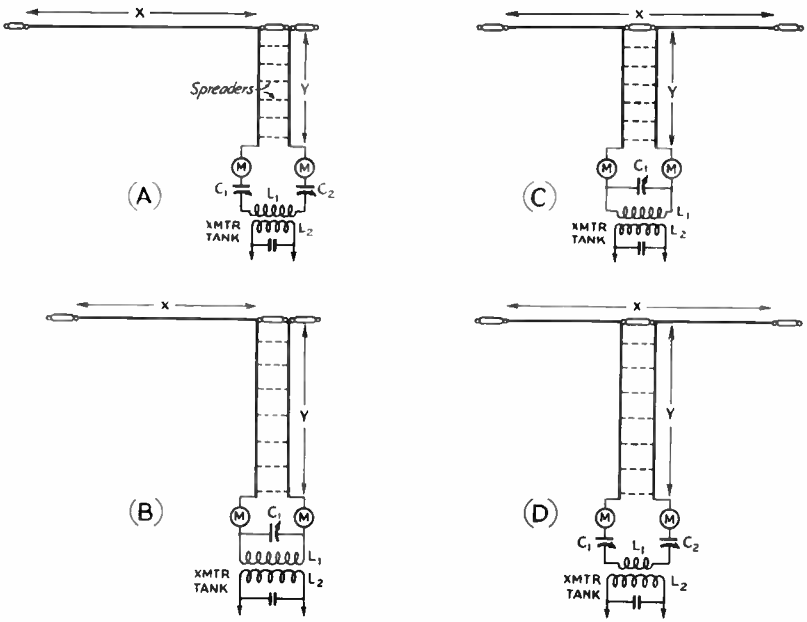


FIG. 1311 — PRACTICAL HALF-WAVE ANTENNA SYSTEMS USING RESONANT-LINE FEED

In the center-feed systems, the antenna length "X" does not include the length of the insulator at the center. Line length is measured from the antenna to the tuning apparatus; leads in the latter should be short enough to be neglected. The two meters shown are helpful for balancing feeder currents; however, one is sufficient for tuning for maximum output, and may be transferred from one feeder to the other other, if desired. The systems at (A) and (C) are for feeders an odd number of quarter-waves in length; (B) and (D) for feeders a multiple of a half wavelength. The drawings correspond electrically to those of Fig. 1310.

Tuning

The tuning procedure with series tuning is as follows: With C_1 and C_2 at minimum capacity, couple the antenna coil L_1 loosely to the transmitter output tank coil and observe the plate current. Then increase C_1 and C_2 simultaneously, watching for the rise in plate current which indicates that the antenna system is being brought into resonance with the transmitting frequency. Continue until the final amplifier takes rated plate current; if further increase of capacity at C_1 and C_2 makes the plate current greater than normal, the coupling between L_1 and L_2 should be reduced. At the rated plate current point, readjust the amplifier tank condenser for resonance, as indicated by minimum plate current (this minimum of course will be near the rated value for the amplifier) since the antenna circuit may

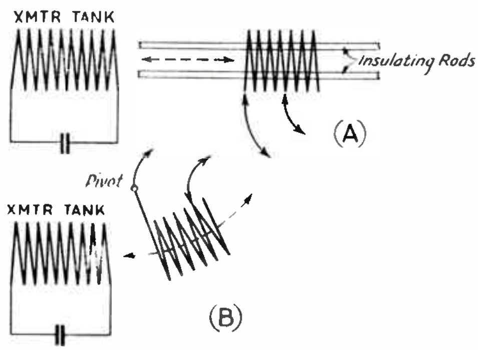


FIG. 1312 — TWO WAYS OF VARYING COUPLING BETWEEN FINAL TANK AND ANTENNA COILS

World Radio History

react on the final tank to change its tuning slightly. Always use the degree of coupling between L_1 and L_2 which will just bring the amplifier plate current to rated value when C_1 and C_2 pass through resonance. The r.f. ammeters should indicate maximum feeder current at this setting; these meters are not strictly necessary, but are useful in indicating maximum output from the transmitter.

With parallel tuning the procedure is quite similar, except that only one antenna condenser is used. Find the value of coupling between L_1 and L_2 which will bring the plate current to the desired value as C_1 is tuned through resonance. Again a slight readjustment of the amplifier tank condenser may be necessary to compensate for the effect of coupling.

Feeder Current

The feeder current as read by the r.f. ammeters is useful for tuning purposes only; the absolute value is of little importance. When series tuning is used the current will be high, but very little current will be indicated in a parallel-tuned system. This is because of the current distribution on the feeders as shown by Fig. 1310. With a given antenna and tuning system, of course, the greatest power will be delivered to the antenna when the readings are highest. However, should the feeder length be changed no useful conclusions can be drawn from comparison between the new and old readings. For this reason any indicator which registers the relative intensity of r.f. current can be used for tuning purposes. Many amateurs, in fact, use flashlight or dial lamps for this purpose instead of meters. They are cheap, and when shunted by short lengths of wire so that considerable current can be passed without burnout will serve very well even with high-power transmitters.

Circuit Values

The values of inductance and capacity to use in the antenna coupling system will depend upon the transmitting frequency, but are not particularly critical. With series tuning, the coil may consist of a few turns of the same construction as is used in the final tank; average values will run from two or three turns at 28 Mc. to perhaps 10 or 12 at 3.5 Mc. The number of turns preferably should be adjustable so that the inductance can be changed should it not be possible to reach resonance with the condensers used. The series condensers should have a maximum capacity of 250 or 350 $\mu\mu$fd. at the lower frequencies; the same values will serve even at 28 Mc., although 100 $\mu\mu$fd. will be ample for this and the 14-Mc. band. Since series tuning is used at a low-voltage point in the feeder system, the plate spacing of the condensers does not have to be large. Ordinary receiving-type condensers are large enough for plate voltages up to 1000, and the smaller transmitting condensers have high-enough voltage ratings for higher-power applications. With high-power 'phone it may

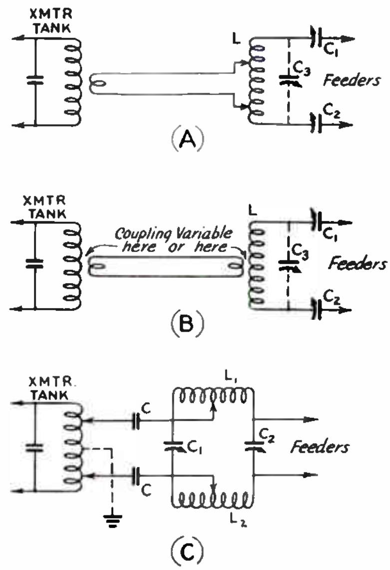


FIG. 1313 — ANTENNA COUPLING SYSTEMS WITHOUT MOVABLE COILS

***A* and *B*, link-coupled circuits for series and parallel tuning; *C*, balanced low-pass filter. In *A* and *B*, dotted lines show connections for parallel tuning when called for; in such case the series condensers, C_1 and C_2, may be set at maximum capacity or short-circuited. Constants for L, C_1, C_2 and C_3 are the same as for inductive coupling, and are discussed in the text.**

In *C*, C_1 and C_2 may be 100 to 250 $\mu\mu$fd. each, the higher-capacity values being used for lower-frequency operation (3.5 and 1.75 Mc.). Plate spacing should in general be at least half that of the final amplifier tank condenser. For operation from 1.75 to 14 Mc., L_1 and L_2 each should be 15 turns 2½ inches in diameter, spaced to occupy 3 inches length, and tapped every three turns. Approximate settings are 15 turns for 1.75 Mc., 9 turns for 3.5 Mc., 6 turns for 7 Mc., and 3 turns for 14 Mc. The coils may be wound with No. 14 or No. 12 wire. See text for method of adjustment.

be necessary to use condensers having a plate spacing of approximately 0.15 to 0.2 inch.

In parallel-tuned circuits the antenna coil and condenser should be approximately the same as those used in the final tank circuit. A high L/C ratio may be of some benefit. The point to remember is that the antenna tank circuit must be capable of being tuned independently to the transmitting frequency.

Alternative Coupling Circuits

The coupling arrangements in Fig. 1311 are simple and easy to adjust, but the antenna coil must be arranged so that its position with

World Radio History

respect to the output tank coil can be changed. In practice, the antenna coil usually is mounted so that it can be moved toward or away from the final tank coil (the two coils being coaxial) on insulating bars or some other device which permits the coil to be slid back and forth. A swinging mount also can be used. The general idea is illustrated in Fig. 1312. These schemes are sometimes inconvenient for mechanical reasons.

Coupling circuits which do not involve moving coils — or at most only a variable link coil of the type now available on manufactured transmitting coils — are shown in Fig. 1313. At *A* is a link-coupled system with taps on the antenna coil for adjusting the loading. The link at the transmitter tank coil may consist of one or two turns wound around the coil at a low-potential point. At the antenna circuit, the taps are kept equidistant from the center of the coil, the number of turns between taps being adjusted to give the desired plate current when the antenna-feeder system is tuned to resonance. The tap adjustment will be right when the antenna condenser or condensers bring the plate current to the desired value just as they are passing through resonance. The system may be used with either series or parallel tuning; the circuit values will be the same as with the inductively-coupled arrangements of Fig. 1311. When the coupling and tuning adjustments are correct there will be practically no detuning effect on the transmitter tank; that is, the resonance setting should be the same both with and without the link in place.

In *B*, link coupling is used at both ends, in which case the coupling between one coil and its link must be variable. Variable coupling at either end will be satisfactory. Swinging links such as those shown in Chapter Eight may be used, or the link coil may be mounted inside the tank or antenna coil and arranged so that it may be rotated with respect to the coil. The adjustment method is the same as with the circuit of *A* except that the link position at the variable-coupling end is changed instead of the taps. Either series or parallel tuning again may be used.

Suitable link lines may be made from twisted rubber-covered pair, just as in the case of link-coupled stages in the transmitter. They may be of any convenient length, so that the antenna tuning unit may be mounted at the point where the feeders enter the building or operating room, if desired, regardless of the position of the transmitter. Fig. 1314 is a photograph of a typical antenna-tuning unit of this type, suitable for transmitters of moderate power; its circuit diagram is given in Fig. 1315. The coil is tapped so that it may be used either for series or parallel tuning on different bands, and the unit is provided with clip leads for connecting the condensers either in series or parallel.

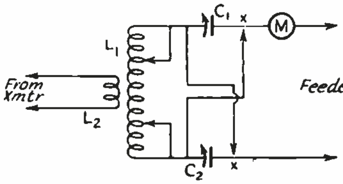


FIG. 1315 — CIRCUIT DIAGRAM OF THE ANTENNA-TUNING UNIT

C_1, C_2 — 100 $\mu\mu$fd., 0.07-inch spacing (National TMC-100).
L_1 — 22 turns No. 14, diameter 2¾ inches, length 4 inches (Coto with variable link).
L_2 — 4 turns rotating inside L_1.
M — R.f. ammeter, 0–2.5 for medium-power transmitters.

For parallel tuning, clips should be attached at points marked "X." Clips left free for series tuning.

A balanced pi-section coupling network is shown in Fig. 1313-C. This is a low-pass filter, and is capable of coupling between a fairly wide range of impedances such as is encountered in going from series to parallel tuning. Suitable constants are given under the diagram. The method of adjustment is as follows: First, with the filter disconnected, tune the transmitter tank circuit to resonance, as evidenced by minimum plate current. Then, with trial settings of the clips on L_1 and L_2 (few turns for high frequencies, more for lower) tap the input clips on the final tank coil at points equidistant from the center so that about half the coil is included between them. A balanced tank circuit must be used. Set C_2 at about half scale, apply power, and rapidly rotate C_1 until the plate current drops to a minimum. If this minimum is not the desired full-load plate current, try a new setting of C_2 and repeat. If, for all settings of C_2, the plate current is too high or too low, try new settings of the taps on L_1 and L_2, and also on the transmitter tank. Do not touch the tank condenser during these adjust-

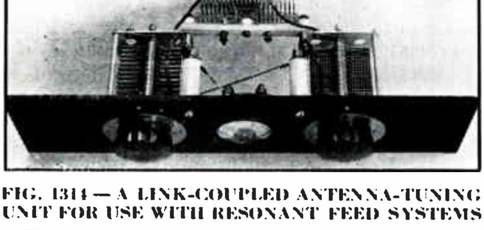


FIG. 1314 — A LINK-COUPLED ANTENNA-TUNING UNIT FOR USE WITH RESONANT FEED SYSTEMS

The inductance, with variable link, is mounted on the condenser frames. Clips are provided for changing the number of turns, and for switching the condensers from series to parallel.

World Radio History

ments. When, finally, the desired plate current is obtained, set C_1 carefully to the exact minimum plate-current point. *This adjustment is important in minimizing harmonic output.*

Feeder Lengths

The fact that the feeder-tuning apparatus makes it possible to vary the electrical length of the feeder obviates, to some extent, the necessity for cutting resonant feeders to exact integral multiples of a quarter wavelength. It is, in fact, possible to depart as much as 25% of a quarter wave from the exact length and still tune the system properly. In such case, the type of tuning to use, series or parallel, will depend on whether the length of the feeder is nearer an odd number of quarter waves or nearer an even number.

Departure from the exact length is often convenient on the lower frequencies, where even a quarter-wave feeder may be physically longer than is desired. At 3500 kc., for example, a quarter-wave line is approximately 67 feet long. Its length could be reduced to 50 feet and still be made to resonate with series tuning by using a sufficiently large coupling coil. In such case the condensers might be shorted out and the tuning done by varying the coil inductance. Alternatively, a 100-foot line could be used on the same frequency by using a smaller coil and reduced series capacity.

Whenever possible, however, it is advisable to stick to the integral multiples of a quarter wavelength. This is the surest way of avoiding the tuning difficulties which often arise when the line is midway between lengths calling for series and parallel tuning.

Antenna Length in Relation to Feeder Operation

It has been previously pointed out that insofar as the operation of the antenna is concerned, departures of a few per cent from the exact length for resonance are of negligible consequence. Such inaccuracies may influence the behavior of the feeder system, however, and as a result may have an adverse effect on the operation of the system as a whole. This is true of the end-fed antennas such as are shown in Fig. 1311-A and -B.

For example, Fig. 1316-A shows the current distribution on the half-wave antenna and quarter-wave feeder when the antenna length is correct. At the junction of the "live" feeder and the antenna the current is minimum so that the currents in the two feeder wires are equal at all corresponding points along their length. When the antenna is too long, as in *B*, the current minimum occurs at a point on the antenna proper, so that at the top of the live feeder there is already appreciable current flowing, whereas at the top of the "dead" feeder the current must be zero. As a result, the feeder currents are not balanced and some power will be radiated from the line. In *C* the antenna is too short, bringing the current minimum to a point on the live feeder, so that again the currents are unbalanced. The more serious the unbalance the greater the radiation from the line.

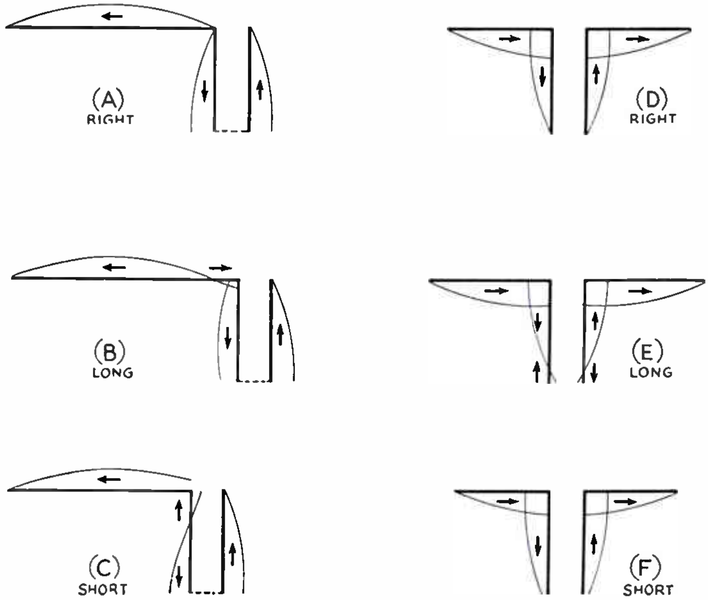


FIG. 1316 — EFFECT ON FEEDER BALANCE OF INCORRECT ANTENNA LENGTH

With center feed, incorrect antenna length does not unbalance the feed system, as it does with end feed.

Strictly speaking, a line having an unbalanced connection such as the one-way termination at the end of an antenna cannot be truly balanced even though the antenna length is correct. This is because of the difference in loading on the two sides. The effect is fairly small, however, when the currents are balanced, and the illustration just given serves to emphasize the importance of correct antenna length.

World Radio History

If the antenna is fed at the center the undesirable effects of incorrect antenna length balance out so that the line operates properly under all conditions. This is shown in Fig. 1316 at *D*, *E* and *F*. So long as the two halves of the antenna are of equal length, the distribution of current on the feeders will be symmetrical so that no unbalance exists, even for antenna lengths considerably removed from the correct value.

Adjusting the Antenna Length

Although the formula and charts for antenna length are sufficiently accurate under average conditions, height, nearness of the wire to houses, trees, etc., may make the required actual length differ somewhat. When the antenna is to be end-fed, then, it is desirable to adjust the length to the right value if feeder radiation is to be avoided.

A fairly simple way to adjust the length is to leave off the connection between the antenna and feeder (but with the feeders in place) and hoist the assembly to its final position. Then carry out the tuning procedure just as described previously, using loose coupling so that the resonance point is quite marked. Low power should be used, especially with series tuning, since without the antenna connected the feeder current will be much greater than normal. Then lower the antenna, connect the feeder, hoist again, and with the coupling just as it was before, again adjust the antenna condensers to resonance. If resonance occurs at the same condenser settings the antenna length is correct. If more capacity must be used, the antenna is too short; if less, the wire is too long. Add or subtract, as the case may be, a few inches to the antenna and try again. The correct length should be found after a few trials. The antenna may be intentionally made a little long in the first place so that no joints in the wire will be needed when the final length is reached.

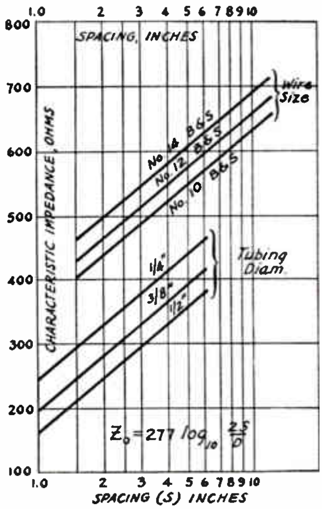


FIG. 1317 — GRAPHICAL TABLE OF CHARACTERISTIC IMPEDANCES OF TYPICAL SPACED-CONDUCTOR TRANSMISSION LINES

An alternative method is to use a regenerative detector as a resonance indicator, coupling it loosely to the antenna, from which the feeders are disconnected for the test. Careful tuning with the detector just oscillating will show resonance as a setting at which the detector is pulled out of oscillation. The frequency at which this occurs may be checked by one of the methods given in Chapter Sixteen; if it is higher than desired the antenna should be lengthened and *vice versa*.

NON-RESONANT TRANSMISSION LINES

As explained in Chapter Four, standing waves will not exist on a transmission line terminated (at the receiving end, or the other end from that at which power is applied) in its characteristic or surge impedance. Such lines may resemble the resonant lines in physical construction, but their operation and adjustment are different. In contrast to the resonant lines, non-resonant or untuned lines may be any desirable length, since there are no standing waves.

The surge impedance of a line consisting of two parallel conductors depends upon the inductance and capacity of the line per unit of length. In turn, these quantities depend upon the size of the conductors, their spacing, and the dielectric constant of the insulating medium between them. When the dielectric is air, the surge impedance of two parallel conductors is given by the formula

$$Z = 276 \log \frac{b}{a} \qquad (3)$$

where Z is the surge impedance, b the spacing, center to center, and a the radius of the conductor. The quantities b and a must be measured in the same units (inches, etc.). Surge impedance as a function of spacing for lines using conductors of different size is plotted in chart form in Fig. 1317.

A less common form of transmission line consists of a wire located axially in a metal tube, the two being insulated from each other. This type of line is useful for special applications where the radiation must be reduced to negligible proportions, and where low impedance is required. The surge impedance of such a *concentric* or *coaxial* line is given by the formula:

$$Z = 138 \log \frac{b}{a} \qquad (4)$$

where Z again is the surge impedance. In this case, however, b is the *inside diameter* (not radius) of the outer conductor and a is the *outside diameter* of the inner conductor. The formula is true for air dielectric, and approximately so for a line having ceramic insulators so spaced that the major proportion of the insulation is air.

A third type of line is simply a single wire. The surge impedance of such a line made of No. 14 wire will be approximately 500 ohms. This type of line has the disadvantage that no provision is made for cancelling radiation as in the case of two-conductor lines. If the line is not too long, however, the radiation will be relatively small because the current in the line is small compared to the antenna current.

In all non-resonant lines feeding antennas it is essential that the line be attached to the antenna in such a way that the impedance at the termination, or "looking out of the line" is equal to the surge impedance of the line. This impedance-matching can be done in various ways, depending upon the line impedance. If the impedance match is not exact, there will be standing waves on the line; their amplitude will be greater as the mismatch is more serious. It is customary to speak of the *standing-wave ratio*, which is the ratio of the current at a current maximum, or *loop*, to the current at a minimum point, or *node*. With a properly-matched line this ratio is 1. It may be as high as 50 on a resonant line; that is, the current at a loop may be 50 times as great as at a node.

In the following sections, several simple types of half-wave antenna systems using non-resonant lines will be considered. Let us repeat that the *antenna* performance is the same as that described earlier in the chapter; the feed system, if properly adjusted, does not affect the antenna's performance.

Single-Wire-Fed Antenna

In the single-wire-feed system the return circuit is considered to be through the "mirror" effect of the ground. There will be no standing waves on the feeder when its characteristic impedance is matched by the impedance of the antenna at the connection point. The principal dimensions are the length of the antenna L, Fig. 1318, and the distance D from the exact center of the antenna to the point at which the feeder is attached. Approximate dimensions can be obtained from Fig. 1303 for an antenna system having a fundamental frequency in any of the amateur bands.

In constructing an antenna system of this type the feeder must run straight away from the antenna (at a right angle) for a distance of at least one-third the length of the antenna. Otherwise the field of the antenna will affect the feeder and cause faulty operation. There

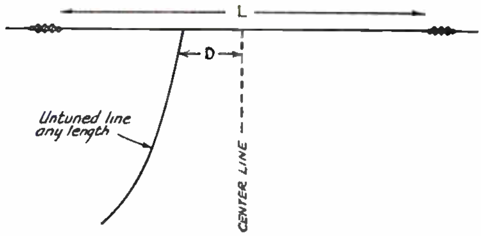


FIG. 1318 — SINGLE-WIRE FEED SYSTEM
The length L (one-half wavelength) and D are determined from the chart, Fig. 1303.

should be no sharp bends in the feeder wire at any point.

Correct antenna length and placing of the feeder should be checked experimentally if best results are to be obtained. If, for instance, impedances are not correctly matched, standing waves will appear upon the line. With simple capacitive coupling to the feeder, high r.f. potentials may, as a result, develop at undesirable points in the transmitter. A good ground connection should be made to the filament center-tap or center point of the filament by-pass condensers when this system is used. The presence of standing waves may be detected most accurately by placing a low-reading thermo-ammeter at several points approximately ¼ wave apart along the transmission line. The reading should be substantially constant all along the line with no indication of pronounced increases or decreases.

Several methods of coupling to the output circuit are shown in Fig. 1319. With an unbalanced output circuit the feeder may be tapped directly on the output tank circuit coil. Starting at the ground end of the tank coil, the tap is moved towards the plate end until the amplifier draws the rated amount of plate current. The condenser in the feeder is for the purpose of insulating the antenna system from the high-voltage plate supply when series plate feed is used. It should have a voltage rating somewhat above that of the plate supply. Almost any capacity greater than 500 $\mu\mu$fds. will be satisfactory. The condenser is unnecessary, of course, if parallel plate feed is used. In coupling to balanced output circuits, the inductive method shown at the lower right is preferred. The antenna tank circuit should tune to resonance at the operating frequency and the tap is adjusted as explained previously. Regardless of the type of coupling, a good ground connection is essential with this system. Single-wire-feed systems work best over moist ground, and poorly over rock and sand.

Twisted-Pair Feeders

It is evident from the formula for characteristic impedance previously given that the

World Radio History

closer the spacing and the larger the wires, the lower will be the impedance. It happens that the impedance of a two-wire line composed of twisted No. 14 rubber-covered wire of the type used in house wiring will be approximately that of the center of the antenna itself, thus simplifying the method of connecting the line to the antenna. Such discrepancy as may exist between line and antenna impedance can be compensated for by a slight fanning of the line where it connects to the two halves of the antenna, as shown in Fig. 1320.

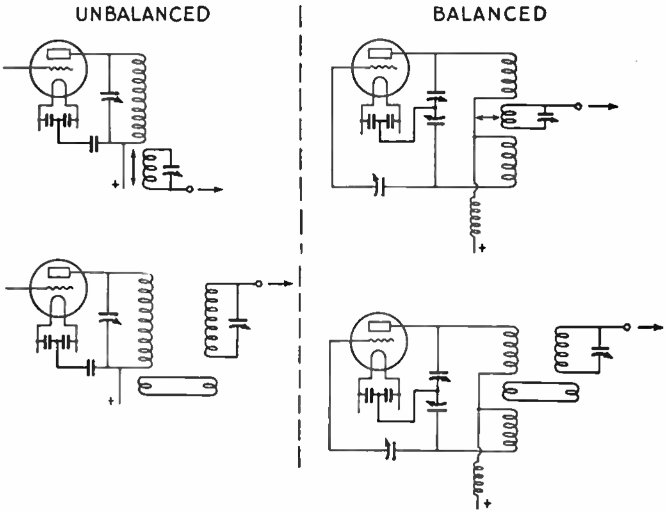


FIG. 1319 — METHODS OF COUPLING THE SINGLE-WIRE FEEDER TO THE TRANSMITTER

Circuits are shown for both single-ended and balanced tank circuits. They are discussed in the text.

The twisted line is a convenient type to use, since it is easy to install and the r.f. voltage on it is low because of the low impedance. This makes insulation an easy matter. The losses are slightly higher than those in spaced lines with air insulation, however, and will increase with frequency. Special twisted line for transmitting purposes, having lower losses than ordinary rubber-covered wire, is available. It is known as "EO-1" cable.

The antenna should be one-half wavelength long for the frequency of operation, as determined by the formula previously given. For accuracy, its length may be checked as described earlier in this chapter, this checking being done before the antenna is cut at the center to insert the feeder. The amount of "fanning" (dimension B) will depend upon the kind of cable used; the right value usually will be found between 6 and 18 inches. It may be checked by inserting ammeters in each antenna leg at the junction of the feeder and antenna; the value of B which gives the largest current is correct. Alternatively, the system may be operated continuously for a time with fairly high r.f. power input, after which the feeder may be inspected (by touch) for hot spots. These indicate the presence of standing waves, and the fanning should be adjusted until they are eliminated or minimized. Each leg of the feeder forming the triangle at the antenna should be equal in length to dimension B.

Methods of coupling to the transmitter are discussed in a later section (Fig. 1323).

Half-Wave Antenna Fed by Concentric Line

A concentric transmission line readily can be constructed to have a surge impedance equal to the 70-ohm impedance at the center of a half-wave antenna. Such a line, therefore, can be connected directly to the center of the antenna, forming the system shown in Fig. 1321.

Solving Equation (4) for an air-insulated concentric line shows that, for 70-ohm surge impedance, the inside diameter of the outer conductor should be approximately 3.2 times the outside diameter of the inner conductor. This condition can be fulfilled by using standard 5/16-inch (outside-diameter) copper tubing for the outer conductor and No. 14 wire for the inner. Ceramic insulating spacers are available commercially for this combination.

Also available is a rubber-insulated concen-

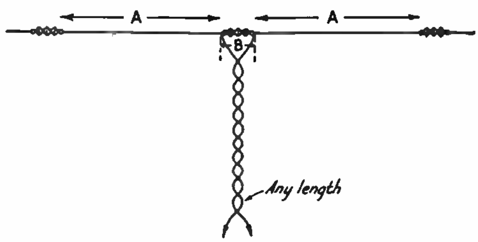


FIG. 1320 — A HALF-WAVE ANTENNA CENTER-FED BY A TWISTED PAIR LINE

An improved impedance match often will result if the antenna end of the line is fanned out in the shape of a "V" for the last 18 inches or so of its length. Two insulators also should be used at the center of the antenna so the open end of the "V" will be approximately 18 inches wide. "A" plus "A" should equal one-half wavelength for the operating frequency. See Equation (1).

World Radio History

tric line, with wire inner conductor and metal braid outer conductor, having the requisite impedance for connection to the center of the antenna. This type is more flexible and considerably lighter, but has somewhat higher losses.

The operation of such an antenna system is similar to that of the twisted-pair system just described, and the same transmitter-coupling arrangements may be used. A simple form of coupling is shown in Fig. 1321, consisting of a loop of a few turns of wire placed around or near the transmitter tank coil. No tuning apparatus is required, the loading being adjusted by varying the coupling between the two coils.

The outer conductor of the line may be grounded if desired. The feeder system is slightly unbalanced because the inner and outer conductors do not have the same capacity to ground. There should be no radiation, however, from a line having the correct surge impedance.

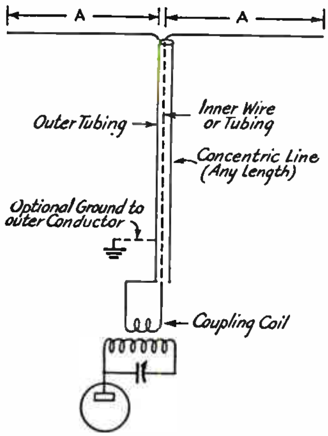


FIG. 1321 — HALF-WAVE ANTENNA WITH CONCENTRIC TRANSMISSION LINE

A plus A should be one-half wavelength as determined by Equation (1).

Half-Wave Antenna with Impedance-Matching "Y"

Because of the extremely close spacing required, it is impracticable to construct an open-wire transmission line which will have a surge impedance low enough to work directly into the center of a half-wave antenna. Such wire lines usually have impedances between 400 and 700 ohms, 600 ohms being a widely-used value. It is therefore necessary to use other means for matching the line to the antenna.

One method of matching is illustrated by the antenna system of Fig. 1322. The section E is "fanned" to have a gradually increasing impedance so that its impedance at the antenna end will be equal to the impedance of the antenna section C, while the impedance at the lower end matches that of a practicable transmission line.

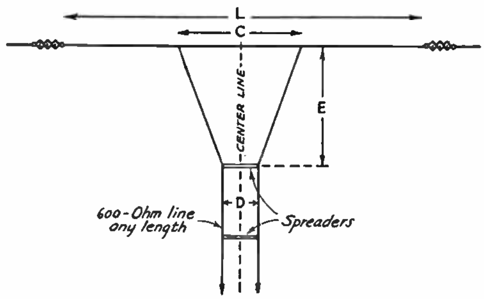


FIG. 1322 — TWO-WIRE MATCHED-IMPEDANCE ANTENNA SYSTEM

The dimensions C, D, and E are given in the text. It is important that the matching section, E, come straight away from the antenna without any bends. L is one-half wavelength for the operating frequency. See Equation (1).

The antenna length L, the feeder clearance E, the spacing between centers of the feeder wires D, and the coupling length C are the important dimensions of this system. The system must be designed for exact impedance values as well as frequency values and the dimensions are therefore fairly critical.

The length of the antenna is figured from the formula or charts previously given.

The length of section C is computed by the formula:

$$C \text{ (feet)} = \frac{123}{\text{Freq. (Mc.)}}$$

The feeder clearance E is worked out from the equation:

$$E \text{ (feet)} = \frac{148}{\text{Freq. (Mc.)}}$$

The above equations are for feeders having a characteristic impedance of 600 ohms and will not apply to feeders of any other impedance. The proper feeder spacing for a 600-ohm transmission line is computed to a sufficiently close approximation by the following formula:

$$D = 75 \times d$$

where D is the distance between the centers of the feeder wires and d is the diameter of the wire. If the wire diameter is in inches the spacing will be in inches and if the wire diameter is in millimeters the spacing will be in millimeters.

Methods of coupling to the transmitter are discussed in the following section.

World Radio History

Coupling to Untuned Lines

Similar coupling methods are used with all types of two-wire transmission lines, whether of high or low impedance. Several systems are shown in Fig. 1323. The inductively coupled methods are preferable to direct coupling when a single-ended or unbalanced tank circuit feeds a balanced transmission line; this avoids line unbalance which might occur with direct coupling. In the direct-coupled circuits, the fixed condensers are useful only when the output amplifier plate supply is series-fed. These condensers, when used, should have a rating somewhat above the maximum plate voltage used and should have a capacity of 500 μμfds. or more. With the methods *B, C, D* or *E,* the taps should be placed symmetrically about the center or r.f. ground point on the coil. The taps should be adjusted to make the final amplifier draw normal plate current; if the line is operating properly the taps will not affect the setting of the plate tank condenser. In the case of the methods shown at *B* and *D* the coupling tank is first adjusted to resonance with the plate tank circuit, using loose coupling; the taps are then set at trial positions and the current in the line measured. The tap positions and coupling between the coils are then adjusted to give maximum line current with normal tube plate current.

The filter network shown at *E* is the same as that already described in connection with resonant transmission lines (Fig. 1313), its adjustment when used with non-resonant lines also is identical.

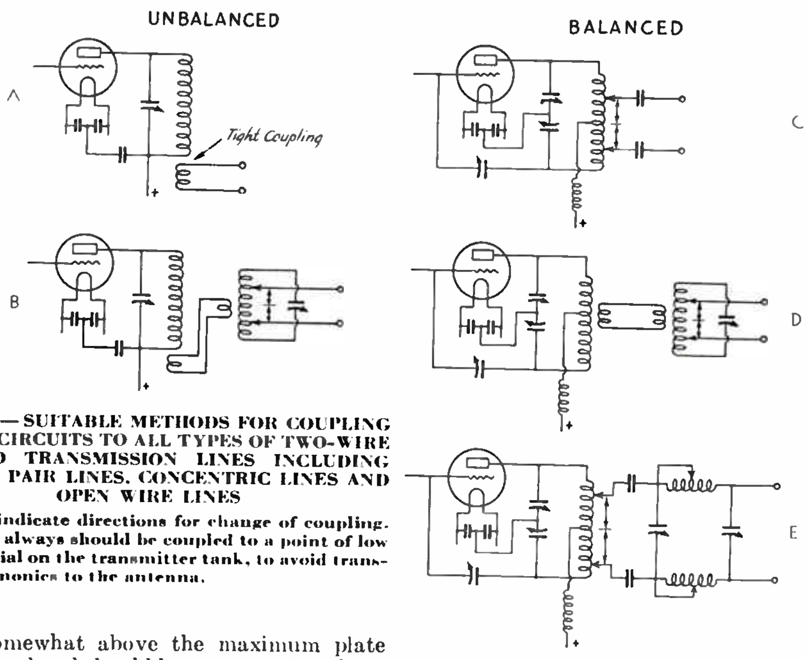


FIG. 1323 — SUITABLE METHODS FOR COUPLING OUTPUT CIRCUITS TO ALL TYPES OF TWO-WIRE UNTUNED TRANSMISSION LINES INCLUDING TWISTED PAIR LINES, CONCENTRIC LINES AND OPEN WIRE LINES

Arrows indicate directions for change of coupling. Link lines always should be coupled to a point of low r.f. potential on the transmitter tank, to avoid transfer of harmonics to the antenna.

LINEAR MATCHING SECTIONS

In the antenna-feeder systems just described, impedance matching depends upon connecting the line to an appropriate point on the antenna. This method is not always possible or convenient, and it therefore becomes necessary to connect an impedance-matching transformer between the line and antenna. The "transformer" ordinarily used does not resemble the ordinary coupled r.f. circuit, but is simply a section of transmission line. A quarter-wave two-wire transmission line is such a "linear transformer." Its operation is described in Chapter Four.

When such a quarter-wave line has a given value of impedance connected to one end, the impedance appearing at the other end depends upon the surge impedance of the line:

$$Z_1 = \frac{Z_s^2}{Z_2}$$

where Z_1 is the unknown impedance at one end, Z_2 the known impedance at the other end, and Z_s is the line surge impedance. At intermediate points on the line the impedance will be intermediate between the two end values. It is therefore possible to tap along the line to match a wide range of impedances, when the

World Radio History

quarter-wave "matching section" is connected to a high- or low-impedance point on the antenna.

Quarter-wave matching sections are particularly useful when a non-resonant line, having a surge impedance of 600 ohms (a popular value) is to be matched to the antenna.

Half-Wave Antenna with Quarter-Wave Matching Section

Fig. 1324 shows two methods of coupling a non-resonant line to a half-wave antenna through a quarter-wave matching section. In the case of the center-fed antenna the free end of the matching section, *B*, is open (high impedance) since the other end is connected to a low-impedance point on the antenna. With the end-fed antenna the free end of the matching section is closed through a shorting bar or link; this end has low impedance since the other end is connected to a high-impedance point on the antenna.

In the center-fed system, the antenna and matching section should be cut to the lengths given by the formulas previously given. Any necessary on-the-ground adjustment can be made by adding to or clipping off the open ends of the matching section. The matching section in the end fed system can be adjusted by making the line a little longer than necessary and adjusting the system to resonance by moving the shorting link up and down. Resonance can be obtained by "shock-exciting" the antenna from a temporary antenna nearby (the transmitter being on the proper frequency, of course) and measuring the current in the shorting bar by a low-range r.f. ammeter or galvanometer. The position of the bar should be adjusted for maximum current reading. This should be done before the untuned line is attached to the matching section.

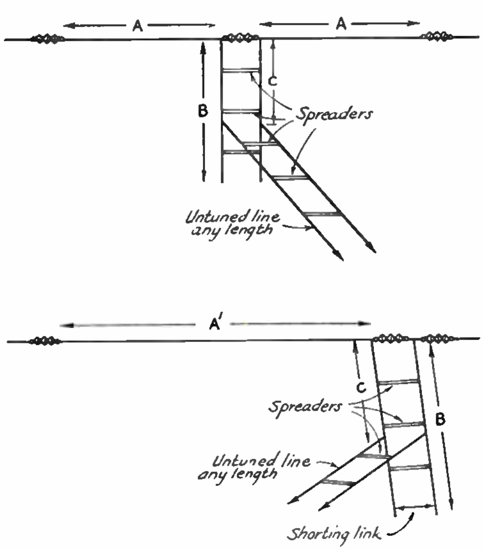


FIG. 1324 — IMPEDANCE-MATCHING ANTENNA SYSTEMS WITH QUARTER-WAVE OPEN WIRE MATCHING TRANSFORMERS

Antenna dimensions, A plus A in upper figure, A' in lower, can be found from Equation (1). The dimension B, one-quarter wavelength, can be found from Equation (2). The dimension C must be found by experiment, as described in the text.

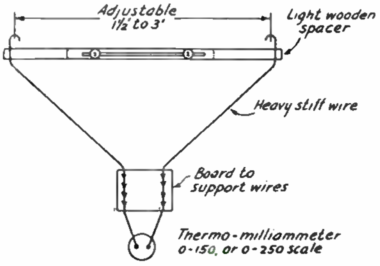


FIG. 1325 — LINE-CURRENT MEASURING DEVICE FOR ADJUSTMENT OF UNTUNED TRANSMISSION LINES

The position of the line taps must be determined experimentally, since it will depend upon the impedance of the line as well as the antenna impedance at the point of connection. The procedure is to take a trial point, apply power to the transmitter, and check the non-resonant line for standing waves. This can be done by measuring the current in the wires, using a device of the type pictured in Fig. 1325. The hooks (which should be sharp enough to cut through insulation, if any, of the wires) are placed on one of the wires, the spacing between them being adjusted to give a suitable reading on the meter. At any one position along the line the currents in the two wires should be identical. Readings taken at intervals of a quarter wavelength will indicate whether or not standing waves are present; if the readings differ by more than a few percent the line is not properly matched to the antenna. In that case the termination should be adjusted to bring the readings at quarter-wave intervals to the same value.

An impedance mismatch of several per cent is of little consequence so far as power transfer to the antenna is concerned. However, the presence of standing waves on the line increases the line losses to sizable amounts on long lines (several wavelengths) and may be responsible for radiation from the line.

When the connection between matching section and antenna is unbalanced, as in the end-fed system, it is important that the antenna be the right length for the operating frequency if a good match is to be obtained. The balanced center-fed system is less critical in this respect.

World Radio History

The shorting-bar method of tuning the center-fed system to resonance may be used if the matching section is extended to a half-wave-length, bringing a current loop at the free end.

The "Q" Antenna

The impedance of a two-wire line of ordinary construction (400 to 600 ohms) can be matched, without tapping, to the impedance of the center of a half-wave antenna by the use of a quarter-wave line of special characteristics. The matching section must have low surge impedance and therefore is commonly constructed of large-diameter conductors such as aluminum or copper tubing, with fairly close spacing. This type of antenna can be purchased in kit form and is known as the "Q" antenna. It is shown in Fig. 1326. The important dimensions are the length of the two halves of the antenna, *A*, the length of the matching section, *B*, the spacing between the two conductors of the matching section, *C*, and the impedance of the untuned transmission line connected to the lower end of the matching section.

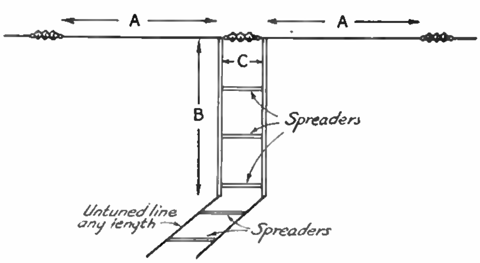


FIG. 1326 — THE "Q" ANTENNA WITH QUARTER-WAVE MATCHING SECTION USING SPACED TUBING

Antenna length, A plus A, can be calculated from Equation (1). The matching section length, B, is given by Equation (5). The spacing, C, depends upon the impedance of the untuned line, and can be found from the charts of Figs. 1317 and 1332.

The required surge impedance for the matching section is

$$Z_s = \sqrt{Z_1 Z_2}$$

where the quantities are the same as previously given. A quarter-wave section matching a 600-ohm line to the center of a half-wave antenna (72 ohms), for example, should have a surge impedance of 208 ohms. The spacings between conductors of various sizes of tubing and wire for different surge impedances are given in graphical form in Fig. 1317. With half-inch tubing, for example, the spacing should be 1.5 inches for an impedance of 208 ohms.

The length, *B*, of the matching section should be equal to a quarter wavelength, and is given by

$$\text{Length of } \tfrac{1}{4} \text{ wave line (feet)} = \frac{234}{\text{Freq. (Mc.)}} \qquad (5)$$

the reduction factor being greater than in the case of open-wire lines. The length of the antenna can be calculated from the formula given earlier in this chapter.

This system has the advantage of the simplicity in adjustment of the twisted pair feeder system and at the same time the superior insulation of an open wire system.

Comparison of Resonant and Non-Resonant Lines

Practically all of the various types of lines just described may be used with more elaborate antenna systems as well as the half-wave antennas used as examples. Each type has its advantages and disadvantages. Resonant lines are, in general, easier to adjust than the untuned lines, and have the advantage that they are adaptable to using the same antenna on more than one band, a question which will be given consideration later. Because of their higher current, however, the losses usually are greater than in a properly-matched non-resonant line of the same length, although this factor need not be given much consideration unless the line is more than one or two wavelengths long, because in short lines the difference in efficiency is negligible.

Most non-resonant line systems are limited to operation on one frequency, although some can be operated at reduced efficiency on more than one band. Open-wire and air-insulated concentric lines are excellent for carrying r.f. power for distances of several wavelengths with minimum loss. With rubber-insulated lines the losses are higher, although these lines are convenient to use. The losses are proportional to frequency, so that it is possible to compare lines by loss in "db per wavelength." With good air-insulated lines the loss is about 0.12 db per wavelength; with rubber-insulated lines the loss is from 1 to 2 db per wavelength, depending upon the grade of rubber employed. These figures assume that the line is properly matched to the antenna. Air-insulated lines are less likely to be affected by dampness.

Where the line is short, or the antenna is to be used on more than one band, open-wire resonant lines are recommended. If only one band is to be used, either type of line may be employed, the non-resonant open-wire type being preferred, but if a short line can be used, the rubber insulated types will be convenient.

LONG-WIRE ANTENNAS

THE length of a single-wire antenna may be made any multiple of a half wavelength. As

World Radio History

the wire is made longer the antenna characteristics also change; this is particularly true of the directional effects. Instead of the "doughnut" pattern of the half-wave antenna, the directional characteristic splits up into "lobes" which make various angles with the wire. In general, as the length of the wire is increased the direction of maximum radiation tends to approach the line of the antenna itself.

The radiation resistance as measured at a current loop becomes larger as the antenna length is increased. Also, a long-wire antenna radiates more power in its most favorable direction than does a half-wave antenna in *its* most favorable direction. This power gain is secured at the expense of radiation in other directions. Fig. 1327 shows how the radiation resistance and power in the lobe of maximum radiation vary with the antenna length.

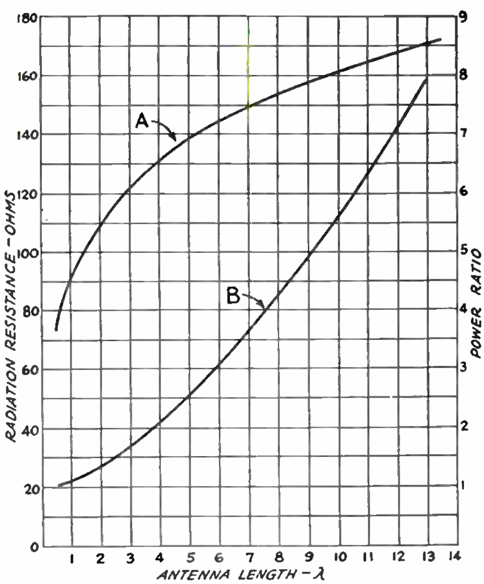


FIG. 1327 — THE IMPORTANT CURVES FOR HARMONICALLY-OPERATED HORIZONTAL ANTENNAS

Curve A shows the variation in radiation resistance with antenna length. Curve B shows the power in the lobes of maximum radiation for long-wire antennas as a ratio to the maximum of a half-wave doublet antenna.

The long-wire antenna is said to be in harmonic-resonance (see Chapter Four) and may be operated on several bands. For example, a 3.5-Mc. half-wave antenna is also a full-wave 7-Mc. antenna, because its length (approximately 133 feet) is sufficient to accommodate two half waves at 7 Mc. At 14 Mc. the same wire is a two-wave antenna, and so on. When such an antenna is used for work in several bands, it must be realized that the directional characteristic will depend on the band in use. Antennas of this type are favorite among amateurs who work on several bands.

Directional characteristics for antennas one wavelength, three half-wavelengths, and two

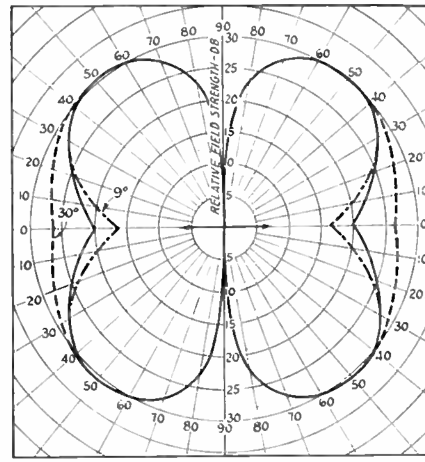


FIG. 1328 — HORIZONTAL PATTERNS OF RADIATION FROM A FULL-WAVE ANTENNA

Solid line, vertical angle 15 degrees; dotted lines, deviation from 15-degree pattern at 9 and 30 degrees. See Fig. 1307 for further discussion.

wavelengths long are given in Figs. 1328, 1329, and 1330, for the three vertical angles of radiation previously considered. Note that as the wire length increases the radiation along the

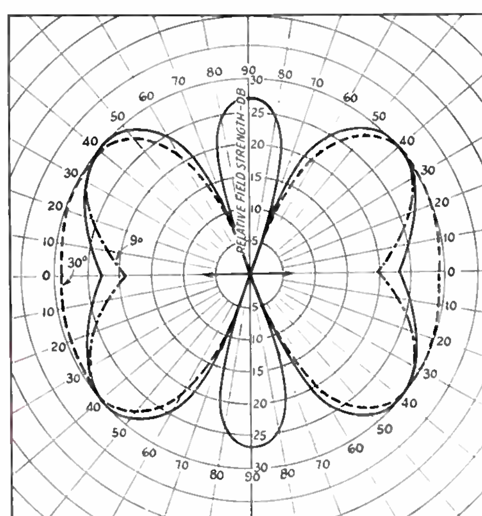


FIG. 1329 — HORIZONTAL PATTERNS OF RADIATION FROM AN ANTENNA THREE HALF-WAVELENGTHS LONG

Solid line, vertical angle 15 degrees; dotted lines, deviation from 15-degree pattern at 9 and 30 degrees. The minor lobes coincide for all three angles. See Fig. 1307 for further discussion.

World Radio History

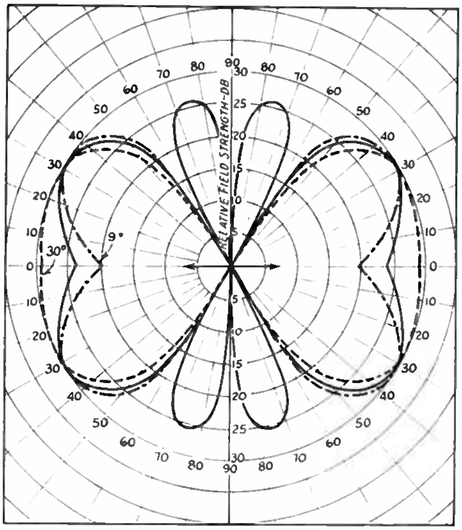


FIG. 1330 — HORIZONTAL PATTERNS OF RADIATION FROM AN ANTENNA TWO WAVELENGTHS LONG

Solid line, vertical angle 15 degrees; dotted lines, deviation from 15-degree pattern at 9 and 30 degrees. The minor lobes coincide for all three angles. See Fig. 1307 for further discussion.

line of the antenna becomes more pronounced. Still longer antennas can be considered to be practically "end-on" radiators, at least at 14 Mc. and lower.

The length of a long-wire antenna is not an exact multiple of a half-wave antenna as calculated by Equation (1). This is because the end effects operate only on the end sections of the antenna; in other parts of the wire these effects are absent and the wire length is approximately that of an equivalent portion of the wave in space. The formula for the length of a long-wire antenna therefore is:

$$\text{Length (feet)} = \frac{492\,(N-0.05)}{\text{Freq. (Mc.)}} \qquad (6)$$

where N is the number of *half*-waves on the antenna. From this it is apparent that an antenna cut as a half-wave for a given frequency will be slightly off resonance at exactly twice that frequency (on the second harmonic) because of the different behavior of end effects when there is more than one standing wave on the antenna. For instance, if the antenna is cut to exact fundamental resonance with a given crystal frequency, on the second harmonic (full-wave) it should be 2.6% longer, and on the fourth harmonic, (two-wave) 4% longer. The effect is not very important except for a slight unbalance in the feeder system, which may result in some radiation from the feeder (see Fig. 1316).

Feeding Long Wires

In a long-wire antenna the currents in adjacent half-wave sections must be out of phase, as shown in Fig. 1331. The feeder system must not upset this phase relationship. This requirement is met by feeding the antenna at either end or at any current *loop.* A two-wire feeder cannot be inserted at a current *node,* however, because this invariably brings the currents in two adjacent half-wave sections in phase; if the phase in one section could be reversed then the currents in the feeders would be in phase and the feeder radiation would not be cancelled out.

Either resonant or non-resonant feeders may be used. With the latter, the systems employing a matching section are best. The non-resonant line may be tapped on the matching section as in Fig. 1324, or a "Q" type section (Fig. 1326) may be employed. In such case, Fig. 1332 gives the required surge impedance for the matching section. It can also be calculated from Equation (3) and the radiation resistance data in Fig. 1327.

Methods of coupling the line to the transmitter are the same as previously described for the particular type of line used.

Multi-Band Operation

As suggested in the preceding section, the same antenna may be used for several bands by operating it on harmonics (as a long wire) where necessary. When this is done, it is necessary to use resonant feeders, since the impedance matching for non-resonant feeder operation can be accomplished only at one frequency unless means are provided for changing the length of a matching section and shifting the point at which the feeder is attached to it. Obviously a matching section which is a quarter-wavelength long on one frequency will

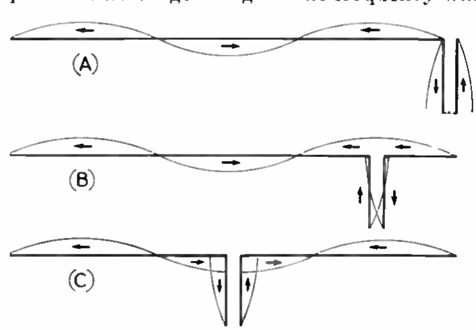


FIG. 1331 — CURRENT DISTRIBUTION AND FEED POINTS FOR LONG-WIRE ANTENNAS

A 3/2-wave antenna is used as an illustration. With two-wire feed, the line may be connected at the end of the antenna or at any current *loop* (note at a current node). The feeders may be of the resonant type, or a 600-ohm line may be used through a quarter-wave matching section (see Fig. 1325 and discussion). The "Q" type of matching section also may be used, the design being based on Figs. 1333 and 1317.

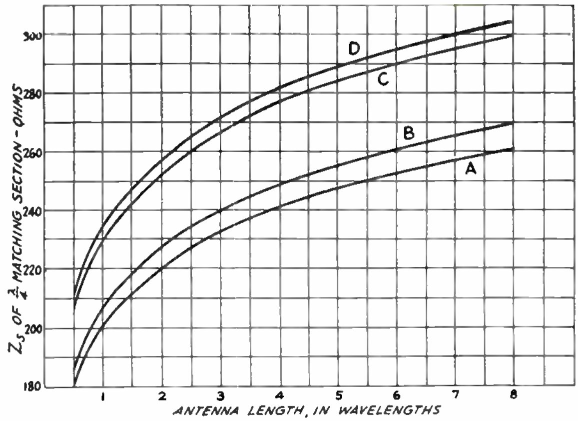


FIG. 1332 — REQUIRED SURGE IMPEDANCE OF QUARTER-WAVE MATCHING SECTIONS FOR RADIATORS OF VARIOUS LENGTHS

Curve A is for a transmission line impedance of 440 ohms, Curve B for 470 ohms, Curve C for 580 ohms and Curve D for 600 ohms.

be a half-wavelength long on twice that frequency, and so on, and it is equally obvious that changing the length of the wires, even by switching, is inconvenient.

Also, the current loops shift to a new position on the antenna when it is operated on harmonics, further complicating the feed situation. It is for this reason that half-wave antennas center-fed by rubber-insulated lines are practically useless for harmonic operation; on all even harmonics there is a voltage maximum at the feed point and the impedance mismatch is so bad that there is a large standing-wave ratio and consequently high losses in the rubber dielectric.

Any of the antenna arrangements shown in Fig. 1311 may be used for multiband operation by making the antenna a half wave long at the lowest frequency to be used. The feeders should be a quarter wave, or some multiple of a quarter wave, long at the same frequency. Typical examples, with the type of tuning to be used, are given in Table I. The figures given represent a compromise to give satisfactory operation on all the bands considered, taking into account the change in required length as the order of the harmonic goes up.

A center-fed half-wave antenna will not operate strictly as a single long wire on harmonics because of the phase reversal at the feeders previously mentioned (Fig. 1331). On the second harmonic, the two antenna sections are each a half-wave long, and since the currents are in phase the directional characteristic is different from that of a full-wave antenna even though the overall length is the same. On the fourth harmonic, each section is a full wave long and again because of the direction of current flow will not operate as a two-wave antenna. It should not be assumed that these systems are not effective radiators — it is simply that the directional characteristic will not be that of a long-wire having the same overall length. Rather it will resemble the characteristic of one side of the antenna, although this picture is not exact. The center-fed antenna, when operated on harmonics, will radiate equally as well as the end-fed.

Antennas with a few other types of feed systems may be operated on harmonics for the higher-frequency bands, although their performance

TABLE I

MULTI-BAND RESONANT-LINE FED ANTENNAS

Antenna Length (ft.)	*Feeder Length (ft.)*	*Band*	*Type of Tuning*
With end feed:			
213	120	1.75-Mc. 'phone	series
		4-Mc. 'phone	parallel
		14 Mc.	parallel
		28 Mc.	parallel
136	67	3.5-Mc. c.w.	series
		7 Mc.	parallel
		14 Mc.	parallel
		28 Mc.	parallel
134	67	3.5-Mc. c.w.	series
		7 Mc.	parallel
67	33	7 Mc.	series
		14 Mc.	parallel
		28 Mc.	parallel
With center feed:			
272	135	1.75 Mc.	parallel
		3.5 Mc.	parallel
		7 Mc.	parallel
		14 Mc.	parallel
		28 Mc.	parallel
137	67	3.5 Mc.	parallel
		7 Mc.	parallel
		14 Mc.	parallel
		28 Mc.	parallel
67.5	34	7 Mc.	parallel
		14 Mc.	parallel
		28 Mc.	parallel

The antenna lengths given represent compromises for harmonic operation because of different end effects on different bands. The 136-foot end-fed antenna is slightly long for 3.5 Mc., but will work well in the region (3500–3600 kc.) which quadruples into the 14-Mc. band. Bands not shown are not recommended for the particular antenna. The center-fed systems are less critical as to length; the 272-foot antenna may, for instance, be used for both c.w. and 'phone on either 1.75 or 4 Mc. without loss of efficiency.

On harmonics, the end-fed and center-fed antennas will not have the same directional characteristics, as explained in the text.

World Radio History

is somewhat impaired. The single-wire fed antenna of Fig. 1318 may be used in this way; the feeder and antenna will not be matched exactly on harmonics with the result that standing waves will appear on the feeder, but the system as a whole will radiate. The same is true of the "Y" fed antenna of Fig. 1322. The "Q" antenna of Fig. 1326 also can be operated on harmonics, but the line must be tuned. It cannot operate as a non-resonant line except at the fundamental frequency of the antenna. For harmonic operation, therefore, the feeder length is important, and the tuning system will depend upon the number of quarter waves on the line, including the "Q" bars. The concentric-line fed antenna of Fig. 1321 may also be used on harmonics if the concentric line is air-insulated. Its operation on harmonics is similar to that of the "Q." This antenna is not recommended for multiband operation with a rubber-insulated line, however. The antenna systems of Fig. 1320 and 1324 also are unsuitable.

A simple antenna system, without feeders, for operation in five bands is shown in Fig. 1333. On all bands from 3.5 Mc. upward it operates as an end-fed antenna — half-wave on 3.5 Mc., long wire on the other bands. On 1.75 Mc. it is only a quarter-wave in length and must be worked against ground, which in effect replaces the missing half of the antenna. Since on this band it is fed at a high-current point, series tuning must be used.

The disadvantages of bringing the antenna into the operating room already have been pointed out.

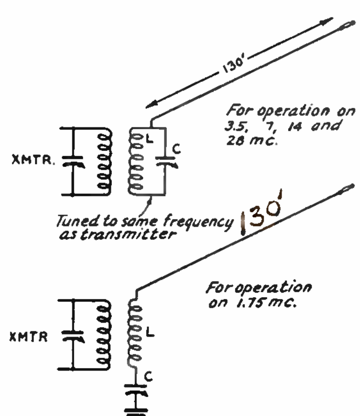


FIG. 1333 — A SIMPLE ANTENNA SYSTEM FOR FIVE AMATEUR BANDS

The antenna is voltage fed on 3.5, 7, 14 and 28 mc., working on the fundamental, second, fourth and eighth harmonics, respectively. For 1.75 Mc. the system is a quarter-wave grounded antenna, in which case series tuning must be used. The antenna wire should be kept well in the clear and should be as high as possible.

If the length of the antenna is approximately 260 feet, voltage feed can be used on all five bands.

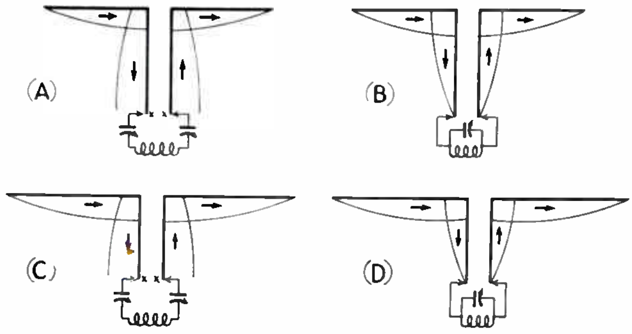


FIG. 1334 — CURRENT DISTRIBUTION ON ANTENNAS TOO SHORT FOR THE FUNDAMENTAL FREQUENCY

These systems may be used when space for a full half-wave antenna is not available. The current distribution on the second harmonic also is shown to the right of each figure. In *A* and *C*, the total length around the system is a half-wavelength at the fundamental frequency.

Compromise Antennas for Restricted Space

If the space available for the antenna is not large enough to accommodate the length necessary for a half-wave at the lowest frequency to be used, quite satisfactory operation can be secured by using a shorter antenna and making up the missing length in the feeder system. The antenna itself may be as short as a quarter wavelength and still radiate fairly well, although of course it will not be as effective as one a half-wave long. Nevertheless such a system is useful where operation on the desired band otherwise would be impossible.

Resonant feeders are a practical necessity with such an antenna system, and a center-fed antenna will give best all-around performance. With end feed the feeder currents become badly unbalanced and, since lengths midway between those requiring series or parallel tuning ordinarily must be used to bring the entire system to resonance, coupling to the transmitter often becomes difficult.

With center feed, practically any convenient length of antenna can be used if the feeder length is adjusted to accommodate at least one half-wave around the whole system. Typical cases are shown in Fig. 1334, one for an antenna having a length of one-quarter wave (*A*) and the other for an antenna somewhat longer (*C*) but still not a half-wave long. Current distribution is shown for both fundamen-

World Radio History

tal and second harmonic. From the points marked X resonant feeders any appropriate number of quarter waves in length may be extended to the operating room. The sum of the distances on each wire from X to the antenna end must equal a half-wave. It is sufficiently accurate to use Equation (1) in calculating this length. Note that X-X is a high-current point on these shortened antennas, corresponding to the center of a half-wave antenna. It is also apparent that the antenna at A is a half-wave antenna on the next higher-frequency band (B).

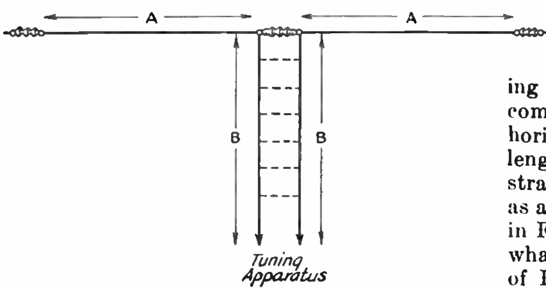


FIG. 1335 — PRACTICAL ARRANGEMENT OF A SHORTENED ANTENNA

The total length A + B + B + A, should be a half-wavelength for the lowest-frequency band, usually 3.5 Mc. See Table II for lengths and tuning data.

TABLE II

Antenna and Feeder Lengths for Short Multi-Band Antennas, Center-Fed

Antenna Length (ft.)	*Feeder Length (ft.)*	Band	*Type of Tuning*
137	68	1.75 Mc. 3.5 Mc. 7 Mc. 14 Mc. 28 Mc.	series parallel parallel parallel parallel
100	38	3.5 Mc. 7 Mc. 14 Mc. 28 Mc.	parallel series series series or parallel
67.5	34	3.5 Mc. 7 Mc. 14 Mc. 28 Mc.	series parallel parallel parallel
50	43	7 Mc. 14 Mc. 28 Mc.	parallel parallel parallel
33	51	7 Mc. 14 Mc. 28 Mc.	parallel parallel parallel
33	31	7 Mc. 14 Mc. 28 Mc.	parallel series parallel

The practical antenna can be made as in Fig. 1335. The Table gives a few recommended lengths. Remembering the preceding discussion, however, the antenna can be made any convenient length provided the feeder is considered to "begin" at X-X, and the line length adjusted accordingly.

Bent Antennas and End Loading

Since the field strength at a distance is proportional to the current in the antenna, the high-current part of a half-wave antenna (the center quarter-wave, approximately) does most of the radiating. Advantage can be taken of this fact when the space available does not permit erecting an antenna a half-wave long. To accomplish it, the ends may be bent, either horizontally or vertically, so that the total length equals a half wave, even though the straightaway horizontal length may be as short as a quarter wave. The operation is illustrated in Fig. 1336. Such an antenna will be a somewhat better radiator than the arrangement of Fig. 1334-A on the lowest frequency, but is not as desirable for multi-band operation because the ends play an increasing part as the frequency is raised. The performance of the system in such a case is difficult to predict, especially if the ends are vertical (the most convenient arrangement) because of the combination of horizontal and vertical polarization as well as dissimilar directional characteristics.

An alternative method of producing much the same effect is shown in Fig. 1336-B. In this case a relatively-large capacity is substituted at each end for the missing wire length. The capacity may be provided by large metal

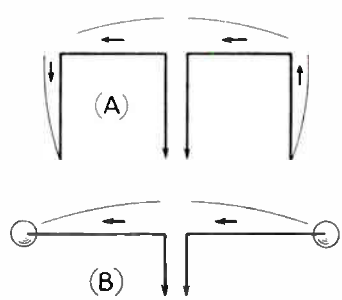


FIG. 1336 — ALTERNATIVE ARRANGEMENTS FOR SHORTENED ANTENNAS

In *A* the total length is a half-wave, not including the feeders. The horizontal part is made as long as convenient and the ends dropped down to make up the required length. The ends may be bent back on themselves in feeder fashion to cancel radiation partially. The horizontal section should be at least a quarter-wave long. *B* shows end-loading with large capacities (large metal plates or spheres). The possible reduction in length by this method must be determined experimentally; in general, it will not be possible to reduce the length very greatly.

World Radio History

plates or spheres connected to the antenna ends to emphasize the "end effect." The size of such loading devices must be determined by experiment for each antenna length. This system also is rather undesirable for multi-band operation.

GROUNDED ANTENNAS

The grounded antenna is used almost exclusively for 1.75-Mc. work, where the length required for a half-wave antenna would be excessive for most locations. An antenna worked "against ground" need be only a quarter-wave long, approximately, because the earth acts as an electrical "mirror" which supplies the missing quarter wave. The current at the ground connection therefore corresponds to the current at the center of a half-wave antenna.

On 1.75 Mc. it is probable that most of the useful radiation is from the vertical part of the antenna, since vertically-polarized waves are characteristic of ground-wave transmission. It is therefore desirable to make the down-lead as nearly vertical as possible, and also as high as possible. The horizontal portion contributes to sky-wave transmission, which is useful for covering relatively-long distances on this band at night.

The lower drawing of Fig. 1333 shows the recommended method of tuning a grounded quarter-wave antenna. The ground connection must have low r.f. resistance to avoid loss of power.

For computation purposes, the *overall* length of a grounded system is given by

$$L \text{ (feet)} = \frac{236}{f \text{ (Mc.)}}$$

This length, it should be noted, is the *total* length from the far end of the antenna to the ground connection.

The ground should preferably be one with conductors buried deep enough to reach natural moisture. In urban locations, good grounds can be made to water mains where they enter the house; the pipe should be scraped clean and a low-resistance connection made with a tightly-fastened ground clamp. If no water-pipes are available several pipes, six to eight feet long, may be driven into the ground at intervals of six or eight feet, all being connected together. The transmitter should be located so as to make the ground lead as short as possible.

In locations where it is impossible to secure a good ground connection because of sandy soil or other considerations, it is preferable to substitute a counterpoise for the ground connection. The counterpoise consists of a system of wires insulated from ground running horizontally above the earth beneath the antenna. The counterpoise should have a sufficient number of wires of sufficient length to cover well the area immediately under the antenna. The wires may be formed into any convenient shape, i.e., they may be spread out fan-shape, in a radial pattern, or three or more parallel wires separated a foot or so running beneath the antenna may be used. The counterpoise should be elevated six or seven feet above the ground so it will not interfere with persons walking under it. Connection is made between the usual ground terminal of the transmitter and each of the wires in the counterpoise.

DIRECTIVE ANTENNAS

For long distance transmission it is often advantageous to arrange the antenna so that the radiation is concentrated in a desired direction. With a simple antenna, the same increase in field strength would require much more power, so that it is customary to measure the effectiveness of a directive antenna in terms of the power increase that would be needed to give the same field strength, using a half-wave antenna as the standard of comparison. The same polarization is assumed. The power gain so obtained may range from slightly over 1 for simple systems to as much as 30 or 40 for the most elaborate ones.

The increased signal strength in the desired direction is obtained at the expense of radiation in other directions. At the higher frequencies, energy may be taken from the higher vertical angles and used to reinforce the existing low-angle radiation without affecting greatly the horizontal directivity. In general, however, an increase in output in one horizontal direction is accompanied by a decrease in some other horizontal direction, so that the user of a directive antenna must be prepared to accept an area of restricted effectiveness. This is particularly true as the antenna gain is made higher.

Directive antennas may be divided into two types, those using long wires (those already discussed are simple forms of directive antennas) and those using half-wave elements in combination to produce the desired effect. In both cases the principle of operation is that of reinforcement and cancellation of waves radiated from different portions of the system. The energy from waves which cancel is available for reinforcement in the appropriate direction. The phased types generally are suitable for operation in one band only, while the long wire types may be operated over several bands with little change in characteristics provided the antenna is fairly large.

A directive antenna is equally as effective for receiving as for transmitting. Such an antenna

World Radio History

always should be used for both purposes if its full benefits are to be realized.

PHASED ANTENNAS

ANTENNAS using combinations of half-wave elements usually are called "phased" systems. Simple forms of such systems, with the current distribution, are shown in Fig. 1337. In *A* is the popular "two half-waves in phase," which will be recognized as simply a center-fed antenna operated at its second harmonic. The way in which the number of elements may be extended for increased directivity and gain is shown in Fig. 1337-B. Note that quarter-wave transmission lines are used between each element; these give the reversal in phase necessary to make the currents in individual antenna elements all flow in the same direction at the same instant. Another way of looking at it is to consider that the whole system is a long wire with alternate half-wave sections folded so that they do not radiate. Any phase-reversing section may be used as a quarter-wave matching section for attaching a non-resonant feeder. A resonant transmission line may be substituted for any of the quarter-wave sections, of course. Also, the antenna may be end-fed by any of the systems previously described, or any element may be center-fed. This is also true of the more complicated systems.

The system shown in Fig. 1337 is known as a *collinear* array. The gain and directivity depend upon the number of elements and their spacing, center-to-center. This is shown by Table III. Although ¾-wave spacing gives greater gain, it is difficult to construct a suitable phase-reversing system when the ends of the antenna elements are widely separated. For this reason the half-wave spacing is generally used.

Collinear arrays may be mounted either horizontally or vertically. Horizontal mounting gives horizontal directivity, with vertical directivity the same as for a single element at the same height. Vertical mounting gives the same horizontal pattern as a single element, but concentrates the radiation at low angles. It is seldom possible to use more than two elements vertically, however, because of the height required.

TABLE IV

THEORETICAL GAIN OF TWO HALF-WAVE ANTENNAS AT DIFFERENT SPACINGS

180° Out of Phase (End Fire)		*In Phase (Broadside)*	
Separation in Fractions of a Wavelength	*Gain in db*	*Separation in Fractions of a Wavelength*	*Gain in db*
⅛	4.3	⅝	4.8
1/20	4.1	¾	4.6
¼	3.8	½	4.0
⅜	3.0	⅜	2.4
½	2.2	¼	1.0
⅝	1.7	⅛	0.3

Broadside Arrays

In-phase antenna elements also may be combined as shown in Fig. 1338. This is known as a *broadside* array because the direction of maximum radiation is broadside to the plane containing the antennas. Again the gain and directivity depend upon the number of elements and the spacing, the gain for different spacings being shown in the right-hand section of Table IV. Half-wave spacing is generally used, since it simplifies the feeding problem when the array has more than two elements.

Broadside arrays may be suspended either horizontally or vertically. In the former case the horizontal pattern is quite sharp while the vertical pattern is that of one element alone. If the array is suspended horizontally the horizontal pattern is that of one element while the vertical pattern is sharp, giving low-angle radiation. The height required limits the number of elements which can be suspended horizontally, so that more than two seldom are used.

Broadside arrays may be fed either by resonant transmission lines or by the use of quarter-wave matching sections and non-resonant lines. In Fig. 1338, note the "crossing over" of the feeder, necessary to bring the elements in proper phase relationship.

TABLE III

THEORETICAL GAIN OF COLLINEAR HALF-WAVE ANTENNAS

Spacing Between Centers of Adjacent Half Waves (A)	*Number of Half Waves in Array vs. Gain in db*				
	2	3	4	5	6
½ Wave	1.8	3.3	4.5	5.3	6.2
¾ Wave	3.2	4.8	6.0	7.0	7.8

TABLE V

THEORETICAL GAIN VS. NUMBER OF BROADSIDE ELEMENTS HALF-WAVE SPACING

No. of Elements	*Gain*
2	4 db
3	5.5 db
4	7 db
5	8 db
6	9 db

World Radio History

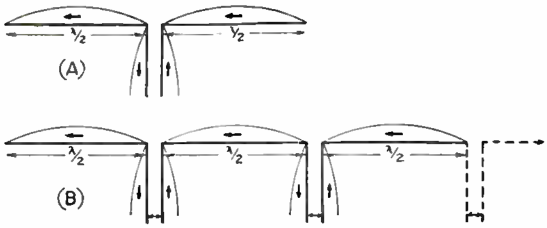


FIG. 1337 — COLLINEAR HALF-WAVE ANTENNAS IN PHASE

The system at *A* is generally known as "two half-waves in phase." *B* is an extension of the system; in theory it may be carried on indefinitely, but practical considerations usually limit the number of elements to four. Gain figures are tabulated in Table III.

Resonant feeders may be connected to the ends of any of the quarter-wave matching sections indicated (the shorting bar of course must be removed from the one used). Alternatively a two-wire line may be matched to the line as in Fig. 1324. Any antenna element also may be center-fed through any of the ordinary methods which permit matching, in the case of a non-resonant line, or through a resonant line. Twisted pair and concentric feeders are not recommended for this purpose because the antenna impedance is not the same as when a half-wave antenna is used singly. Generally speaking, it is preferable to feed a multi-element antenna near the center of the system in order to make the power distribution to the elements as uniform as possible.

Combined Broadside and Collinear Arrays

Broadside and collinear arrays may be combined to give both horizontal and vertical directivity, as well as additional gain. The general plan of constructing such antennas is shown in Fig. 1339. The lower angle of radiation resulting from "stacking" elements in the vertical plane is desirable at the higher frequencies. In general, doubling the number of elements in an array by stacking will raise the gain 2 to 4 db, depending upon whether vertical or horizontal elements are used.

End-Fire Arrays

Fig. 1340 shows a pair of parallel half-wave elements with currents out of phase. This is known as an end-fire array because it radiates best along the line of the antennas, as shown.

The end-fire array may be used vertically or horizontally, and is well adapted to amateur work because it gives maximum gain with relatively close element spacing. Table IV shows how the gain varies with spacing. It may also be combined with additional collinear and broadside elements further to increase the gain and directivity.

Either resonant or non-resonant lines may be used with this type of array, the latter being preferably matched to the antenna through a quarter-wave resonant line.

Checking Phasing

Figs. 1338 and 1340 illustrate a point in connection with feeding a phased antenna system which sometimes is confusing. Taking Fig. 1340 as an example, when the transmission line is connected as at *A* there is no crossover in the line connecting the two antennas, but when the transmission line is connected to the center of the connecting line the crossover becomes necessary *B*. This is because in *B* the two halves of the connecting line are simply *branches* of the same line. In other words, even though the connecting line in *B* is a half-wave in length, it is not actually a half-wave line but *two quarter-wave lines in parallel.*

Practical Phased Systems

Besides the two half-waves in phase already mentioned, several other simple directive antenna systems are in rather wide use among amateurs. They are shown in Fig. 1341. Tuned feeders are assumed in all cases; however, a matching section readily can be substituted if a non-resonant transmission line is preferred. Dimensions given are in terms of wavelength; actual lengths readily can be calculated from Equation (1) for the antenna and Equation (2) for the resonant transmission line or matching section. Remember that, in cases where the transmission line proper connects to the mid-point of a phasing line, only *half* the length of the latter is added to the line to find the quarter-wave point.

At *A* and *B* are two-element end-fire arrangements using close spacing. They are electrically equivalent; the only difference is in the method of connecting the feeders. *B* may also be used as a four-element array on the second harmonic, although the spacing is not optimum in that case; however, it is a useful two-band directive

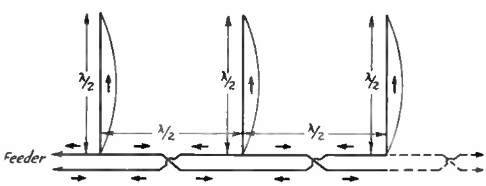


FIG. 1338 — THE BROADSIDE ARRAY USING HALF-WAVE ELEMENTS

Arrows indicate direction of current flow. The transposition in feeders is necessary to bring the antenna currents in phase. Any reasonable number of elements may be used. The array is bi-directional perpendicular to the plane of the antenna; i.e., perpendicularly through this page.

Resonant feeders or quarter-wave matching sections may be bridged across the line at any antenna junction. If the transmission line is connected to the phasing line at a point midway between two antennas, the phasing line in that section should not be transposed. Feed near the center of the system is preferable in order to distribute the power as evenly as possible among the antennas.

See Table V for gain data.

World Radio History

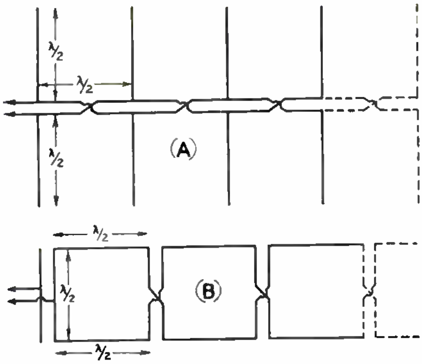


FIG. 1339 — COMBINATION BROADSIDE AND COLLINEAR ARRAYS

A, with vertical elements; B, with horizontal elements. Both arrays give low-angle radiation. Two or more sections may be used. See Fig. 1338 for remarks on feeding and directivity. The transmission-line connection in B illustrates the use of a non-transposed phasing line when the connection is midway between antenna elements.

The gain in db will be equal, approximately, to the sum of the gain for one set of broadside elements (Table V) plus the gain of one set of collinear elements (Table III). For example, in A each broadside set has four elements (gain 7 db) and each collinear set two elements (gain 1.8 db) giving a total gain of 8.8 db. In B each broadside set has two elements (gain 4 db) and each collinear set three elements (gain 3.3 db) making the total gain 7.3 db. The result is not strictly accurate because of mutual coupling between elements, but is good enough for practical purposes.

antenna. A close-spaced four-element array is shown at C. It will give about 2 db more gain than the two-element array. The antenna at D is designed to take advantage of the greater gain possible with collinear antennas having greater than half-wave center-to-center spacing, but without introducing feed complications. The elements are made longer than a half wave to bring this about. The gain is 3 db over a single half-wave antenna, and the broadside directivity is quite sharp.

The antennas of A and B may be mounted either horizontally or vertically; horizontal suspension (with the two elements in a plane parallel to the ground) is recommended, since this tends to give low-angle radiation without an unduly sharp horizontal pattern. Thus these systems are useful for coverage over a wide horizontal angle. The system at C also should be mounted horizontally. It will have a sharper horizontal pattern than the two-element arrays.

Parasitic Antennas

All the preceding systems are bi-directional; that is, they will radiate to the "front" or the "back" of the antenna system. If radiation is wanted in only one direction (for instance, north only, instead of north-south) it is necessary to use different element arrangements. In most of these the additional elements receive power by induction or radiation from the antenna and reradiate it in the proper phase relationship to achieve the desired effect. They are called *parasitic* elements, as contrasted to *driven* elements which receive power directly from the transmitter through the transmission line.

The parasitic element is called a *director* when it reinforces radiation on a line pointing to it from the antenna, and is called a *reflector* when the reverse is the case. Whether the parasitic element is a director or reflector depends upon the parasitic element tuning (which is adjusted by changing its length) and, particularly when the element is self-resonant, upon the spacing between it and the antenna.

The gain of an antenna-reflector or antenna-director combination varies chiefly with the spacing between elements. The way in which gain varies with spacing is shown in Fig. 1341, for the special case of self-resonant parasitic elements. This chart also shows how the attenuation to the "rear" varies with spacing. The same spacing does not necessarily give both maximum forward gain and maximum backward attenuation. Backward attenuation is desirable when the antenna is used for receiving, since it greatly reduces interference coming from the opposite direction to the desired signal.

Simple and practical combinations of antenna, reflector and director are shown in Fig. 1343. Spacings for maximum gain or maximum front-to-back ratio (ratio of power radiated in the desired direction to power radiated in the opposite direction) may be taken from Fig. 1342. In the chart, the front-to-back ratio in db will be the sum of gain and attenuation at the same spacing.

The antenna length is given by Equation (1), as usual. The director and reflector lengths must be determined experimentally for maximum performance. The preferable method is to aim the antenna at a receiver a mile or so distant and have an observer check the signal

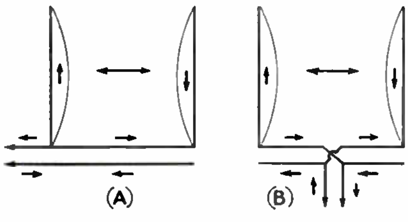


FIG. 1340 — END-FIRE ARRAYS

They are shown with half-wave spacing to illustrate feeder connections. In practice, closer spacings are desirable, as shown by Table IV. Direction of maximum radiation is shown by the large arrows. End-fire arrangements are shown in Fig. 1342 at A, B, and C.

World Radio History

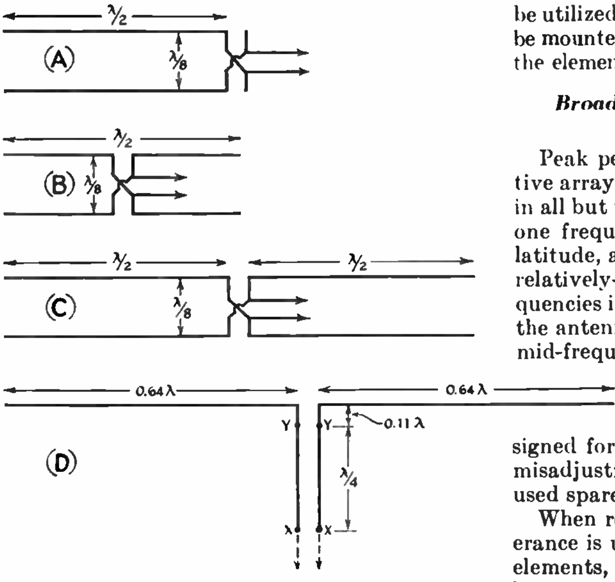


FIG. 1341 — SIMPLE DIRECTIVE SYSTEMS

A, two-element end-fire array; *B*, same with center feed, which permits use of the array on the second harmonic, where it becomes a four-element array with quarter-wave spacing. *C*, four-element end-fire array with ⅛-wave spacing. *D*, extended in-phase antennas ("extended double-Zepp"). The gain of *A* and *B* is slightly over 4 db (Table IV). On the second harmonic, *B* will give about 5 db gain. With *C*, the gain is approximately 6 db, and with *D*, approximately 3 db.

In the first three, the phasing line contributes about 1/16th wavelength to the transmission line; when *B* is used on the second harmonic this contribution is ⅛ wavelength. Alternatively, the antenna ends may be bent to meet the transmission line, in which case each feeder is simply connected to one antenna. In *B* and *C* the construction is the same as shown, but each antenna element would be 1/16th wavelength shorter. In *D*, points Y–Y indicate a quarter-wave point (high current) and X–X a half-wave point (high voltage). The line may be extended in multiples of quarter-waves, if resonant feeders are to be used.

Resonant feeders may be used with all types shown, and are necessary if *B* is to be used on two bands. Non-resonant feeders may be coupled to the antennas through quarter-wave matching sections for single-band operation.

A, *B*, and *C* may be suspended on wooden spreaders. The plane containing the wires should be parallel to the ground.

strength (on the "S" meter) while the reflector or director is adjusted a few inches at a time, until the length which gives maximum signal is found. The attenuation may be similarly checked, the length being adjusted for minimum signal. In general, the length of a director will be 1% to 2% less than that of the antenna. The reflector probably will be somewhat longer than the antenna.

Systems of this type are popular for rotary beam antennas, in which the whole antenna is rotated to permit its gain and directivity to be utilized for any compass direction. They may be mounted either horizontally (plane containing the elements parrallel to the earth) or vertically.

Broadness of Resonance in Directive Systems

Peak performance of a multi-element directive array depends upon proper phasing, which in all but the simplest systems can be exact for one frequency only. However, there is some latitude, and most arrays will work well over a relatively-narrow band such as 14 Mc. If frequencies in all parts of the band are to be used, the antenna system should be designed for the mid-frequency; on the other hand, if only one frequency in the band will be used the greater portion of the time the antenna might be designed for that frequency and some degree of misadjustment tolerated on the occasionally-used spare frequencies.

When reflectors or directors are used the tolerance is usually less than in the case of driven elements, partly because the parasitic-element lengths are fixed and the operation may change appreciably as the frequently passes from one side of resonance to the other, and partly because the close spacing ordinarily used results in a sharp-tuning system. With parasitic elements operation should be confined to a small region about the frequency for which the antenna is adjusted, if peak performance is to be secured.

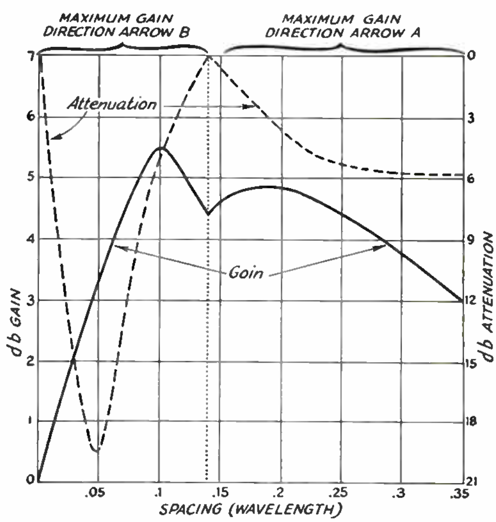


FIG. 1342 — FORWARD GAIN AND BACKWARD ATTENUATION FOR A HALF-WAVE ANTENNA WITH A SINGLE PARASITIC ELEMENT, AS A FUNCTION OF SPACING

The parasitic element is self-resonant. Somewhat greater front-to-back ratio can be secured by lengthing or shortening the parasitic element as described in the text.

World Radio History

ANTENNAS FOR ULTRA-HIGH FREQUENCIES

THE principles already discussed apply equally as well to the ultra-high frequencies as to communication frequencies. In practice, vertical polarization is used almost exclusively on ultra-high frequencies because it has been found more satisfactory for the type of work normally carried on in that region. A favorite antenna for 56-Mc. work is a vertical half-wave, elevated as much as possible above surrounding objects. Collinear half-waves in phase, also suspended vertically, often are used to give the low angle of radiation desirable for line-of-sight work.

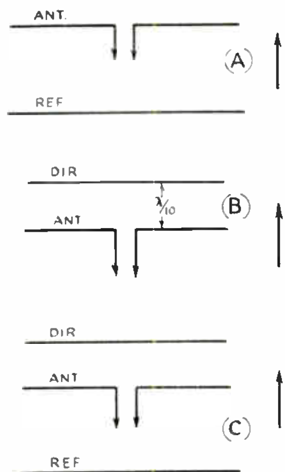


FIG. 1343 — HALF-WAVE ANTENNAS WITH PARASITIC ELEMENTS

A, with reflector; B, with director; C, with both director and reflector. Gain is approximately as shown by Fig. 1342 in the first two cases. With C, a gain of about 7 db can be realized in practice. Resonant feeders or a non-resonant line with matching section are recommended. Because of the close spacing in B and C the antenna impedance is very low, so that currents are high. Also, rigid conductors should be used since swinging will cause serious detuning. These systems are often used for rotary-beam work.

Because of the smaller dimensions of u.h.f. antennas, directive systems are in widespread use. Combinations of broadside and collinear arrays, with reflectors or directors, may be used to advantage. Such arrays usually will be of the type shown in Fig. 1339-A, often with a parasitic reflector behind each antenna element. A typical antenna of this type is shown in Fig. 1344, which consists of three in-phase collinear elements in broadside array, with a six-element parasitic reflector one-quarter wave behind the antenna.

The trend today is toward further investigation into the merits of horizontal antennas for u.h.f. work. The horizontally polarized waves transmitted from such antennas have been shown, in recent experiment, to provide better signals over long indirect paths than vertically polarized waves. Any of the arrays described may be made to radiate horizontally polarized waves by suspending them with the antenna elements horizontal.

It should be pointed out that the horizontal antenna on the ultra-high frequencies will perform very poorly in transmitting to or receiving from a station using a vertical antenna.

THE "V" ANTENNA

IT HAS been emphasized in connection with long-wire antennas that as the antenna length is increased the lobe of maximum radiation makes a more acute angle with the wire. Two such wires may be combined in the form of a horizontal "V" so that the main lobes from each wire will reinforce along a line bisecting the angle between the wires. This increases both gain and directivity, since the lobes in directions other than along the bisector cancel to a greater or lesser extent. The horizontal "V" antenna is therefore practically a bi-directional antenna whose gain depends upon the length of the wires. When each wire is several wavelengths long the gain will be

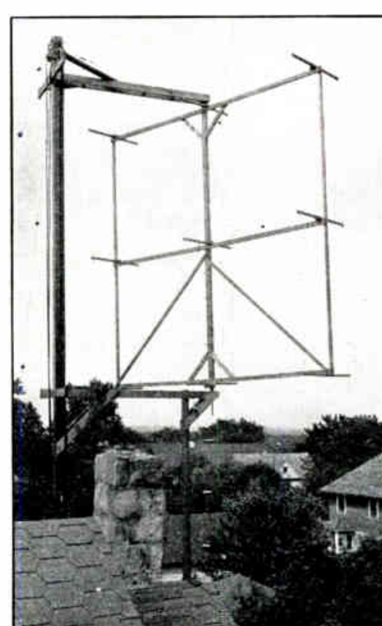


FIG. 1344 — THE 112-MC. ARRAY AT W2CUZ; AN EXCELLENT EXAMPLE OF CONSTRUCTION TO ALLOW ROTATION OF THE SYSTEM

Twelve elements are used; two collinear sets of three broadside driven antennas, backed by parasitic reflectors.

World Radio History

greater than can be obtained with phased antennas of simple construction. Provided the necessary space is available, the "V" is a simple antenna to build and operate, and can be used readily on harmonics so that it is suitable for multi-band work. The "V" antenna is shown in Fig. 1345.

Fig. 1346 shows the dimensions that should be followed for an optimum design to obtain maximum power gain for different-sized "V" antennas. The longer-type systems give good performance on multi-band operation. Angle α is approximately equal to twice the angle of maximum radiation for a single wire equal in length to one side of the "V."

The "V" can be made unidirectional through eliminating the rear pattern by the use of another "V" one-quarter wave to the rear to act as a reflector. This is quite cumbersome for amateur practice and restricts correct operation to a single frequency band. The "V" usually is operated as a bi-directional antenna.

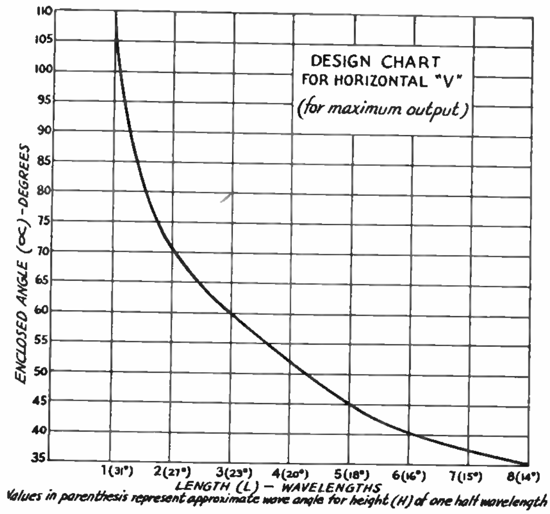


FIG. 1346 — DESIGN CHART FOR HORIZONTAL "V" ANTENNAS

Enclosed angle between wires versus length of sides.

The wave angle referred to in Fig. 1346 is the vertical angle of maximum radiation. Tilting the whole horizontal plane of the "V" will tend to increase the low-angle radiation off the low end and decrease it off the high end.

The gain increases rapidly with the length of the wires, but is not exactly twice the gain for a single long wire as given in Fig. 1327. In the longer lengths, the gain will be somewhat increased because of mutual coupling between the wires. A "V" eight wavelengths on a leg, for instance, will have a gain of about 12 db over a half-wave antenna, whereas twice the gain of a single 8-wavelength wire would be approximately 9 db.

The two wires of the "V" must be fed out of phase for correct operation. A resonant line may simply be attached to the ends as shown in Fig. 1345. Alternatively, a quarter-wave matching section may be employed and the antenna fed through a non-resonant line. If the antenna wires are made multiples of a half-wave in length (use Equation (6) for computing the length) the matching section will be closed at the free end.

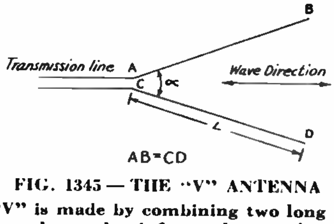


FIG. 1345 — THE "V" ANTENNA

The "V" is made by combining two long wires in such a way that each reinforces the other's radiation. The important quantities are the length of each leg and the angle between legs.

THE RHOMBIC ANTENNA

A popular form of long-wire directive antenna is the rhombic or "diamond" antenna shown in Fig. 1347. Like the "V," it requires a good deal of space for erection, but is capable of giving excellent gain and directivity. It can also be used for multi-band operation. In the terminated form shown in Fig. 1347 it operates, like a non-resonant transmission line, without standing waves and is uni-directional. It may also be used without the terminating resistor, in which case there are standing waves on the wires and the antenna is bi-directional.

The important quantities influencing the design of the rhombic antenna are shown in Fig. 1347. While several design methods may be used, the one most applicable to the conditions existing in amateur work is the so-called "compromise" method. The charts of Figs. 1348 and 1349 give design information when two of the quantities are assumed. The examples given illustrate the practical use of the charts.

For multi-band work, it is satisfactory to design the rhombic antenna on the basis of 14-Mc. operation, which will permit work on the 7- and 28-Mc. bands as well.

Fig. 1348 is based on an original given premise of length and height from which is determined the proper angle of tilt and corresponding wave angle for maximum output. This chart is based upon an effective height of ½ wavelength, which represents a practical value for most amateurs. For any different height other than the one shown the curve may be plotted from the expression:

World Radio History

$$\frac{H}{\tan\frac{(2\pi H\sin\Delta)}{\lambda}} = \frac{\lambda}{2\pi\sin\Delta} - \frac{l\sin\Delta}{\tan\frac{(\pi l\sin^2\Delta)}{\lambda}}.$$

The solution of this equation for l in terms of wavelength (λ) may be obtained by the trial and error method.

Fig. 1349 is based upon a premise of a given length and wave angle to determine the remaining optimum dimensions for best operation. Curves for values of length of 2, 3 and 4 wavelengths are shown, and additional curves for any length may be similarly plotted from the relationship:

$$\sin\phi = \frac{l - .371\,\lambda}{l\cos\Delta}.$$

With all other dimensions correct, an increase in length causes an increase in power gain and a slight reduction in wave angle. An increase in height also causes a reduction in wave angle and an increase in power gain but not to the same extent as a proportionate increase in length.

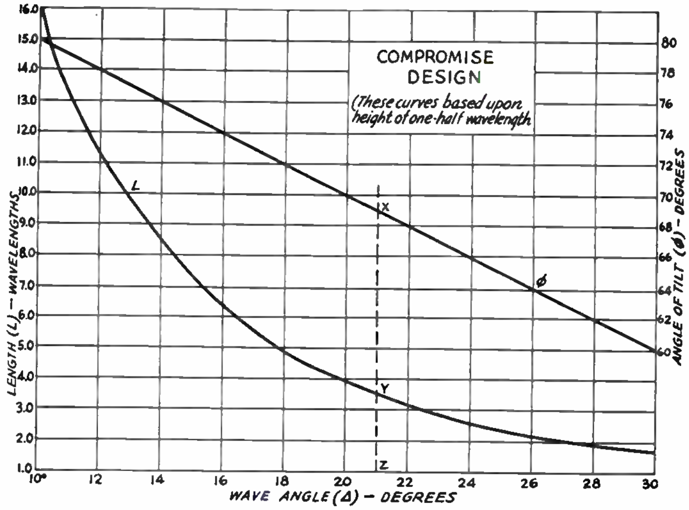


FIG. 1348 — DESIGN CHART FOR RHOMBIC ANTENNAS WITH FIXED HEIGHT (ONE-HALF WAVELENGTH)

The following example illustrates the use of the Chart:

Given: Height = ½ wavelength.

Available length of one leg = 3.5 wavelengths.

To Find:

Angle of Tilt (Φ).

Wave Angle (Δ).

Method:

Place straight edge on curve "L" at 3.5 wavelengths (point y) and drawn line XYZ. Read angle Φ from intersection at point X (right hand ordinate) and angle Δ at point Z (intersection of abscissa).

Result:

H = ½ wavelength, L = 3.5 wavelengths — given.

Tilt angle Φ = 69 degrees, Wave angle Δ = 21 degrees — from curves.

A value of 800 ohms is correct for the terminating resistor for any properly constructed rhombic, and the system behaves as a pure resistive load under this condition. This terminating resistor must be capable of safely dissipating one-half the power output (to eliminate the rear pattern) and be absolutely non-inductive. Such a resistor may be made up from a carbon or graphite rod or from a long 800-ohm transmission line. If the carbon rod or a similar form of lumped resistance is used the device should be suitably protected from weather effects, i.e., covered with good asphaltic compound and sealed in a small lightweight box or fibre tube. Suitable resistors recently have been made available commercially.

An 800-ohm line may be constructed from No. 16 A.W.G. wire spaced 20 inches or from No. 18 A.W.G. wire spaced 16 inches. The 800-ohm line is somewhat ungainly to install, however, and may be replaced by low-impedance lines of the concentric or twisted pair vari-

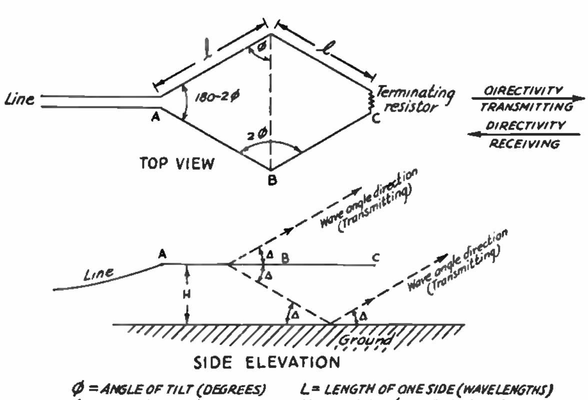


FIG. 1347 — THE HORIZONTAL RHOMBIC OR DIAMOND ANTENNA, TERMINATED

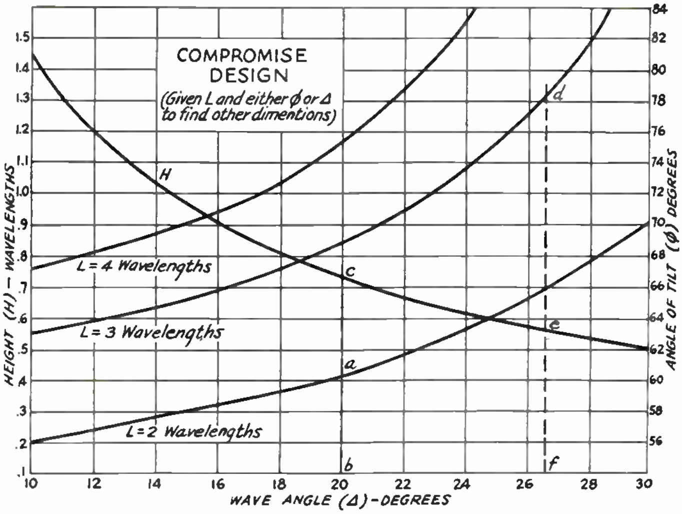


FIG. 1349 — COMPROMISE METHOD DESIGN CHART FOR VARIOUS LEG LENGTHS AND WAVE ANGLES

The following examples illustrate the use of the Chart:

(1) Given: Length (L) = 2 wavelengths.
Desired wave angle (Δ) = 20°.
To Find: H, Φ.
Method:
Draw vertical line thru point "a" (L = 2 wavelengths) and point "b" on abscissa (Δ = 20°.) Read angle of tilt (Φ) for point "a" and height (H) from intersection of line ab at point "c" on curve H.
Result:
Φ = 60.5°.
H = .73 wavelengths.

(2) Given:
Length (L) = 3 wavelengths.
Angle of tilt (Φ) = 78°.
To Find: H, Δ.
Method:
Draw vertical line from point "d" on curve L = 3 wavelengths at Φ = 78°. Read intersection of this line on curve H (point "e") and intersection at point "f" on the abscissa for Δ.
Result:
H = .56 wavelengths.
Δ = 26.6°.

ety by the incorporation of a coupling network between the 800-ohm and low-impedance line connection. Such a coupling unit might be installed in a box at the base of the first pole or supporting structure. If such an arrangement is used it will be necessary to change the network constants for each different band of operation.

The same design details apply to the unterminated rhombic as for the terminated type. Resonant feeders are preferable to use for the unterminated rhombic. A non-resonant line may be used by incorporating a matching section at the antenna, but is not readily adaptable to multi-band work.

THE RECEIVING ANTENNA

Because of the high sensitivity of modern receivers a large antenna is not necessary for picking up signals at good strength. Often it will be found that the receiving antenna in the amateur station is an indoor wire only 15 or 20 feet long.

On the other hand, the use of a tuned antenna unquestionably improves the operation of the receiver because the signal strength is greater in proportion to the stray noises picked up by the antenna than is the case with the antenna of random length. Also, since the transmitting antenna is usually given the more choice location, it can be used to great advantage for receiving, especially on the DX bands, and always when a directive antenna is used. A change-over switch or relay connected in the antenna leads can be used to transfer the connection from the receiver to the transmitter while the transmitter is on the air. For best results, an antenna tuning unit, as shown in Chapter Seven, should be used at the receiver.

If a separate receiving antenna is preferred, a doublet antenna of the type shown in Fig. 1350 will give very good results. The length of the lamp cord transmission line may be anything convenient. The antenna itself should be a half-wave long for the frequency band most used; despite the fact that the antenna is resonant for only one band, it will give good results on others as well. A popular length is 65 feet or so, designed to resonate in the 7000-kc. band.

The increasing popularity of short-wave broadcast receiving antennas has led to the development of many excellent commercial types available in kit form at reasonable prices. Designs such as the "Double-Doublet" and the "V Doublet" perform effectively for amateur work at 14 Mc. and lower frequencies.

CHOOSING THE ANTENNA

The choice of a suitable antenna or antennas will not present much of a problem to those who have an acre or so of clear space. However, most of us are not so fortunate. Frequently space cannot be found for more than a single antenna for all bands and many do not have space in which to put up, in the clear, a half-wave antenna for the lowest frequency at which operation is desired. In other words, the

World Radio History

space available usually dictates the most suitable type of antenna possible.

A vertical antenna occupies the smallest terrestrial area, it will radiate equally well in all directions unless shielded by near-by objects. Unfortunately, however, supports for vertical antennas are costly, except for antennas for the higher frequencies. Reliable masts or towers which will not endanger life and property will average about one dollar per foot in cost for heights up to about seventy-five feet. To be most effective, the lower end of the vertical antenna should be well above surrounding objects; in any event the center should be at least one-half wavelength above ground. Lesser heights usually will result in some sacrifice in performance.

If a vertical antenna is to be used on more than one frequency band, it is well to feed it in

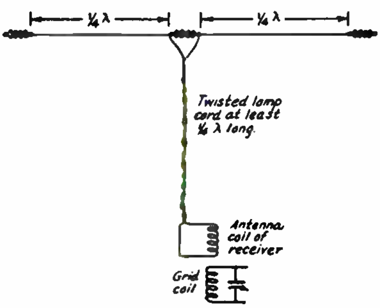


FIG. 1350 — DOUBLET RECEIVING ANTENNA

the center with tuned feeders, in order to take advantage of the added low-angle radiation obtained on the higher frequency.

In general, where one antenna must serve for all frequencies, it should be at least one-half wavelength long for the lowest frequency at which operation is desired. When this practice is followed with horizontal antennas, certain benefits result in operation at the higher frequencies. The number of lobes in the pattern increases with the antenna length and the angle of chief radiation becomes lower. Providing nearby surrounding objects are cleared, little benefit will usually result in elevating the horizontal antenna to a height greater than one-half wavelength. It will usually pay to orientate the antenna so that the main lobes of the radiation pattern point in the directions in which communication is especially desired or especially difficult. It is quite frequently possible to run the antenna in such a direction that a main lobe will fall in the approximate direction of each of several continents. Directions should be taken from a globe. Whenever possible the antenna should be located well away from telephone or power wiring or at least run at right angles to their directions.

In selecting the most suitable method of feeding the antenna, it should be remembered that antennas with tuned feeders are the only types (directly-excited antennas excepted) capable of operation at harmonics. The Zepp or end-fed type is probably the most popular type not only because it is usually more convenient to feed the antenna at one end instead of the center, but also because the end-fed antenna is somewhat less directive than the center-fed antenna when operated at harmonics as pointed out previously.

ANTENNA CONSTRUCTION

If the antenna system is to operate most effectively the conductors must be of low resistance. On the other hand the insulators must be of high mechanical strength and low losses. For short antennas an entirely satisfactory conductor is No. 14 gauge hard-drawn enamelled copper wire. For long antennas and directive arrays No. 14 or No. 12 enamelled copper-clad steel wire should be used to prevent any possible stretch. It is best to make feeders of ordinary No. 14 or No. 12 enamelled copper wire. It will be found difficult to make a neat-looking feeder with hard-drawn or copper-clad steel wire unless it is under considerable tension at all times. Every effort should be made to make the wires in one piece so that the only joints are at the output terminals of the transmitter. Where joints cannot be avoided they should be carefully soldered.

If the feeder system is of the tuned type the currents in it will be of the same order as or larger than those in the antenna, and the same care in avoiding joints is necessary. In the open-wire untuned feeder system, however, the currents are relatively low and this consideration is therefore not as important. In these cases small wire can be used if necessary.

In building a resonant two-wire feeder as much care should be taken with the quality of insulation used in the spacers as is taken with the antenna insulators proper. For this reason one of the many good ceramic spacers available should be used. Wooden dowels boiled in paraffin can be used with untuned lines but their use is not recommended for tuned lines. The wooden dowels can be attached to the feeder wires by drilling a small hole in the dowels, then binding them to the feeders with wire.

It should be kept in mind that the ends of tuned feeders or the ends of the antenna are points of maximum voltage. It is at these points that the insulation is most important, and Pyrex glass, isolantite or steatite insulators with long leakage paths are recommended. Glazed porcelain also is good. Insulators should be cleaned once or twice a year, especially

World Radio History

if they are subjected to much smoke and soot.

It is hardly possible to give practical instructions for the suspension of the antenna since the methods used will vary so widely in individual instances. In most cases poles are desirable to lift the antenna clear of surrounding buildings but in some locations the antenna is in the clear when strung from one chimney to another or from a chimney to a tree. Small trees are not usually satisfactory as points of suspension for the antenna on account of their movements in windy weather. If the antenna is strung from a point near the center of the trunk of a large tree this difficulty is not as serious. If the antenna must be strung from one of the smaller branches, it is best to tie a pulley firmly to the branch and run a rope through the pulley to the antenna, with the other end of the rope connected to a counterweight near the ground. The counterweight will keep the tension of the antenna constant, even when the branches sway and when the rope tightens and stretches under varying climatic conditions.

Small 28- and 56-Mc. arrays can be supported entirely by strong fish line that is counterweighted at the ends. However, light cord is not recommended for any really permanent installation except in very mild climates.

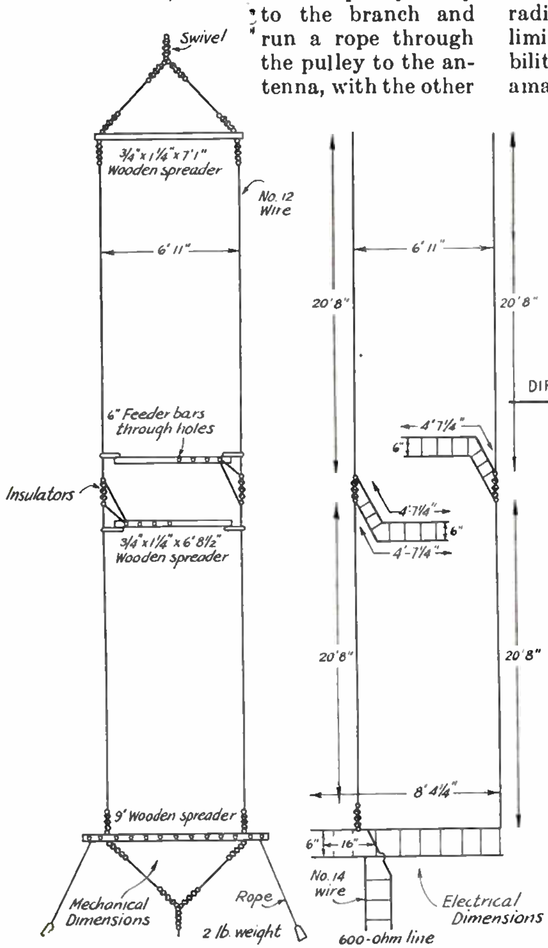


FIG. 1351—A SIMPLE ARRANGEMENT FOR A ROTATABLE DIRECTIVE ANTENNA

It may be suspended from any suitable support, such as another antenna, having the requisite height. The antenna shown is a 28-Mc. extended double Zepp with reflector. (W6AM, July, 1938, *QST*.)

Rotary Beam Construction

While the power gain given by a directive antenna unquestionably is desirable, it is only obtained through a decrease in the power radiated in unfavored directions, and therefore limits the "all-around" communication possibilities of the station. To overcome this, many amateurs mount the simpler types of directive antennas in such a way that the antenna can be rotated to shift the direction of the beam at will.

Obviously the use of such rotary antennas is limited to the higher frequencies if a structure of practicable size is to be used. For this reason the majority of rotary beam antennas are constructed for the 28-Mc. band, although many are in use at 14 Mc. They are relatively easy to construct for the ultra-high frequencies, since the element lengths are small.

Rotating directive antennas usually consist of a half-wave element with a director or reflector, or both, the electrical construction being as shown in Fig. 1343. More elaborate ones occasionally use a pair of collinear half-wave antennas in phase, with collinear directors or reflectors in "front" or "back." If sufficient height is available, additional elements sometimes are stacked, as in Fig. 1339. It must be realized that the antenna arrangements themselves do not differ from those used when the wires are fixed in position; the problems involved in the construction of a rotary beam antenna are almost purely mechanical.

The antenna elements may be arranged either vertically or horizontally as desired. At the frequencies for which most rotary antennas are built, horizontal polarization is usually more desirable, particularly in reception. This is because of the fact that the arriving waves usually are horizontally polarized and because electrical noises, bothersome at the high frequencies, are vertically polarized, as discussed early in this chapter. With horizontal elements it is therefore possible to get a better signal-to-noise

World Radio History

ratio under average conditions. However, it must not be thought that the vertically-polarized antenna suffers from a lack of effectiveness — it is simply that where circumstances permit a choice, horizontal polarization is to be preferred. It is true, also, that the mechanical construction of a rotating antenna with vertical elements often is simpler than that of a horizontal antenna having the same electrical arrangement.

The problems in rotary beam construction are those of providing a suitable mechanical support for the antenna elements, furnishing a means of rotation, and in attaching the transmission line so that it does not interfere with the rotation of the system. Quite simple and inexpensive arrangements can be used, although they may not be as convenient in operation as the more elaborate structures which some amateurs have built. An extremely simple method is indicated in Fig 1351. The particular antenna shown is the extended double Zepp of Fig. 1341-D, with a parasitic reflector, the elements being assembled on wooden spreaders and suspended vertically from any convenient point. The system is simply moved by hand to the desired position, the two-pound weights acting as anchors to hold it in place. Of course the ropes between the weights and lower spreader should be long enough to allow the weights to lie on the ground. The swivel at the top permits easy rotation without binding or twisting. The height required for this particular antenna, which is designed for the 28-Mc. band, is approximately 50 feet. It could be hung from a regular horizontal antenna of appropriate height. A similar suspension could readily be used for a half-wave antenna with director or reflector, in which case the antenna assembly would be only 25 feet or so long.

Fig. 1352 shows another mechanical arrangement for vertical elements. The antenna, which is a vertical section of metal tubing, is fixed in position and is provided with a director and reflector which rotate about it. The advantage of this arrangement is that no provision need be made for special contacts between the antenna and the feeder system, since the position of the antenna is fixed. A rope and pulley arrangement provides rotation from the

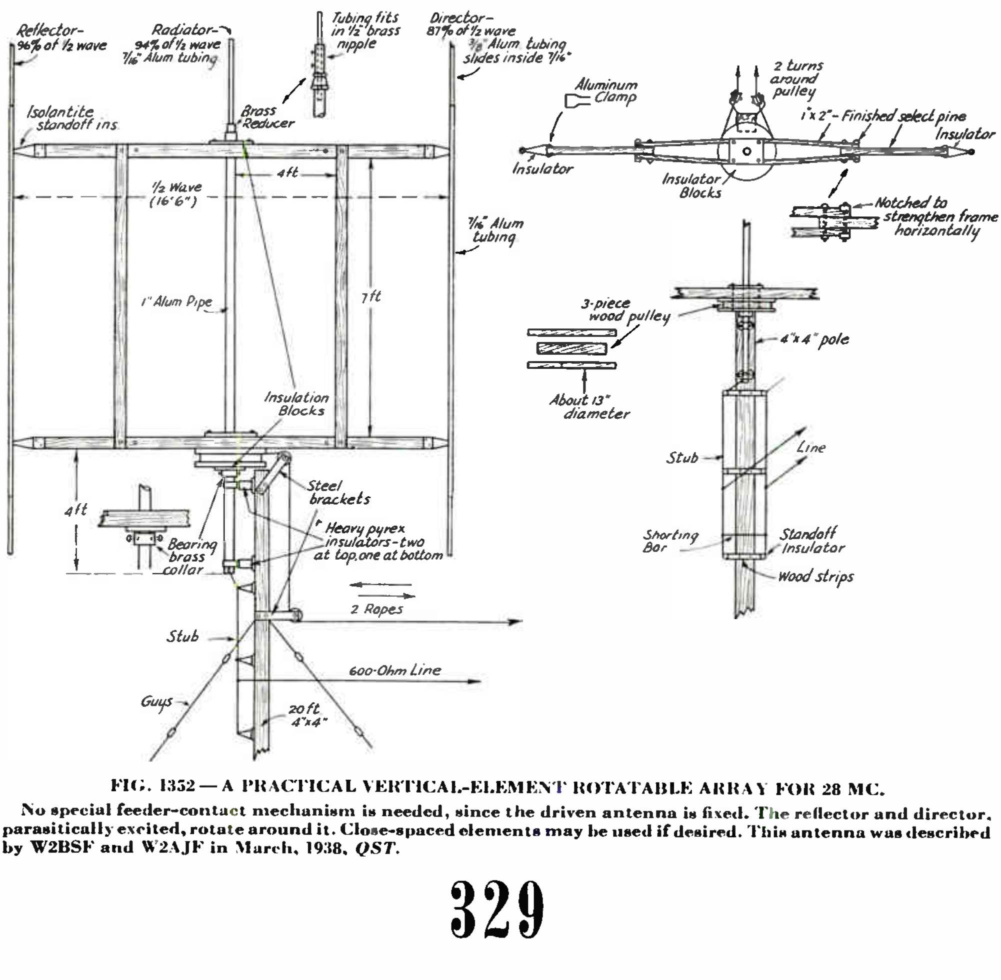


FIG. 1352 — A PRACTICAL VERTICAL-ELEMENT ROTATABLE ARRAY FOR 28 MC.

No special feeder-contact mechanism is needed, since the driven antenna is fixed. The reflector and director, parasitically excited, rotate around it. Close-spaced elements may be used if desired. This antenna was described by W2BSF and W2AJF in March, 1938, *QST*.

operating room, so that when a signal is picked up the antenna can be rotated rapidly to the position which gives maximum response. It is then also pointing in the proper direction for transmission to the same station. The antenna system shown can be varied in details, of course; for instance, close spacing might be used between the parasitic elements and the antenna to give somewhat greater gain.

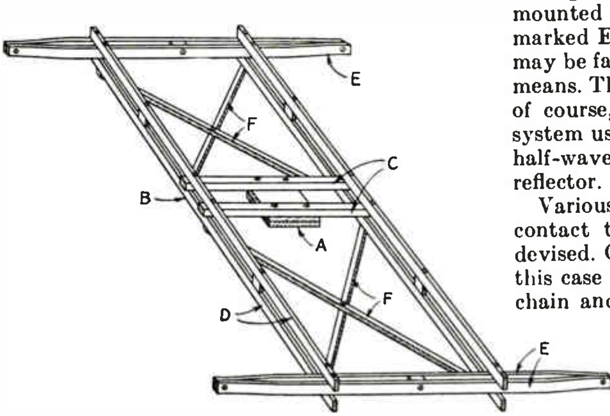


FIG. 1353 — EASILY-BUILT SUPPORTING STRUCTURE

Made chiefly of 1 by 2's, the structure is strong yet light-weight. Antenna elements are supported on stand-off insulators on the "E" arms. The length of the "D" sections will depend upon the element spacing. (W2DKJ, October, 1938, *QST*.)

When elements are suspended horizontally it is necessary to make a supporting structure, usually of light but strong wood. In such case, also, it is desirable, both to simplify the structure and to provide rigidity in the elements, to make the elements of light-weight metal tubing. Dural tubes often are used, and thin-walled corrugated steel tubes with copper coating also are available for this purpose. The elements usually are constructed of several sections of telescoping tubing, making length adjustments quite easy

An easily-constructed supporting frame for a horizontal rotary beam is shown in Fig. 1353. It may be made of 1 by 2 lumber, preferably oak for the center sections, with white pine or cypress for the outer arms. The self-supporting tubing antenna elements are intended to be mounted on stand-off insulators on the arms marked E. The square block at the center (A) may be fastened to the pole by any convenient means. The dimensions of such a structure will, of course, depend upon the type of antenna system used. It is particularly well suited to a half-wave antenna with a single director for reflector.

Various means of rotation and of making contact to the transmission line have been devised. One method is shown in Fig. 1354. In this case the supporting pole is rotated by the chain and sprocket arrangement shown, with the base of the pole resting on a bearing. Feeders are brought down the pole from the antenna to a pair of wire rings, against which sliding contacts press.

Parts from junked automobiles often provide gear trains and bearings for rotating the antenna. Rear axles, in particular, can readily be adapted to the purpose. Some amateurs use motor-driven rotating mechanisms which, although complicating the construction, simplify the remote-control of the antenna. More or less elaborate indicating devices to show, in the operating room, the direction in which the antenna is pointed, often are used with motor-driven beams.

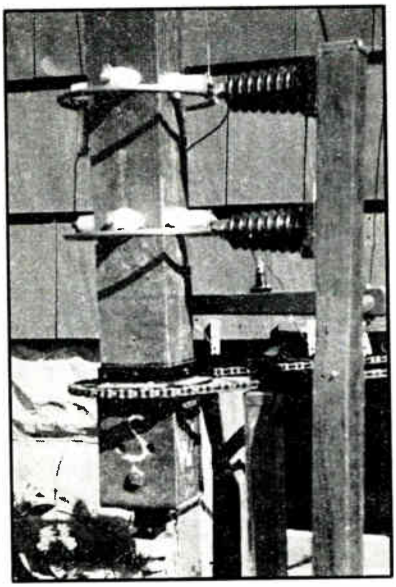


FIG. 1354 — ONE FORM OF ROTATING MECHANISM

A bicycle sprocket and chain turn the pole which supports the beam antenna. Feeder connections from the antenna are brought to the metal rings, which slide against spring contacts mounted on the large stand-offs on the short pole. (W8EEP, *QST*, October and November, 1938.)

Generally speaking, a rotary beam antenna is useful for only one band, and if multi-band operation is contemplated an additional antenna or antennas of conventional construction must be installed. A few systems, however, are adaptable to operation on two bands. The arrangement of Fig. 1341-B, for instance, can be used for this purpose.

The full benefit of a rotating directive antenna is realized only when the system is unidirectional, since such an antenna offers the maximum possibility of reducing interference and noise in reception. An incidental advantage to other amateurs is the fact that a unidirectional

World Radio History

antenna also reduces interference to other stations not along the line of transmission. Bidirectional systems, while somewhat less advantageous from this standpoint, are, however, somewhat easier to build mechanically, because it is only necessary to rotate the antenna through 180 degrees rather than 360. Feeder contact is not so difficult in such a case. When the antenna is designed for 360-degree rotation, it is preferable to have the feeders arranged so that continuous rotation is possible, rather than to have a stop at some point on the circle. This avoids the necessity for retracing almost the whole circle when it is desired to move the antenna the few degrees from one side of the stop to the other.

Time spent in adjustment of the rotary beam for maximum results, particularly in obtaining the best front-to-back ratio, is well repaid. The fact that the antenna is rotatable facilitates this process, since any convenient receiving location can be used for checking field strength.

The amateur's ingenuity will suggest many mechanical arrangements to suit the conditions which may exist. It is not our purpose here to attempt to give detailed designs, but rather to outline broadly the methods generally adopted. Detailed information may be found in articles in the following issues of *QST:* November, 1938; October, 1938; September, 1938; May, 1938; July, 1938; March, 1938; December, 1937; June, 1937; June, 1936; April, 1936.

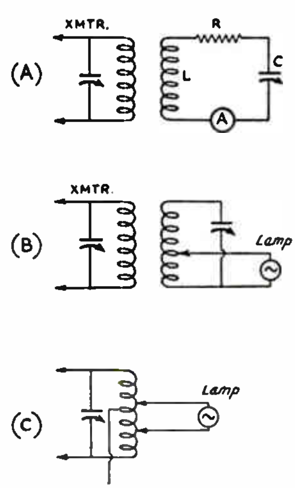


FIG. 1355 — DUMMY ANTENNA CIRCUITS

DUMMY ANTENNAS

In tuning the antenna system to the transmitter the antenna ammeter's chief function is that of providing a means for comparing the effects of different adjustments. The actual power output must be measured by adopting a different method. The simplest of these is that involving the use of a non-radiating or "dummy" antenna.

Such a dummy antenna should be part of the equipment available in all good stations. By its use, during periods of adjustment and tuning of the transmitter, much unnecessary interference with the communication of other stations may be avoided.

The dummy antenna is a resistance of suitable value capable of dissipating in the form of heat all the output power of the transmitter. One of the most satisfactory types of resistors for amateur work is the ordinary incandescent electric lamp. Other non-inductive resistors of sufficient power-dissipating capacity can be used, however.

Three circuits for use with dummy antennas are given in Fig. 1355. The first of these is for use with a low-resistance dummy — say 25 ohms or less. The resistor is connected in series with a tank circuit which tunes to the same frequency as the transmitter, and which is coupled inductively to it. If the value of the resistance is known accurately — measurement is difficult, however, because of skin effect at high frequencies — the power may be determined by measuring the radio-frequency current in the resistor and applying Ohm's Law ($W = I^2R$). The resistor must be non-inductive.

Incandescent bulbs, which in the 115-volt sizes have a resistance of 75 ohms or more at operating temperature for ratings of 150 watts or less, will work more satisfactorily in either of the other two circuits. The lamp should be equipped with a pair of leads, preferably soldered right to the terminals on the lamp base. The number of turns across which the lamp is connected should be varied, together with the tuning and the coupling between the dummy circuit and the transmitter, until the greatest output is obtained for a given plate input.

In using lamps as dummy antennas, a size corresponding to the expected power output should be selected so that the lamp will operate near its normal brilliancy. Then when the adjustments have been completed an approximation of the power output can be obtained by comparing the brightness of the lamp with the brightness of one of similar power rating in a 115-volt socket.

World Radio History

CHAPTER FOURTEEN

DESIGN AND CONSTRUCTION OF POWER SUPPLY EQUIPMENT

Rectifiers — Filters — Practical Plate and Filament Supply for Transmitters and Receivers — Voltage Dividers — Transmitter Biasing Voltage Supplies — Transformer and Filter Choke Construction — Portable and Independent Systems

THE a.c.-operated power supply is, because of the extent to which it is used, an important adjunct of nearly every amateur station. If a power supply is carefully designed, it may be useful at different times for different purposes with only a minor change (or none at all) required. A good receiver supply, for instance, may be used as a supply for an oscillator or oscillator-doubler combination, it may readily be applied to a speech amplifier, or it may be put to work as a transmitter bias supply so that all r.f. amplifier stages are biased past the point of cutoff and hence draw no current when excitation is removed. Because of this versatility of a good power supply, it is usually well worth while for an amateur to design a supply for sufficient output current for any purpose for which the supply might later be needed, to incorporate a good filter which will deliver essentially pure direct current, and to design the supply for good voltage regulation (small change of plate voltage with relatively large changes in load).

> **DANGER—HIGH VOLTAGE**
>
> **IT MUST be realized that the plate supply equipment of even a low-powered transmitter is a potential lethal machine. It is ever ready to deal out sudden death to the careless operator. A number of amateurs, indeed, have been killed by the output of their power supplies during the last few years. Many more have suffered severe injury. We cannot urge too strongly the observance of extreme care in the handling of power supplies and transmitters.**

The multi-use feature of a.c.-operated power supplies is not limited to small units of the type used for receivers. A power pack originally designed for a final r.f. amplifier plate supply may later be used for a Class-B modulator, or it may be used at another time as plate supply for a buffer stage. Frequently a unit designed to provide plate power for a final r.f. amplifier alone is used to supply two loads — the final amplifier and a buffer, or the final amplifier and a Class-B modulator. Thus, more expensive components used originally in power supplies to increase the range of possible use represent a good investment when it is later found that the smallest components which might have been used would have so limited the supply that a new one would be necessary to supply a somewhat increased load.

The transmitter power supply is very often the last consideration of the constructor. It is an "after thought" when the gear is completed and ready for a trial run. The power supply *should* be considered *initially* as an important integral part of the station. Its design will either reward the amateur with years of useful service or be a constant source of trouble, often at crucial moments when spares are not available. Apparatus described throughout this *Handbook* is conservatively rated. Even more conservatism will pay dividends in the equipment that delivers plate and filament energy. Often it will be called on to carry overloads. Bear these thoughts in mind when initially designing the power supply.

In this chapter we shall discuss power supplies for transmitters and receivers. These supplies will operate from the regular mains of 110-volt alternating current. It is the function of both to provide steady power for the tube filaments and direct current for the plates. Filament supply with modern transmitting and receiving tubes is relatively simple; the design of the plate supply, however, depends to a considerable extent upon the type of service to which it is to be put and is therefore

World Radio History

worthy of careful consideration. Time spent designing a power supply is time well spent.

Although the operating principles of modern power packs for receivers and power supplies for transmitters are essentially the same, the large difference of physical requirements of the two divide them so that they may best be considered separately. Noticeable differences between the supplies for medium- or high-power transmitting units and those for receivers are: use of mercury-vapor rectifiers almost exclusively in the large transmitting power supplies, whereas high-vacuum rectifiers are more commonly used for receiver supplies (mercury-vapor tubes are sometimes used in the latter); provision for preheating the filaments of the mercury-vapor rectifiers in the transmitter supplies, while the rectifier filament and plate voltages are usually applied simultaneously in receiver supplies; use of separate rectifier filament and plate transformers in transmitting supplies, while a common transformer in receiving packs supplies filament and plate voltage to the rectifier tube, and usually filament power to the receiver in addition; use of compact and inexpensive electrolytic high-capacity filter condensers in the receiver packs, whereas the filter condensers for high-voltage transmitter plate supplies usually are expensive, lower-capacity, oil-filled or oil-impregnated paper dielectric condensers; and the design of a receiver power supply on the basis of combined filament (or heater) and plate requirements, as compared to the design of a large transmitter plate supply without regard to the filament consumption of the stage to which the power supply will be attached, since the filament supply is usually separately provided by a step-down transformer obtained specifically for the purpose.

There is very little variation in type and size of receiver power supplies, and for that reason, it is simpler to choose a well-suited circuit design from the small number of different ones in common use, and to duplicate the supply insofar as practicable.

RECEIVER POWER SUPPLIES

POWER supplies for receivers differ materially from those for transmitter high-power stages also in that the very smallest trace of "ripple," or a.c. hum, must be completely eliminated to make possible satisfactory reception. Nothing is more annoying than a "hummy" B supply. The ripple can be reduced to satisfactory proportions by the use of three filter condensers (a three-section electrolytic condenser with capacities of 2, 4 and 8 μfd. will be satisfactory) and two receiver-type 30-henry chokes. Fig. 1401-A is the wiring diagram of a typical receiver power supply. It uses a power transformer of the type used in broadcast receivers, delivering approximately 350 volts each side of the center-tap on the high-voltage winding. This type of power supply will take care of an ordinary amateur receiver and in addition will easily handle an audio power amplifier stage using a 47 pentode or a pair of 45's in push-pull.

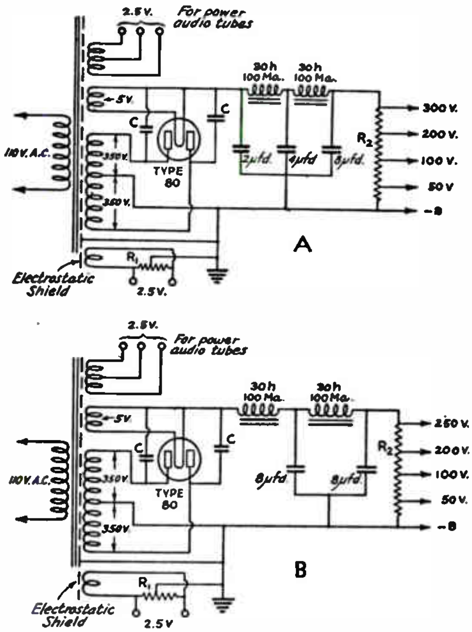


FIG. 1401 — WIRING DIAGRAMS FOR RECEIVER POWER SUPPLIES

Condenser C should be a mica condenser of about 0.002 μfd. capacity. Its size is not critical and it will be required only if tunable hums are present, as explained in the text. Resistor R_1 is 20 ohms total, tapped at the center. R_2 is the voltage divider for obtaining different voltages from the power supply. If the receiver itself is equipped with a divider (the preferable method) R_2 will be a simple bleeder of about 15,000 ohms. Otherwise it may be any of the regular voltage dividers sold commercially for this use, or may be a 15,000 ohm resistor tapped at every 3000 ohms. The resistance needed between taps will depend upon the currents to be drawn at each of the taps. It is not usually necessary to have the voltages nearer rated values than within 20%, with modern receiving tubes.

The output voltage will be rather higher than is required for the receiver itself, however, so the filter may be rearranged somewhat to use choke input, which will reduce the voltage and give better regulation. This is shown in Fig. 1401-B. Alternatively, a transformer giving lower output voltage might be used if the receiver has no power stages and therefore does not take much current.

Special care must be taken with power packs for autodyne receivers to make certain that the voltage output will be constant and that "tunable hums" do not appear. A varying output voltage will make the detector oscillation frequency change and hence make signals sound wavering and unsteady. The choke-input filter of Fig. 1401-B is recommended on this score; it will be especially valuable if the receiver volume control operates on the bias on the r.f. amplifiers. Tunable hums are hums which appear only at certain frequencies to which the receiver is set and only with the detector oscillating. It may be that no hum can be heard with the detector out of oscillation but a strong hum is noticed as soon as the detector is made to oscillate. This is a tunable hum and cannot be eliminated by the addition of more filter condensers or chokes since it is caused by r.f. getting into the power supply and picking up modulation. Small condensers connected across the plates and filament of the rectifier tube as shown in both diagrams usually will eliminate this type of hum. A grounded electrostatic shield between the primary and secondaries of the power transformer also will help. Not all transformers have such a shield, however. Of course the power leads coming from the receiver itself should be well by-passed to prevent r.f. from getting into the power supply.

For some applications where the current to be taken from the power supply is not more than a few milliamperes — a separate power supply for a frequency meter, for example — resistors can be substituted for the filter chokes to make a compact power supply. Resistors of 10,000 to 50,000 ohms should be satisfactory, depending upon the voltage drop that is permissible. With a midget power transformer and a low-voltage high-capacity electrolytic condenser, together with one of the smaller rectifier tubes listed in the table, a physically small but adequate power supply can be built.

Regulated Power Supply for Audio Amplifiers or Receivers

For the amateur who needs a power supply with excellent regulation at approximately 250 volts and 70 ma. there is one shown in Fig. 1402.

In this system the fundamental principle is that of "lossing"; that is, the power supply without regulation must be capable of furnishing more voltage than is wanted at the output, under any and all conditions. The regulator cannot add anything to the output; it can only hold down excess input. In this it is similar to all a.v.c. systems. Therefore, the first requisite is a power transformer which will give, under full load conditions, at the lowest line voltage likely to be encountered, the desired output voltage *plus* the minimum drop through the regulator tube. The most suitable regulator tubes are triodes having low plate resistance, and of those available the 2A3 comes nearest to being the ideal. Allowing 60 or 70 milliamperes per 2A3, the lowest possible tube drop is at zero bias. The grid of the tube cannot be swung positive in this application, because the voltage drop across the control tube's plate resistor, R_5 in Fig. 1402, cannot reverse in polarity. The limiting condition is zero bias, attained when the plate current of the control tube, a 6J7, is completely cut off. At zero bias, the drop between plate and cathode of a 2A3 at 70 milliamperes is approximately 70 volts. It is best to figure on a minimum drop of about 100 volts through the regulator tube, however, because at very low control-tube plate currents the neon tube is likely to extinguish, thereby destroying the control. While the neon is conducting, the voltage drop across the lamp is approximately constant at 65 volts.

Since a considerable voltage drop has to be tolerated, and since as much output as possible is wanted from a standard b.c. receiver type transformer, a condenser-input filter should be used. Further, to increase the output voltage, an 83-V low-drop rectifier is used in place of the customary 80. The net result is that at the full-load rating of the transformer, 70 milliamperes, a regulated output of 250

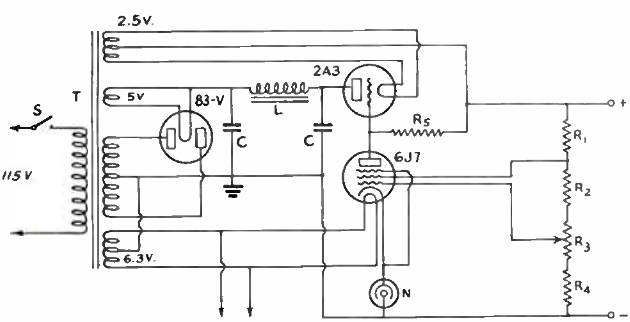


FIG. 1402 — PRACTICAL VOLTAGE-REGULATED SUPPLY FOR RECEIVERS, SPEECH-AMPLIFIERS OR DEVICES HAVING COMPARABLE VOLTAGE AND CURRENT REQUIREMENTS

C — Double 8-μfd. dry electrolytic, 450-volt working (Aerovox).
L — 12 henrys, 75 ma. (Thordarson T-47C07).
R_1 — 10,000 ohms, 1 watt.
R_2 — 25,000 ohms, 1 watt.
R_3 — 10,000-ohm potentiometer (Yaxley Y10MP).
R_4 — 5000 ohms, 1 watt.
R_5 — 0.5 megohm, 1 watt.
N — 1-watt G-10 neon bulb with base resistor removed.
T — Power transformer, 350 volts each side c.t., 70 ma.; 6.3 volts at 3 amp.; 2.5 volts at 4 amp.; 5 volts at 2 amp. (Thordarson T-70R21.)
A 6C6 may be substituted for the 6J7 if desired.

World Radio History

volts can be secured. The output control, R_3, gives a range from 160 to 365 volts; the output current is limited at the higher voltages, but at 200 and below considerably more than the rated current can be taken without losing control.

A transformer with two filament windings in addition to the rectifier winding is a requisite unless one wants to install a separate filament transformer for either the regulator tube or the control tube. In this case the transformer used has a 2.5-volt winding and a 6.3-volt winding; the former supplies the 2A3, while the latter handles the control tube and the receiver or whatever device is used in conjunction with the supply. Transformers with two 2.5-volt windings are also generally available, in case the receiver uses 2.5-volt tubes. In such case a 57 can be substituted for the 6J7.

The neon lamp is the 1-watt G-10 type, the 1-watt size being used simply because the common half-watt size is not recommended, according to the manufacturers, for d.c. For good regulation, it is essential that the resistor be taken out of the base, or else that one of the lamps without a base resistor be secured. The cement holding the base to the bulb may be softened with boiling water or a gas flame. If the resistor is left in, the regulation is considerably better than that of the power supply alone, but not nearly as good as when the resistorless lamp is used.

There are no special "tricks" to be observed in getting the thing to work. As already pointed out, the values given in Fig 1402 are the ones found best in practice. R_5 may be made as low as 0.1 megohm; lowering the resistance will increase the range of control with varying loads, but does not give quite as good

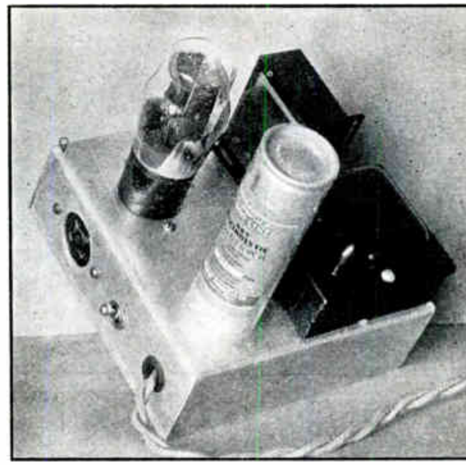


FIG. 1403 — LOW-POWER RECEIVER POWER SUPPLY

regulation as a half megohm. With the latter, the variation in output voltage from zero output current to 70 milliamperes is of the order of a volt or two — scarcely perceptible on a 500-volt meter, while the lower value of R_5 shows a change of 7 to 10 volts under the same conditions. Most of the change takes place between 0 and 25 milliamperes, however, so that there is very little practical difference when used with the ordinary receiver which has a fairly high minimum current.

Output Voltage	*Max. Output Current*
350	35 ma.
300	50 ma.
250	75 ma.
200	95 ma.
160	over 100 ma.

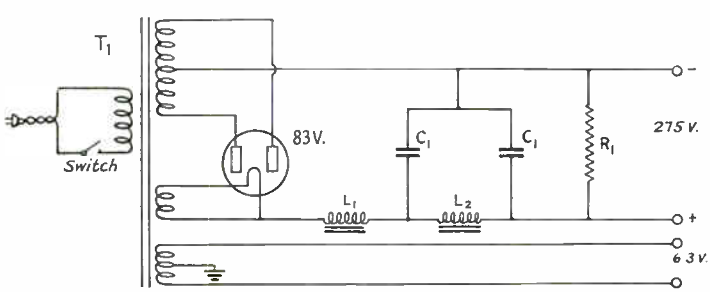


FIG. 1404 — A LOW-CURRENT POWER SUPPLY FOR THE REGENERATIVE RECEIVERS OR T.R.F. RECEIVER

T_1 — 300- to 350-volt, 40-ma. plate winding, 6.3-volt 2-ampere heater winding, 5-volt 3-ampere rectifier winding.

L_1, L_2 — 30-henry, 40-ma. filter chokes.

C_1 — Dual 8-mfd. 425-volt filter condenser (electrolytic).

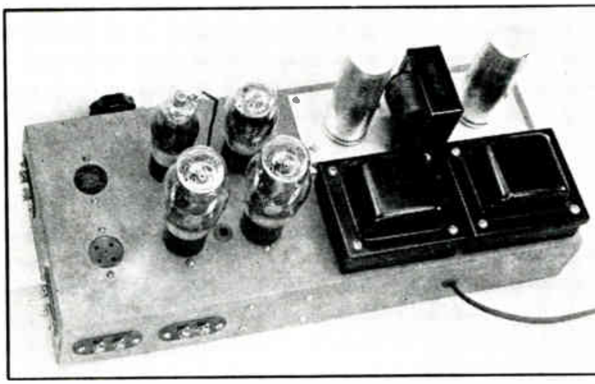
R_1 — 50,000-ohm, 10-watt resistor.

2.5 volt heater windings may be substituted, subject to receiver requirements.

The regulating capabilities of the supply depend to a considerable extent upon the output voltage selected. With constant line voltage (115 volts) the output will stay under control from zero output current up to the maximum limits as shown above.

Line voltage variations, as well as output current variations, are compensated for to the extent to which the transformer is capable of supplying the excess voltage required. At 250 volts output, the voltage will stay constant over a range from 108 to 135 volts (the maximum available from the Variac autotransformer used for this test). At 200 volts output, the same thing is true over a range of 100 to 135 volts on the primary, and at 180 volts, over

World Radio History



HIGH-CURRENT VOLTAGE-REGULATED SUPPLY

The circuit is that of Fig. 1402, with addition of a second 2A3 tube in parallel with that shown and a second transformer added with high-voltage secondary connected in parallel (and in phase) with that shown in Fig. 1402. Thus, the current values applying to the supply of 1402 are doubled. In addition, fil. voltages are available from all of the filament windings of the second transformer (including those designed for heating rectifier tubes).

90 to 135 volts. Momentary variations (such as caused by switching on a motor or similar operation which cause current surges and a resultant dip in the line voltage) can occur over a much wider range without affecting the output voltage because enough energy is stored in the filter condensers to bridge such a short gap.

The neon tube is a visual indication of control, since the voltage is regulated so long as the tube glows. If the supply is used on a receiver and the load current increased or line voltage dropped to the point where the bulb goes out, there will be a click and a perceptible hum, indicating that control has been lost and that the filtering action of the regulator likewise has disappeared. With the regulator working, it is extremely difficult to detect any hum. The additional filtering makes it possible to dispense with the second filter section ordinarily required, so that a voltage-regulated supply actually costs very little more than a non-regulated supply having equivalent filtering.

All in all, a well-regulated power supply should find many uses in the station.

TRANSMITTER FILAMENT SUPPLY

The first division of the power supply for the transmitter is the supply to the filaments of the tubes used. Though batteries are sometimes used for this supply, alternating current obtained from the house current through a step-down transformer usually is more practical and more satisfactory. In some cases the filament-supply turns are wound over the core of the high-voltage transformer, thus eliminating the necessity for a separate filament transformer. This practice, however, is not always to be recommended. The filament supply must be constant if the transmitter is to operate effectively, and with both filament and high-voltage supplies coming from one transformer this constancy is obtained only with great difficulty, since changes in the load taken from the high-voltage winding cause serious changes in the voltage obtained from the filament winding — unless the transformer is operating well under its rating or unless special compensating apparatus is employed. Where the two windings are combined it necessitates shutting off the filament each time the plate voltage is shut off. This is very hard on filaments and shortens their life considerably. Wherever possible the high-voltage and filament transformers should be separate units operating, if it can be arranged, from different power outlets, particularly with transmitters using tubes larger than the 10. This also allows a change in transformer high voltage by means of a tapped one-to-one ratio transformer in the primary or by use of an autotransformer without changing filament voltage. (See Fig. 1413.)

Examination of any of the power-supply circuits will make it obvious that the filaments of the rectifier tubes must be well insulated from the filaments of the oscillator tubes. The filaments of the rectifiers provide the positive output lead from the plate-supply system while the filaments of the transmitter tubes are connected to the negative side of the high-voltage supply. The fact that the two filament supplies must be insulated does not, however, mean that two transformers are required. The two windings can be on the same core, the necessary insulation being provided between them. Should the filament transformer be bought and should it have no windings suitable for the filaments of the rectifiers, an extra winding usually can be fitted without difficulty. For 866 rectifiers two No. 12 gauge wires in parallel should be used for the winding, the number of turns being determined by the "cut and try" method. With most transformers only a few turns will be necessary to give the required voltage. The rectifier-filament winding can be center-tapped or a center-tapped resistor can be used across it in the manner described for the transmitter filaments. The center-tap is not an absolute necessity, however; the positive high-voltage lead can be taken from either side of the rectifier filament winding instead.

World Radio History

For medium- and high-power r.f. stages of transmitters, and for high-power audio stages, it is considered most desirable to use a separate filament transformer for each section of the transmitter, installing the transformer near the tube sockets and feeding the primary lines instead of the secondary lines through the interconnecting cables of the transmitter. In this way, necessity of abnormally large wires carrying filament power is avoided, and two small, well-insulated leads may be used to carry the total filament power for all stages without appreciable filament voltage drop. This is very important in large stages with heavy-current, low-voltage filaments, since a very small resistance in series with the filament of the stage may reduce the voltage applied to a value at which the tube is likely to be damaged. Loss of emission of power tubes is often caused by under-voltage filament operation, even for short periods of time.

PRINCIPLES OF THE TRANSMITTER PLATE SUPPLY

UNDER the regulations governing amateur stations the plate supply must deliver adequately-filtered direct current to the plates of all tubes in transmitters operating on frequencies below 60 Mc. This requirement is designed to insure that the emitted signal will be "pure d.c." on the six most important amateur bands, and to prevent transmitters having poor frequency stability from producing broad signals.

High-voltage direct current for the transmitting tubes can be obtained in a number of ways. These include banks of dry or storage cells connected in series to give the required voltage, dynamotors and motor-generators, and transformer-rectifier-filter systems. The latter are by far the most generally used.

Other sources of power than a.c. mains are treated in Chapter Fifteen as emergency power supplies. In addition a direct-current motor-generator set is an excellent source of plate power. It is relatively costly, however, and its output is not as pure as that from batteries because of the ripple caused by commutation. The commutator ripple can be filtered out with little difficulty; a 1- or 2-μfd. condenser shunting the output usually will be sufficient.

A dynamotor is a double-armature machine; one winding drives it as a motor while the other delivers a few hundred volts d.c. for the transmitting tubes. The motor winding usually operates from a six- or twelve-volt storage battery. The dynamotor also has commutator ripple, which must be filtered out just as with the motor-generator set.

Rectifier Operation and Rectifier Systems

Assuming that alternating-current power is available at 110 or 220 volts, a very effective high-voltage supply system can be built up from a high-voltage transformer, a rectifier system and a filter. The details of the transformer and the filter are to be given complete treatment later. We will limit these remarks to the rectifier.

An understanding of how a rectifier functions may be obtained by studying Fig 1405. At (1) is a typical a.c. wave, in which the polarity of the current and voltage goes through two complete reversals in each cycle. The object of rectification is to transform this wave into one in which the polarity is always the same, although the *amplitude* of the current and voltage may vary continuously. At (2) we have the secondary of a power transformer connected to a single rectifier element. The rectifier is assumed to be "perfect," that is, current can only flow through it in one direction, from the plate to the cathode. Its resistance to flow of current in that direction is zero, but for current of opposite polarity its resistance is infinite. Then during the period while the upper end of the transformer winding is positive, corresponding to A in (1), current can flow to the load unimpeded. When the current reverses, however, as at (1) B, it cannot pass through the rectifier, and consequently nothing flows

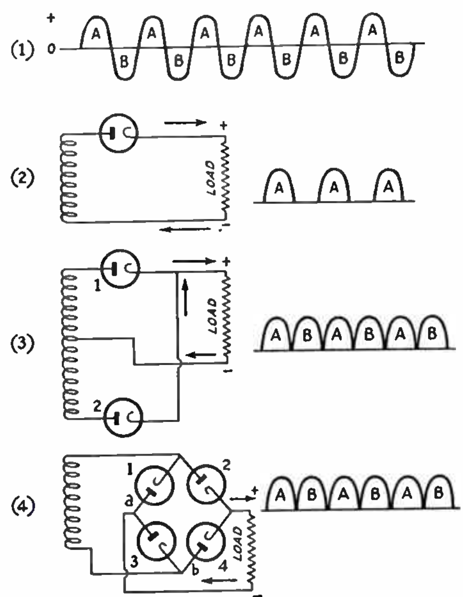


FIG. 1405 — FUNDAMENTAL RECTIFIER CIRCUITS

At (1) is the conventional representation of the a.c. wave; (2) shows a half-wave rectifier; (3) is the full-wave center-tap system, and (4) is the "bridge" rectifier. The output waveform of each type of rectifier is shown at the right.

World Radio History

to the load. The drawing shows how the output from the transformer and rectifier looks. Only one half of each cycle is useful in furnishing power to the load, so this arrangement is known as a "half-wave" rectifier system.

In order to utilize the remaining half of the wave, two schemes have been devised. At (3) is shown the "full-wave center-tap" rectifier, so called because the transformer secondary winding must consist of two equal parts with a connection brought out from the center. In (3), when the upper end of the winding is positive, current can flow through rectifier No. 1 to the load; this current cannot pass through rectifier No. 2 because its resistance is infinite to current coming from that direction. The circuit is completed through the transformer center-tap. At the same time the lower end of the winding is negative and no current can flow through rectifier No. 2. When the current reverses, however, the upper end of the winding is negative and no current can flow through rectifier No. 1, while the lower end is positive and therefore rectifier No. 2 passes current to the load, the return connection again being the center-tap. The resulting wave shape is again shown at the right. All of the wave has been utilized, and the amount of power which can be realized at the load is doubled. In order to maintain the same output voltage (instantaneous, not average), as at (2), however, each half of the transformer secondary must be wound for the same voltage as that furnished by the whole winding in (2); or, conversely, the total transformer voltage with the connections shown in (3) must be twice the desired output voltage.

If the transformer has no center-tap, or if the total voltage it furnishes is the same as the desired output voltage, scheme (4), known as the "bridge" rectifier, may be used to obtain full-wave rectification. Its operation is as follows: When the upper end of the winding is positive, current can flow through No. 2 to the load, but not through No. 1. On the return circuit, current flows through No. 3 back to the lower end of the transformer winding. When the wave reverses and the lower end of the winding becomes positive, current flows through No. 4 to the load and returns through No. 1 to the upper side of the transformer. The output wave shape is shown at the right. Although this system does not require a center-tapped transformer, and the voltage of the winding need only be the same as that desired for the load, four rectifier elements are required, so that the center-tap may actually prove to be more economical, all things considered.

Although the rectifier output is direct current in the sense that the polarity is always the same, the amplitude is not uniform but varies continually as shown in Fig. 1405. Before the power can be supplied to the transmitting-tube plates the "humps" must be smoothed out by a filter. Filters will be considered in detail in a later section.

Types of Rectifiers

Practically all rectifiers in use to-day by amateurs are of the vacuum-tube type; in former years when suitable tube rectifiers were not available many other types, including chemical, rotating (synchronous), and mercury-arc, were in general use. These are now of relatively little importance in amateur transmitters, and since they have no particular advantages over the widely-used tube rectifiers will not be treated in this chapter.

There are two types of tube rectifiers: those having a high vacuum, in which the conduction is purely by means of the electronic stream from the cathode to the plate; and those in which a small quantity of mercury has been introduced after the tube has been evacuated. In the latter type, part of the mercury vaporizes when the cathode reaches its operating temperature, and during the part of the cycle in which the rectifier is passing current the mercury vapor is broken down into positive and negative ions; the positive ions decrease the normal resistance of the plate-cathode circuit so that the voltage drop in the tube is less than with high-vacuum types. As a result of the lower voltage drop the power lost in the rectifier is decreased, and the efficiency of the mercury-vapor rectifier is therefore greater than that of the high-vacuum type.

Operating Limits of Rectifiers

Two factors determine the safe operating limits of mercury-vapor tube rectifiers. These are the maximum inverse peak voltage and the maximum peak current.

The inverse peak voltage is the maximum voltage which appears between the plate and cathode of the rectifier tube during the part of the cycle in which the tube is not conducting. Referring again to Fig. 1405, in (2) it is apparent that during the "B" part of the cycle when the half-wave rectifier does not conduct, the inverse potential between the plate and cathode will be equal to the full transformer voltage; the peak value of this voltage is 1.4 times the r.m.s. or effective output voltage. In the full-wave centertap rectifier of (3), during the part of the cycle when rectifier No. 1 is non-conducting the inverse potential across its elements is equal to the sum of the potentials of both halves of the secondary of the transformer; the peak inverse voltage is again 1.4 times the full transformer voltage. Inspection will show that this is similarly the case with the bridge rectifier, circuit (4). It is well to remember that, no matter what the type of rectifier,

World Radio History

the inverse peak voltage is always 1.4 times the *total* transformer voltage. Strictly speaking, the voltage drop in one rectifier tube should be subtracted from the figure so calculated, but since the rectifier drop usually is negligible in comparison with the transformer voltage, no practical error results from neglecting it. Because it is always the total transformer voltage which must be considered, we find that for a given inverse peak voltage rating the permissible output voltage with the bridge rectifier circuit is twice that with the center-tap circuit, because in the latter circuit only half the total transformer voltage is available for the load. However, only half the current may be taken from the windings compared to that taken when a center tap is used. For given power ratings, when doubling the voltage the current must be cut in half. The bridge circuit requires twice as many rectifier elements.

The peak current through the rectifier tube is chiefly a function of the load and the type of filter circuit used. We shall have more to say on this point in the section on filters.

While inverse peak voltage and peak current ratings apply to both high-vacuum and mercury-vapor rectifiers, they have more significance with the mercury-vapor types than with the vacuum types. In the vacuum-type rectifiers the inverse voltage which the tube will handle safely is limited chiefly by the spacing between the plate and cathode and the insulation between the leads from these elements in the glass press and in the base. In the mercury-vapor rectifier, however, the inverse peak voltage is a function of the design of the tube and the operating temperature; for a given tube type there is a critical voltage above which an "arc-back" will occur, ruining the tube. The higher the temperature of the mercury vapor the lower the voltage at which arc-back will take place; for this reason mercury-vapor rectifier tubes should always be located so that there is free circulation of air around them for cooling. The tubes are usually rated at a peak inverse voltage which will permit safe operation at normal current in a room of average temperature.

The peak current rating is based on an electron flow from the filament which will give a filament life of 1000 hours or more. In the high-vacuum types the tube voltage drop depends upon the current; the higher the current the greater the voltage drop. High-vacuum tubes therefore tend to protect themselves under overload, because excessive current causes a larger voltage drop which in turn reduces the voltage across the load circuit, thus limiting the current flow. In mercury-vapor rectifiers, however, the voltage drop is substantially constant for all values of current, hence the rectifier cannot protect itself from overloads. A heavy overload on a mercury-vapor rectifier, even though instantaneous, is likely to destroy the filament or cathode of the rectifier tube, because under such conditions the positive ions of the mercury vapor are attracted to the cathode with such force as actually to tear off the emitting material with which the cathode is coated. A less drastic overload applied over a longer period of time will have the same effect. Mercury-vapor rectifiers should always be worked within the peak current ratings if normal tube life is to be expected.

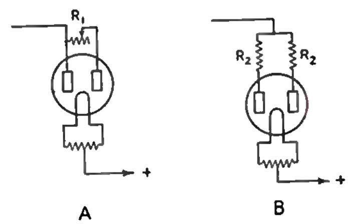


FIG. 1406 — METHODS OF BALANCING FULL-WAVE RECTIFIER PLATE CURRENTS WHEN PLATES ARE CONNECTED IN PARALLEL. R_1 MAY BE AN ORDINARY 30-OHM FILAMENT RHEOSTAT. R_2 SHOULD BE 50 TO 100 OHMS

Standard types of rectifier tubes are listed in the table in Chapter 5, together with their ratings and a brief description of each type. In the smaller sizes, the tubes are generally manufactured as full-wave rectifiers; that is, a cathode and two plates are provided in one bulb so that full-wave rectification can be obtained with a center-tapped transformer. Tubes for high voltages are always half-wave rectifiers; two of them are needed for the center-tap system.

The principal advantages of the mercury-vapor rectifiers over the high-vacuum type are the lower voltage drop and the fact that this drop is independent of the load current. In all the mercury-vapor tubes the voltage drop can for practical purposes be considered to be 15 volts regardless of load current. This low, constant drop results in a power supply having better voltage regulation — discussed in a later section — than one using high-vacuum rectifiers, and is responsible for the wide use of mercury-vapor rectifiers in amateur transmitting equipment. The most popular rectifier tubes are the 82, 83, and 866. Occasionally high-power transmitters employ 872 rectifiers.

Mercury-vapor rectifiers always should be operated with the rated voltage applied to the filament. If the filament voltage is low (filament or cathode temperature too low) the effect is exactly the same as though the tube was heavily overloaded, and the cathode will rapidly lose its emission. For this reason, in operating high-voltage mercury-vapor recti-

World Radio History

fiers the filament power always should be applied for at least 15 seconds before the plate voltage is turned on so that the filament will be certain to reach its correct operating temperature. If the rectifiers have been out of service for some time it is also advisable to heat the filaments for 10 or 15 minutes before applying plate voltage so that all the mercury that may have condensed on the filament will be vaporized.

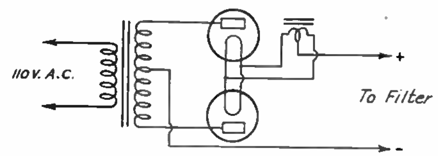


FIG. 1407 — FULL-WAVE RECTIFIER WITH CENTER-TAPPED PLATE TRANSFORMER

Filament voltage should be measured right at the socket terminals, not at the transformer, when tubes such as the 866 and 872 are used because of the heavy filament currents taken by these tubes. It is also advisable to pick out a socket which will make very good contact with the tube pins and also to make sure that the socket is capable of carrying the current.

In attempting to use both plates in parallel in 82 and 83 rectifiers, it is sometimes difficult to get the load to divide evenly between the two halves of the rectifier. Generally one of the plates will take all the load and the other will not "start." This is almost certain to happen if the positive lead is taken off one side of the rectifier filament transformer.

This can be corrected by using a filament center-tap connection or by means of low resistances in series with the plates of the rectifier tubes as shown in Fig. 1406. In *A* a low resistance filament rheostat is connected between the rectifier plates while a fixed resistance of 50 to 100 ohms is used in series with each rectifier plate in *B*.

Reference to the table of rectifier tubes in Chapter Five will show that the smaller mercury-vapor tubes are rated for a given output current and a maximum r.m.s. applied transformer voltage, while the ratings on the larger tubes are exclusively in terms of inverse peak voltage and peak current. Because of the low voltage at which the small tubes are operated, the ratings for them will hold regardless of the type of filter into which the rectifier works. The 866 and 872, on the other hand, are high-voltage tubes and must be handled with more care; the peak current, which must not exceed the rated value, will depend largely on the type of filter used, while the inverse peak voltage is a function of the transformer voltage and the rectifier circuit. With rectifier tubes having an inverse peak voltage rating of 7500 volts the transformer voltage, in the center-tap circuit, should not exceed 2600 volts each side of the center tap. If the bridge circuit is to be used, the total transformer voltage should not exceed 5200 volts. The corresponding voltages with 10,000-volt tubes are 3500 and 7000 volts. Few amateurs use plate voltages exceeding 3000 volts; the average for high-power amateur transmitters is 2000 to 2500 volts. The high-voltage rectifiers in the table are therefore sufficient for practically all amateur needs.

When heavy currents are being used the positive high voltage connection should always be made at the rectifier tube center tap instead of one side of the filament. This is necessary to evenly divide the load only when max. current ratings of the tubes is being approached.

Rectifier Circuits

The elementary rectifier circuits of Fig. 1405 are shown in practical form in Figs. 1407 and 1408. Fig. 1415-B is the center-tap circuit for use with a full-wave rectifier tube, and is used only for low-voltage power supplies — 500 volts or less. Both center-tap and bridge circuits are given in Figs. 1407 and 1408, half-wave rectifier tubes being used in both cases.

Using the same plate transformer, approximately twice the voltage output of the center-tap circuit may be obtained with the bridge circuit. Four rectifiers and three filament-heating transformers are required for the bridge arrangement, however, and the original maximum current rating of the high voltage transformer must be halved. A transformer delivering 1000 volts with a maximum current rating of 200 ma. with the center-tap circuit will deliver approximately 2000 volts with the bridge circuit but the maximum current which may be drawn without overloading the transformer will be 100 ma.

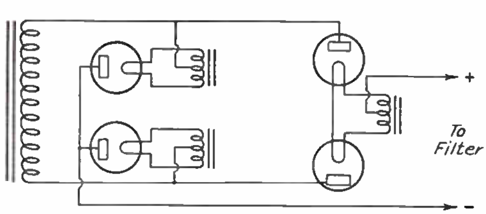


FIG. 1408 — FULL-WAVE OR BRIDGE RECTIFIER WHEN PLATE TRANSFORMER HAS NO CENTER TAP

Using the same plate transformer as in Fig. 1407 the voltage output would be double but the current would have to be half as great for the same transformer kva rating. Note that it is necessary to have three separate rectifier filament windings or separate transformers, as the case may be. Insulation between windings must be able to withstand full voltage.

World Radio History

The Filter

The filter is a very important section of the power supply. Primarily its purpose is to take the electrical pulses from the rectifier (see Fig. 1405) and smooth them out so that the power delivered to the plates of the transmitting tubes is perfectly continuous and unvarying in just the same way that the current from a battery is continuous and unvarying. But in addition to this, the design of the filter will greatly affect the voltage regulation of the power supply and the peak current through the rectifier tubes.

In analyzing the output of a rectifier-filter system, it is customary to consider the output voltage to consist of two components, one a steady "pure d.c." voltage and the other a super-imposed a.c. voltage — the ripple voltage — which when combined with the assumed unvarying voltage gives the same effect as the actual rapid variations in the output of an incompletely-filtered power supply. When the r.m.s. or effective value of the ripple voltage is divided by the d.c. voltage the result, expressed as a percentage, gives a "figure of merit" (per cent. ripple) for comparing the performance of various filter circuits; furthermore, the amount of filter needed for various transmitter applications is dependent upon the ripple percentage that can be tolerated. Experience has shown that a ripple of 5% or less will give "pure d.c." for c.w. telegraphy if the transmitter has high frequency stability; for radiotelephony the ripple should be .25% or less to reduce hum to a satisfactory level.

Filters are made up of combinations of inductance and capacity — chokes and condensers. Although there are several ways of considering the operation of chokes and condensers in the filter, possibly the simplest is from the standpoint of energy storage as discussed in Chapter Three. Both chokes and condensers possess the property of storing electrical energy, the former in the form of the electromagnetic field, the latter in the dielectric field. While the amplitude of the rectified a.c. wave is increasing, energy is stored in both the inductance and capacity; after the peak has been reached and the amplitude of the rectified wave begins to decrease, the stored-up energy is released and fills in the valleys between the rectified humps. A little consideration of the action will make it evident that the energy storage required will depend upon the rate of occurrence of the rectified waves; the closer they are together the less will be the energy storage required. In other words, the amount of inductance and capacity needed will be inversely proportional to the frequency of the a.c. supply. A supply frequency of 60 cycles with full-wave rectification gives 120 rectified waves per second, corresponding to a frequency of 120 cycles. Similarly, full-wave rectification with 50-cycle supply gives a frequency of 100 cycles, and with 25-cycle supply a frequency of 50 cycles. The discussion to follow is based on full-wave rectification with 60-cycle supply; to maintain a given ripple percentage at the lower frequencies both inductance and capacity must be increased over the 60-cycle values. The required increases will be directly proportional to 60 divided by the supply frequency.

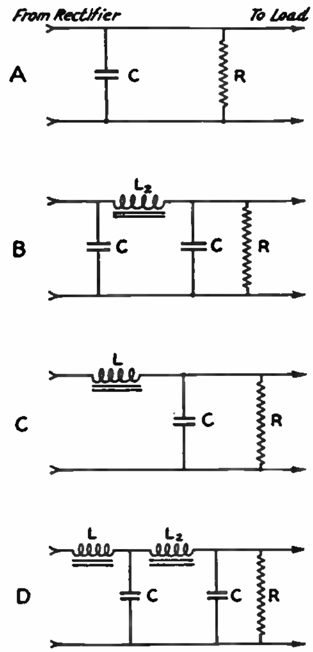


FIG. 1409 — FILTERS

At A is the simplest type of filter — a single condenser of high capacity connected across the rectifier output. With the addition of a filter choke and a second condenser this becomes the "brute force" circuit of B. C is a single-section choke-input filter. The two-section filter at D is recommended when the ripple voltage in the output must be low.

Types of Filters

Inductance and capacity can be combined in various ways to act as a filter. Four representative arrangements are given in Fig. 1409. The single condenser at *A* is not a complete filter, but will give considerable smoothing. This type of filter will not, generally speaking, be sufficient to meet the requirement that the plate supply for an amateur transmitter must be adequately filtered. The arrangement at *B* used to be a popular one. This is known as a condenser-input filter because a condenser is connected directly across the output of the rectifier. The condenser-input filter is characterized by high output voltage, poor voltage regulation and high rectifier peak current. These disadvantages make it unpopular in supplies delivering over 750 volts.

A third type of filter is shown at *C*. It consists of a single choke and condenser, and because the rectifier output goes to the choke, is known as a choke-input filter. Chief characteristics of the choke-input filter are good voltage regulation and low rectifier-tube peak current; for a given transformer voltage the output voltage will be lower than from the condenser input filter over most of the load range, however. The choke-input filter is the only type whose performance can be calculated accurately; there is no simple method of predetermining the performance of a condenser-input filter. The filter at *D* consists of two filters of the *C* type connected in series; this more elaborate arrangement is known as a two-section filter and is used to obtain greater smoothing than can be had economically with the single-section filter. Because of the many advantages of choke-input filters, they will be given detailed consideration in this chapter. In most cases the choke input filter is ideal for all around use in the amateur station.

Filter Condensers

Two types of filter condensers are commonly available: electrolytic condensers, and condensers using paper as the dielectric. In electrolytic condensers, the dielectric is an extremely thin film of oxide which forms on aluminum foil when the foil is immersed in a suitable electrolyte and is subjected to a d.c. voltage of the proper polarity. Electrolytic condensers are characterized by high capacity for a given size and cost, but cannot be made in single units for very high voltages, 600 volts being about the limit under present conditions. Electrolytic condensers are made in two types, "wet" and "dry." The "wet" condensers are provided with a liquid electrolyte in a sealed container; in the "dry" type the electrolyte is mixed with a filler to form a paste which is then placed between strips of aluminum foil. In neither type is the dielectric a perfect insulator; there is always an appreciable current flow between the electrodes, although it is only of the order of a few milliamperes. This leakage current is greater with the wet than with the dry types; the wet condensers, however, can stand voltage overloads better than the dry types because excessive voltage will simply increase the leakage current. Excessive voltage applied to the dry type will result in a "blown" condenser which must be replaced. Either type of electrolytic condenser will be satisfactory for condenser-input filters used with transformers delivering 350 volts each side of the center tap. Electrolytic condensers can be obtained in various capacities; 8 μfd. is a popular size.

If the maximum voltage of the power supply is greater than the rating of a single electrolytic condenser, two or more units may be placed in series to handle the higher voltage. It is not economically practical to use more than 2 electrolytic condensers in series as shown in Fig. 1410.

Electrolytic condensers are suitable for use only in d.c. circuits, and must be connected correctly. In the types having a metal container, the container usually is the negative terminal while the stud terminal is positive. A popular condenser for series connection is the double 8 μfd. condenser having four leads — the can being insulated from the condenser, in this case, and the negative leads are usually black. In any event the polarities are always plainly marked. Reversing the polarity will ruin the condenser.

If electrolytic condensers are allowed to stand idle for a time, the dielectric film will gradually disappear and the condenser must be "reformed." To prevent damage to the condensers and other power-supply components, the voltage always should be lowered before application to a power supply after it has been out of service for a few weeks. The film will re-form after a few minutes of low-voltage operation.

Paper condensers also are made in two types, with and without oil impregnation of the paper dielectric. The oil-impregnated condensers generally are suitable for higher voltages than the plain types. Condensers having a working-voltage rating equal to the highest output voltage of the power-supply system (see discussion on condenser-input filters) always should be purchased. Paper condensers can be purchased with voltage ratings up to 3000 volts and more. High-voltage condensers of modern design should be purchased from reputable dealers; it does not pay to "economize" by buying a cheap high-voltage condenser. Although the first cost of a good condenser may be higher, it will last indefinitely if not abused. Poor condensers may work for a

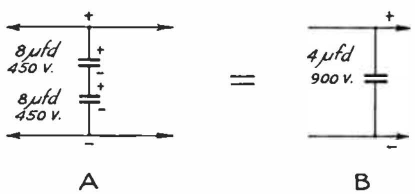


FIG. 1410 — ECONOMICAL CONDENSER FOR POWER SUPPLY WITH VOLTAGES UP TO 750

Two electrolytics may be connected in series, halving the capacity and doubling the voltage rating.

time, but eventually may "blow" and have to be replaced. Failure of a high-voltage condenser may also mean the destruction of the rectifier tubes.

Filter Chokes

The inductance of a choke will vary with the current through it and with the value of the ripple voltage impressed on it in the filter; inductance decreases with increasing direct current and with decreasing ripple voltage. In purchasing a choke information should be obtained as to its actual smoothing inductance at full d.c. load current and at the ripple voltage at which it is to work. The latter requirement can be expressed more simply by determining whether the choke is to be used as an input choke or as a smoothing choke (second choke) in a two-section filter. Input chokes usually are of the swinging variety.

Most of the small chokes obtainable from radio dealers are given a commercial rating of 20 or 30 henrys. This rating is meaningless unless the conditions under which the choke's inductance was measured are stated. Fortunately the smaller chokes are inexpensive and usually have enough inductance to work quite well in condenser-input filters; it is better, however, to buy a choke of good make than to trust to luck with a cheap, but unknown, product.

Filter chokes for high voltages should in every case be purchased from a reputable manufacturer. It must be realized that the design formulas given previously are based on *actual* inductance under load conditions; an over-rated choke will nullify the calculations and probably lead to an entirely different order of performance.

Specifications for building chokes at home are given in a table at the end of this chapter. The design data apply particularly to smoothing chokes; if a choke having an inductance equal to the critical value is chosen for the input choke the results will be satisfactory, although such a choke will not be as economical of materials as a properly-designed swinging choke. The design of swinging chokes to fulfill predetermined conditions is a difficult problem and is beyond the scope of this *Handbook*.

Voltage Regulation

The term "voltage regulation" is used to indicate the change in terminal voltage of a plate-supply system with different load currents. The windings of transformers and filter chokes used in plate supplies all have some resistance; as the current drawn from the power supply is increased the voltage drop in the transformer and chokes also increases with the result that the terminal voltage drops. Besides these ohmic effects, there may be other causes contributing to the decrease in terminal voltage with load, such as the behavior of the filter.

As ordinarily used in electrical engineering, the term "voltage regulation" refers to the increase in voltage resulting when the load current is decreased from the rated value to zero, expressed as a percentage of the terminal voltage at full-load current. It is often more convenient in speaking of plate-supply systems, however, to use the terminal voltage at no load as a base, in which case the percent regulation will be the *decrease* in terminal voltage from the no-load value to the value of load at which the power supply is to be worked. Amateur plate supplies are seldom used at a definitely-fixed load current, hence the greater convenience of expressing voltage regulation as a percentage of the no-load terminal voltage.

As an illustration, suppose the measured terminal voltage of a power supply is 1200 volts at no load — i.e., no current being drawn by the transmitting tubes. Then with the transmitter in operation the voltage is measured and found to be 900 volts. The voltage regulation will be

$$\frac{1200 - 900}{1200} = .25 \text{ or } 25\%$$

The voltage regulation will be found to vary with the load and with the type of filter used. Good plate supplies will have a regulation of the order of 10% or less; poorly-designed power supplies often have regulation as high as 50% — in other words, the voltage at full load drops to half its no-load value. Good voltage regulation is highly desirable with the self-controlled transmitter because in such a transmitter the frequency depends upon the plate voltage; if the plate voltage dives suddenly every time the key is pressed the note will have a chirpy or "yooping" character and be hard to read. While this consideration is not as important in the amplifier stages of more modern transmitters, good voltage regulation is still desirable because it tends to reduce key thumps.

Voltage regulation is extremely important in a power supply for a Class B modulator.

DESIGNING PLATE SUPPLY

As suggested before, the ripple voltage tolerable in the output of the power supply will depend upon the type of service. The percent ripple allowable for c.w. telegraphy will depend upon the design of the transmitter itself. If the dynamic stability of the transmitter is high — that is, if changes in plate voltage cause no noticeable change in the transmitter frequency — a larger ripple voltage can be tolerated without seriously affecting the tone of the transmitter than would be the case with transmitters in which a small change in plate

World Radio History

voltage produces an audible change in frequency. As a working rule, we can say that the plate supplies for all oscillators — and especially self-controlled oscillators — should have not more than 1% ripple in the d.c. output. Since filter apparatus for low-power stages — oscillators and buffers in almost all transmitters are low-power — is inexpensive, plate supplies for all low-power stages should conform to the rule of not more than a 1% ripple. For amplifier stages in which frequency modulation is not a factor, the figure of 5% or less ripple will be satisfactory for c.w. telegraphy.

For radiotelephony this figure should be .25% or less.

To illustrate the method of designing a plate supply, let us go through a specific problem. Suppose that two 838 tubes are to be supplied 1000 volts at 350 milliamperes; the tubes are to be used in the final amplifier stage of a crystal-controlled transmitter and a ripple of 5% or less will be satisfactory. It can be assumed that for ripple percentages of this order a single section filter such as that in Fig. 1409-C will represent the most economical design; for 1% or less ripple two sections, Fig. 1409-D, should be used. For our particular problem, then, a single-section filter will suffice. The per cent ripple will depend upon the product of the choke inductance and condenser capacity; the following formula gives the ripple percentage directly:

$$\left.\begin{array}{l}\text{Single}\\ \text{Section}\\ \text{Filter}\end{array}\right\}\ \%\ \text{ripple} = \frac{100}{LC}$$

where L is in henrys and C in microfarads. Transposing, we find that the product of LC must be 20 or more to result in 5% or less ripple.

The most economical filter design will be that in which choke cost is balanced against filter-condenser cost to give the required total of inductance and capacity. There are other considerations, however, which must be taken into account before the constants of the filter can be determined upon. These have to do with the functions of the input choke in the filter system.

The Input Choke

Upon the input choke falls the burden of improving voltage regulation and reducing rectifier peak current as well as contributing to the smoothing. The inductance required in the input choke to maintain a constant output voltage and a reasonably low peak current depends upon the load to be placed on the power-supply system; i.e., the amount of current to be drawn. The load on the system can be expressed in ohms, and is equal to the output voltage divided by the total load current in amperes. The optimum value of input-choke inductance is equal to

$$L_{opt.} = \frac{\text{Full-load resistance in ohms}}{500}$$

With an input choke having optimum inductance, the rectifier peak current will not exceed the d.c. output current by more than 10%; in other words, the current from the plate-supply system can approach 90% of the peak-current rating of one tube in the full-wave rectifier without danger to the tubes.

In a condenser input filter the d.c. output current must be kept down to 50% of the peak current rating of a single tube. If there is no load at all on the system, the filter condensers will charge up to the peak value of the rectified a.c. wave; the peak of this wave is approximately 1.4 times the r.m.s. or rated transformer voltage. To keep some load on the system at all times a bleeder resistor, R in Fig. 1409, is used. Since it is desirable to keep down the amount of power dissipated in the bleeder, a fairly high resistance is ordinarily used. The bleeder resistance will be much higher than the resistance of the total load, which includes the load represented by the transmitting tubes and that of the bleeder itself. The critical value of input choke inductance which will prevent the d.c. output voltage from rising to the peak of the rectified wave is equal to

$$L_{crit.} = \frac{\text{Resistance of bleeder in ohms}}{1000}$$

With this value of input choke the rectifier-tube peak current will be greater than with optimum choke inductance, but with only the bleeder as a load the current will be low and no harm will be done to the tubes.

Since the no-load current (bleeder only) will usually be considerably less than the full-load current, it is evident that these two formulas will give widely different values for input choke inductance; in fact, the critical value of inductance will be about five times that of the optimum value. It should be pointed out that both these values represent the *minimum* input choke inductance that should be used; some improvement will result if the inductance is increased, although the improvement will be slight in comparison to the extra cost. A choke having the critical inductance value can therefore be used with entirely satisfactory results, but it is more economical to use a "swinging" choke which adjusts itself automatically to all loads. The desirable range will be from the "optimum value" at max. current (min. load resistance) to the "critical value" at min. current (max. load resistance). Such chokes are available from several manufacturers.

World Radio History

Returning now to the specific problem in hand, it will be found after consultation of manufacturers' catalogs that swinging chokes capable of carrying the desired load current can be obtained with an inductance swing of 5 to 25 henrys. Based on the critical value of 25 henrys, the bleeder resistance should be 25 × 1000, or 25,000 ohms; the bleeder therefore will take 40 milliamperes. The power dissipated in the bleeder will be 1000 × .040, or 40 watts; a resistor having this or larger power-dissipation rating should be used. The full-load inductance value of 5 henrys should be used in the calculation for per cent. ripple. We have previously determined that the product of inductance and capacity must be at least 20 (single section filter) for 5% or less ripple, so that the required condenser capacity will be 20/5, or 4 microfarads. A greater capacity will give a correspondingly smaller ripple voltage.

Bleeder resistances should be mounted so that they receive as much ventilation as possible as they become very hot in operation.

After the size of the filter condenser and choke have been determined, it is necessary to ascertain whether the particular combination chosen will be such as to resonate at or near the ripple frequency. If the combination should through accident be resonant, the operation of the plate supply system is likely to be unstable and the smoothing will be impaired.

Study Fig. 1411 to make certain that the combined L and C in the first section of the filter are not resonant at 120 cycles. For supplies other than 60 cycles, solve the following formula to determine the resonant frequency of any combination of L and C.

$$f_{res.} = \frac{159}{\sqrt{LC}}$$

where L is in henrys and C in microfarads, and f should be well below the supply-line frequency. In our example, the resonance frequency by

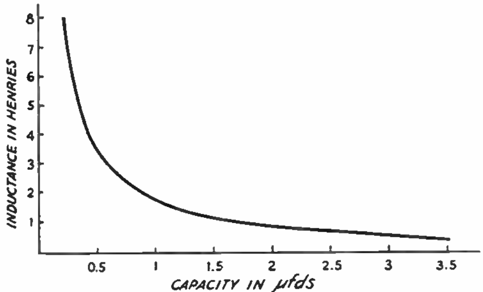


FIG. 1411 — VALUES OF L AND C THAT COMBINE TO RESONATE AT 120 CYCLES AND SHOULD BE AVOIDED

This refers to the first section in the filter. As an example, a 4-henry choke and ½-µfd. condenser combination would resonate around 120 cycles.

the formula above is approximately 35 cycles, so the filter design is satisfactory from this standpoint.

Calculating the Required Transformer Voltage

After the filter has been decided upon, the next step in the design of the power supply system is to select suitable rectifier tubes and determine the necessary ratings of the power transformer. For a plate supply of the type we have been considering, the logical rectifier tube is the 866; a pair of them can be used in the center-tap circuit, or four of them can be connected in bridge. Since the voltage is well below the inverse peak ratings of the tubes, it is probably more economical to use the center-tap circuit. The transformer must be capable of handling the same amount of power with either type of rectifier, so that the cost of the power transformer will not be a deciding factor in the choice of the rectifier circuit. Assuming that the center-tap circuit is to be used, we are now ready to determine the secondary voltage required to insure having 1000 volts at the power supply terminals under full-load.

To find the secondary voltage needed, the voltage drops in the system at full-load current must be calculated. To do this it is necessary to know the resistance of the filter choke. The type of choke we have been considering probably will have a resistance of about 50 ohms; the voltage drop in it at full load will therefore be 50 × .375, or approximately 18 volts. There will be an additional drop in the rectifier tubes; we have only to consider one tube, however, since only one works at a time. This drop is approximately 15 volts. The total is therefore 33 volts, which added to 1000 gives 1033 volts as the average value of the a.c. voltage from one side of the transformer secondary. Transformers are rated in effective or r.m.s. voltages, however, so to find the required voltage in r.m.s. values it is necessary to divide the average value by .9. The required secondary voltage therefore will be 1033/.9 or 1150 volts. The general formula for determining transformer voltage is

$$\text{Sec. } E_{rms} = \frac{E_o + IR_c + E_t}{.9}$$

where E_o is the d.c. output voltage of the power supply, I is the full-load current, including the bleeder current, R_c is the resistance of the choke or chokes in the filter, and E_t is the voltage drop in one rectifier tube in the center-tap circuit, or the sum of the drops of two tubes in the bridge circuit.

If the design principles given in the preceding discussion have been followed through, the required secondary volt-amperes will be

$$\text{Sec. VA} = \text{Total } E_{rms} \times I \times .75$$

World Radio History

where I is the d.c. output current, and E_{rms} is the *total* secondary voltage (both sides of center-tap). In our illustration, the secondary VA capacity required therefore will be 2300 × .375 × .75, or 650 VA. The actual watts drawn from the transformer will be less than this figure, but a somewhat higher VA capacity is required because the rectifier-filter system distorts the secondary-voltage wave-form, and it is necessary to take this into account in computing the heating effect of the current in the secondary winding. Because the heating effect is greater than in ordinary transformer applications, additional VA capacity must be built into the transformer.

In purchasing a transformer, it should be borne in mind that standard designs do not always fit exactly an individual problem. It therefore becomes necessary to select a transformer with ratings which fit the desired ones as closely as possible.

The d.c. output voltage which may be obtained from a given transformer with given rectifier tubes and filter chokes may be obtained by rearranging the preceding formula as follows:

$$E\ (output) = .9\ E_{rms} - IR_c - E_t$$

Greater Smoothing

In the specific design problem just used as an illustration, the permissible ripple voltage was assumed to be 5%. As we have pointed out previously, this will be satisfactory when the plate supply is to be used on the amplifier stages of an oscillator-amplifier transmitter used exclusively for c.w., but the ripple voltage must be smaller for self-controlled transmitters and radio telephone sets. The most satisfactory way to get the additional smoothing is to use the two-section filter shown at Fig. 1409-D. The per cent. ripple for a two-section filter is found by the following formula:

$$\left.\begin{matrix}\text{Two}\\ \text{Section}\\ \text{Filter}\end{matrix}\right\}\ \%\ \text{Ripple} = \frac{650}{L_1L_2\ (C_1 + C_2)^2}$$

For 1% ripple, satisfactory for oscillators, the numerical value of the denominator must therefore be at least 650; for .25% ripple, satisfactory for radiotelephony, the denominator must be four times as great, or, at least 2600. The ripple in the power supply design previously discussed can be reduced considerably simply by the addition of a smoothing choke (not the swinging type) having an inductance of about 8 henrys, and a second 4-μfd. condenser at the filter output terminals. Substituting these values in the formula above will give a ripple of approximately .25%. The two-section filter will have better voltage regulation and will require less inductance and capacity than a single-section filter having equivalent smoothing. The voltage drop in the second choke should be included in the calculation for determining the required transformer secondary voltage. If the design data given above are followed carefully, the voltage regulation of the power supply will be less than 10% — a very good figure.

Condenser-Input Filters

The great advantages of the choke-input filter in reducing rectifier-tube peak current and in making possible good voltage regulation have been pointed out in the preceding discussion. These two points are of utmost importance in high-voltage plate-supply systems. The life of the rectifier tube is determined by the peak current it has to pass, while poor voltage regulation makes it necessary to buy filter condensers rated for the maximum voltage that is likely to appear across the condenser terminals. The cost of filter condensers goes up at a rapid rate as the voltage increases.

For low-voltage plate supplies — 500 volts or less — these considerations are of less economic importance. The smaller rectifier tubes, besides being inexpensive, are rated to work into either choke- or condenser-input filters; low-voltage filter condensers also are inexpensive. Plate supplies for low-power transmitters are often built around a power transformer of fixed design (transformers giving 350 and 550 volts each side of the center-tap are legion) and in such cases the requisite smoothing is often obtained most economically by using a condenser-input filter. No simple formulas are available for computing the per cent. ripple with a condenser-input filter, but experience has shown that a filter of the type shown in Fig. 1409-B will have excellent smoothing if each condenser is 2 to 8 μfd. and if the choke has an inductance (commercial rating) or 20 to 30 henrys. With the condenser-input filter, the d.c. output voltage tends to be greater than the r.m.s. output voltage of the transformer secondary; at very light loads the output voltage will be approximately 1.4 times the secondary voltage (approaching the peak value of the rectified a.c. wave) gradually decreasing with load until at the nominal output rating of the transformer, the d.c. output voltage will be approximately equal to the secondary r.m.s. voltage. This characteristic is of value in low-power sets where the highest output voltage consistent with the power-supply apparatus used is wanted.

The large change in voltage with load represents poor voltage regulation and possibly may result in a chirpy signal from the low-power self-controlled oscillator. It has no such effect with the oscillator-amplifier transmitter, and therefore can be tolerated. The filter condensers, however, must be rated to stand continu-

World Radio History

ously the *peak* value of the voltage — 1.4 times the rated secondary voltage of the transformer. This means that the filter condensers for a 350-volt transformer must be rated at at least 500 volts; those for a 550-volt transformer at at least 800 volts. With condenser-input filters the chief function of the bleeder resistor is to discharge the filter condensers when the power is turned off and thus prevent accidental shocks, because filter condensers will hold a charge for a long while. A resistor of 15,000 to 30,000 ohms is customary for low-voltage plate supplies, the higher resistances being used for the higher voltages.

Voltage Dividers

In addition to the voltages shown in Fig. 1415, lower voltages may be taken from any of the power supplies diagrammed by substituting a voltage divider, or tapped resistor, for the plain bleeder resistor. For example, suppose the power supply of Fig. 1415-D is to be used to furnish power for all three stages of a three-tube transmitter (47, 10, 203-A). A voltage divider can be installed to furnish 350 volts at 30 ma. for the oscillator and 500 volts at 60 ma. for the buffer-doubler, in addition to the 1000 volts for the final amplifier.

To calculate the resistance required between taps, the voltage divider should be laid off in sections, as shown in Fig. 1412. Starting from the negative end, the voltage drop across the first section will be 350 volts, the voltage required by the oscillator. The drop across the second section will be 150 volts, bringing the total voltage between negative and the doubler tap to 500 volts. The last resistor section will have a drop of 500 volts across it. Then, knowing the current to be drawn at each tap and the idle current to be bled off through the lowest resistor section, it is an easy matter to calculate the resistances required at each section by applying Ohm's Law. The power supply Fig. 1415-D calls for a bleeder current of 40 ma. (1000 volts divided by 25,000 ohms); the lower section therefore is equal to

$$\frac{350}{.04} = 8750 \text{ ohms.}$$

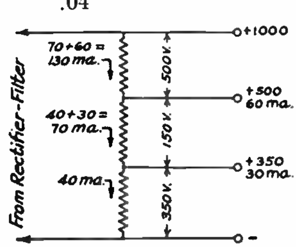


FIG. 1412—VOLTAGE DIVIDER COMPUTATIONS CAN BE MADE BY PLOTTING THE VOLTAGE DROPS AND CURRENT DIVISION IN A DIAGRAM SIMILAR TO THIS ONE

The second section has the 30 ma. for the oscillator in addition to the 40 ma. idle current flowing through it, therefore the resistance required is

$$\frac{150}{.07} = 2150 \text{ ohms (app.).}$$

In the third (upper) section, the current becomes 60 ma. plus the 70 ma. already flowing through the section below, a total of 130 ma. The resistance value is

$$\frac{500}{.13} = 3850 \text{ ohms.}$$

The total resistance of the divider is therefore 14,750 ohms, safely below the value necessary to maintain constant output voltage when the tubes are not drawing current from the power supply. This will increase the no-load bleeder current, but will not affect the operation of the power supply under full load. In the above example, the no-load resistor current will be

$$\frac{1000}{14{,}750} = 63.5 \text{ ma.}$$

Under no-load conditions the voltage across each resistor will be proportional to its individual resistance compared to the total resistance. The drop across the lower section would be

$$\frac{8750}{14{,}750} \times 1000 = 600 \text{ volts (app.).}$$

The drop across the middle section is

$$\frac{2150}{14{,}750} \times 1000 = 150 \text{ volts (app.).}$$

Across the upper section

$$\frac{3850}{14{,}750} \times 1000 = 250 \text{ volts (app.).}$$

The above calculations make it clear that the voltage regulation of the tap voltages is rather poor, since the voltage rises considerably when the load is removed. This is characteristic of voltage dividers. The output voltages will be correct only when the load currents used in the calculations are drawn.

The power dissipated by each resistor may be calculated by multiplying the voltage drop across it by the current flowing through it. This should be done for both no-load and full-load conditions, and a resistor selected having a rating well above that of the higher of the two values. It may not be possible to get stock resistors of the exact resistance calculated, in which case the nearest available size usually will be satisfactory. Semi-variable resistors, having sliding contacts so that any desired resistance value may be selected, can be used if more exact adjustment of voltage is required.

World Radio History

In case it is desired to have the bleeder resistance total to a predetermined value — for instance, if the bleeder in the illustration above is to total 25,000 ohms instead of the calculated value of 14,750 ohms — the same method of calculation may be followed, but different values of idle current should be tried until the correct result is found. An idle current of 20 instead of 40 ma., for instance, will work out to a total resistance of approximately 25,000 ohms in the illustration above.

The method may be extended to a greater number of taps, and is equally applicable to the calculation of voltage dividers for receivers.

25- and 50-Cycle Supply

The filter design data just given is, as previously mentioned, applicable only to full-wave rectifiers working from a 60-cycle supply line. For lower frequencies, both inductance and capacity must be increased in proportion to the decrease in frequency to maintain the same reduction in ripple. After following through the design for 60 cycles, the inductance and capacity values obtained should both be multiplied by 2.4 to obtain the values necessary for 25 cycles; for 50 cycles the multiplying factor is 1.2. In practice, the 60-cycle design usually will be found to be usable for 50 cycles also.

Transmitter Operation from 110-volt d.c. Lines

Where only 110 volt d.c. supply is available, it is recommended that tubes designed especially for this service be used. Transmitters delivering up to 25 or 30 watts output may be constructed using the type RK-100. Such a transmitter was described in *QST* for June, 1935. Otherwise, a high-voltage d.c. generator or 110-volt rotary converter will be required.

Line Voltage Regulation

In certain communities trouble is sometimes experienced from fluctuations in line voltage. Usually these fluctuations are caused by a variation in the load on the line and may be taken care of by the use of a manually-operated compensating device. A simple arrangement is shown in Fig. 1413. A toy transformer is used to boost or buck the line voltage. The transformer should have a tapped secondary varying between 6 and 20 volts in steps of 2 or 3 volts and its secondary should be capable of carrying the full load current of the entire transmitter.

The secondary is connected in series with the line voltage and, if the phasing of the windings is correct, the voltage applied to the primaries of the transmitter transformers can be brought up to the rated 110 volts by setting the toy transformer tap-switch on the right tap. If the phasing of the two windings of the toy transformer happens to be reversed, the voltage will be reduced instead of increased. This connection may be used in cases where the line voltage may be above 110 volts. This method is preferable to using a resistor in the primary of a power transformer since it does not affect the voltage regulation as seriously.

Another scheme by which the primary voltage of each transformer in the transmitter may be adjusted to deliver the desired secondary voltage with a master control for compensating for changes in line voltage is shown in Fig. 1414.

This arrangement has the following features:

1. Adjustment of S_1 to make the voltmeter read 105 volts automatically adjusts all primaries to the predetermined correct voltage.
2. The necessity for having all primaries work at the same voltage is eliminated. Thus, 110 volts can be applied to the primary of one transformer, 115 to another, etc.
3. Independent control of the plate transformer is afforded by the tap switch S_2. This permits power input control and does not require an extra auto-transformer.

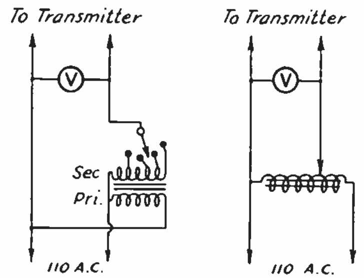


FIG. 1413 — TWO METHODS OF TRANSFORMER PRIMARY CONTROL

At the left is a tapped 1-to-1 transformer with the possibilities of considerable variation in the secondary output. At the right is indicated a variable transformer or autotransformer in series with the transformer primaries.

The system simplifies the adjustment of various filament voltages, since the primary voltage can be selected over a range of 20 volts or so, and that if these voltages are properly set when the rig is constructed then forever afterward a single adjustment of S_1 takes care of all of them. When filament transformers are home built it is somewhat difficult to get, for example, exactly 10 volts at 6.5 amps without excessive cut-and-try. The expedient of tapping a particular primary along the auto-transformer until the proper voltage is obtained at the filament terminals is most convenient. It is of course presupposed that this adjustment is made after proper regulation of S_1 and after all filament wiring has been finished. Some fifteen taps at S_1 are needed for close regula-

World Radio History

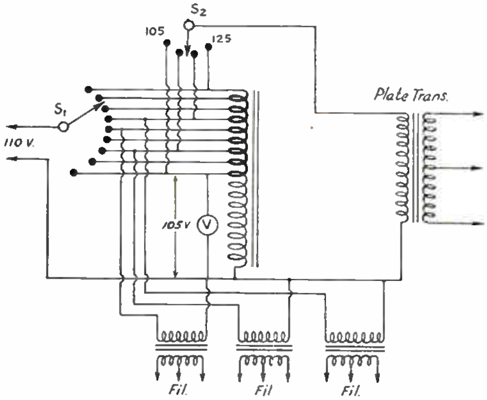


FIG. 1414 — WITH THIS CIRCUIT, A SINGLE ADJUSTMENT OF SWITCH S_1 PLACES THE CORRECT PRIMARY VOLTAGE ON ALL TRANSFORMERS IN THE TRANSMITTER

Information on constructing a suitable auto-transformer at negligible cost is contained in the text. The light winding represents the regular primary of a revamped transformer, the heavy winding the voltage-regulating section.

tion, although only a few have been shown for the sake of simplifying the diagram.

The auto-transformer need not be expensive nor even tedious to wind. Ninety per cent of burned-out broadcast-receiver transformers have a good primary left, and can be picked up for little or nothing at a service shop. If the secondaries are removed and the insulation isn't "shot," the transformer may be connected to the line for a few minutes to see if heating occurs. Usually the high-voltage secondary will be badly charred but the primary will be in good shape. Choose a large transformer (the kind used for ten- or twelve-tube sets or for P.A. systems). A 250-watt unit will handle approximately 1 kw. in the circuit. The voltage per turn can be readily determined, either by counting turns on one of the filament windings of known voltage output, or by winding on a few turns and measuring with a low-range voltmeter. (Measured voltage divided by number of turns equals volts per turn.) This figure divided into the voltage range desired (20 volts is usually sufficient) gives the number of turns on the new winding, shown in heavy lines in the diagram. The winding is then put on, taps being taken out at suitable intervals — approximately 1.5 volts between each tap. The taps preferably should be staggered along the winding to avoid bunching and to make identification easy. Taps can be made quite easily by slipping a piece of cambric under the turn to be tapped, scraping off the insulation at the desired point, and soldering on a length of stranded rubber-covered wire. No. 10 enamelled wire can be used for the winding; with this size wire and a husky b.c. transformer the regulation from no-load to full-load will be very good.

The plate transformer switch, S_2, need not have as many positions as the regulating switch, S_1; taps at every 5 volts will be ample. The same taps can be used for both switches, of course.

TRANSMITTER PLATE SUPPLY CONSTRUCTION

AMATEUR power supplies should be so arranged that the operator will not come in contact with the high voltage while making adjustments. June 1937 *QST* contained several automatic methods of protection against accidental contacts with high voltage. Metal chassis covers or doors to cabinets that house any equipment which uses high voltages should have door or cover snap switches. These switches have a lever that springs open; thus opening power supply primaries (connected in series with the switch). Before high voltage can be applied the switch must be manually closed or the door or cover placed back in its operating position.

Practical Power Supplies

The wide varieties of rectifying and filtering equipment available to amateurs, together with the different classes of service for which power supplies may be used, make it almost impossible for us to show complete constructional details of such equipment for any but the simplest of transmitters. The foregoing information should enable the amateur to choose the type of rectifier and filter best suited to his needs. As a guide in construction, however, Fig. 1415 shows a number of rectifier-filter combinations to give various output voltages and currents. All will give adequately-filtered direct current to the transmitting tube, and in the cases where mercury-vapor rectifier tubes are shown the necessary protection is afforded them by the use of an input choke to the filter. In all circuits except that at *C* the voltage regulation will be good. The voltage at no load will not be very much higher than at the load currents indicated. In these cases the filter condensers need be rated to stand only the voltage delivered by one-half of the high-voltage secondary; for example, a condenser with a working-voltage rating of 1250 volts d.c. will be ample for the 1000-volt power supply shown at *D*. This assumes, of course, that the bleeder resistance is used. Without this resistor, the condensers should be rated to stand 50% more voltage than half the secondary voltage of the transformer. In the arrangement at *C* the condensers should have the higher rating whether the bleeder is used or not.

World Radio History

The input choke may be omitted in diagram *A* even though the small mercury-vapor rectifiers are used because the tubes are built to stand working into a condenser-input filter. Should this be done, however, the filter condensers must be rated at 600 volts working. The condensers need not have 8 μfd. capacity each, but this is a standard size with electrolytic condensers and is recommended.

The rectifier-filter system at *A* will handle a small transmitter using receiving-type tubes. The ripple will be ¼% or less, depending upon how well the choke inductance holds up under load. Diagram *B* will take care of a pair of '10 tubes with ease; the ripple should be about the same as in *A*. The rectifier-filter at *C* does not use mercury-vapor rectifiers and hence can dispense with the input choke. Its output voltage will be variable between approximately 750 and 550 volts, however, depending upon the load current. It will be suitable for a pair of 10 tubes if it should be thought desirable to run them at more voltage than can be obtained with Diagram *B*. At *D* is shown a power supply for one or two tubes of the 203-A, 211 or 845 type. It is practically the same thing as the illustrative problem previously discussed. The arrangement at *F* is suitable for use with one or two T125 or T200 tubes. With the filter values shown the ripple will be .20% or less. The circuit in *E* is suitable for the 838 and 805 tubes.

The circuit of Fig. 1418 is of the bridge type. By using the additional tap and filter system indicated by the dotted lines, a half voltage tap with good voltage regulation may be obtained. The total load current should be limited to 300 ma. if type 866's are used or 1600 ma. if type 872's are used. When the total load current does not exceed the rated values, the combination of low and high voltages makes a convenient arrangement for a high power final amplifier and its driver. This power supply using the values given will be suitable for operating a pair of 806's, 250-T's, one or two 354's or other tubes operating at 3000 volts with a driver tube operating at 1500 volts. This type of circuit provides much better voltage regulation at the half-voltage tap than an arrangement in which the low voltage is obtained from a tap on a voltage divider resistor. This same principle may be applied with benefit to lower voltage supplies. The

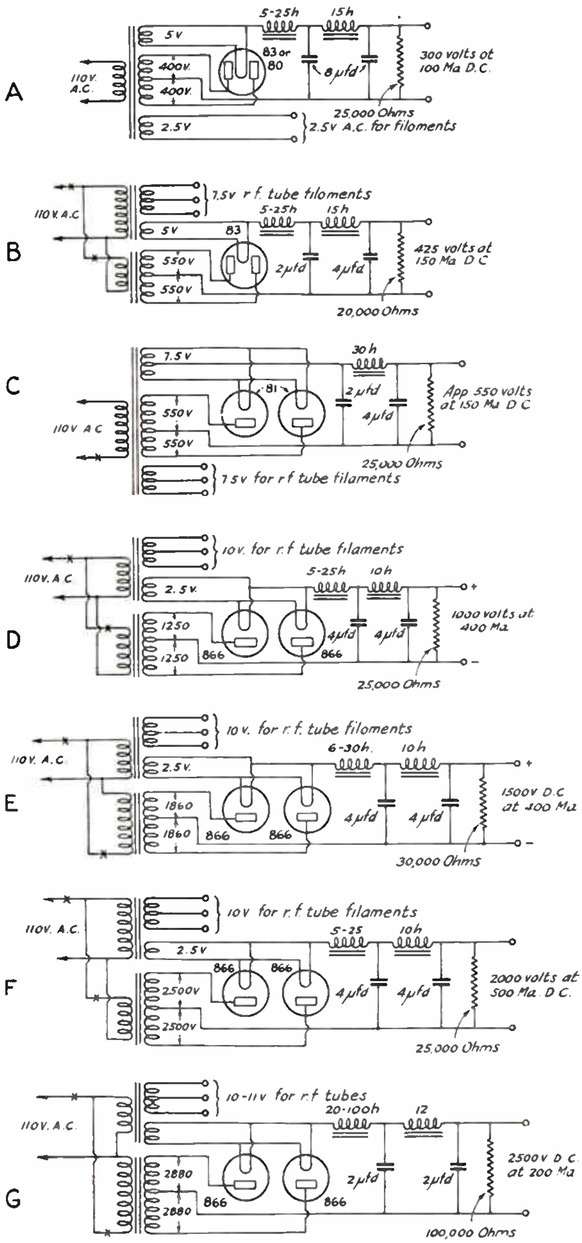


FIG. 1415 — POWER-SUPPLY ARRANGEMENTS FOR DIFFERENT TRANSMITTING TUBE NEEDS (SEE TABLE ON PAGE 360)

All of these diagrams will give adequately-filtered d.c. output for different classes of services. (See Power Supply Table.) They are explained fully in the text. Many other arrangements are possible. Control switches should be inserted in the transformer primaries at the points marked "X" to permit the filament supplies to be turned on before the plate supply and to make it impossible to put on the plate power before the filament.

World Radio History

bridge rectifier using type 83 rectifier tubes described on the following pages is a good example.

In cases where the low voltage required is some value different than one-half of the high voltage value, a scheme such as that shown in Fig. 1421 may be used if a suitable transformer is available.

The cost of the equipment is considerably less since but one transformer and filter is required to produce several different voltages. Compactness is another advantageous feature of the circuit.

The transformer is center-tapped at the various voltages required. These voltages are rectified independently of each other and then filtered through a common filter whose chokes are in series with the center-tap or negative lead from the transformer. Transformers having taps at all the voltages likely to be required may be hard to obtain commercially, especially if more than two voltages are needed. One can be made especially for the job, however, or an old one can be rewound.

The rectifier performance will be improved if the input choke, L_1, is of the swinging variety instead of the smoothing type. Filter constants are not given since they will depend upon the voltages and currents to be handled. The chokes must of course be built to handle the total direct current to be taken from all taps on the power supply. Other combinations can be worked out without much difficulty. It is not absolutely necessary to follow exactly the specifications in the filter section of the diagrams; for example 1-μfd. condensers or smaller chokes can be substituted in the filter of the high-power plate supply if the big tubes are amplifiers used for c.w. work in a crystal-controlled or oscillator-amplifier transmitter. For 'phone it is better to have as much filter as available to keep the carrier free from hum.

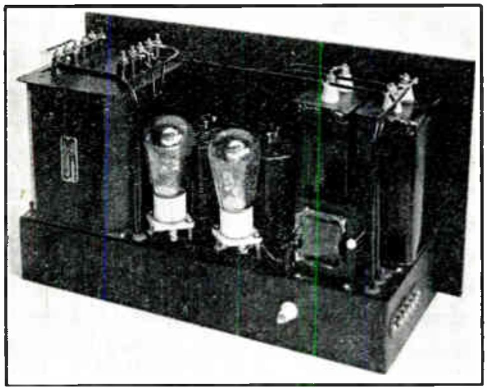


FIG. 1417 — MEDIUM-POWER SUPPLY FOR RACK-MOUNTED TRANSMITTERS

This supply uses the circuit of Fig. 1415-D, with the exception that the power transformer and chokes are rated at 300 ma. rather than 500 as required for the 400-ma. output of Fig. 1415-D. The rectifiers used in this unit are 866 Jrs.

In all these diagrams it is of course necessary to use power transformers of adequate capacity and chokes of high enough current rating to carry the load currents indicated. In *D* and *E* the plate transformers should be rated at about 650 and 850 VA, respectively, to give the necessary output.

Should more current than that obtainable from 866's be needed, the circuit shown in Fig. 1422 may be used.

Fig. 1423 is a photograph of a power supply suitable for use with a low-power transmitter. Its circuit diagram, Fig. 1424, will be seen to be similar to A in Fig. 1415 with the exception of the fact that the input choke to the filter is omitted. The filter condenser is a double-unit dry electrolytic condenser having a capacity of 8 μfd. per section. The power transformer

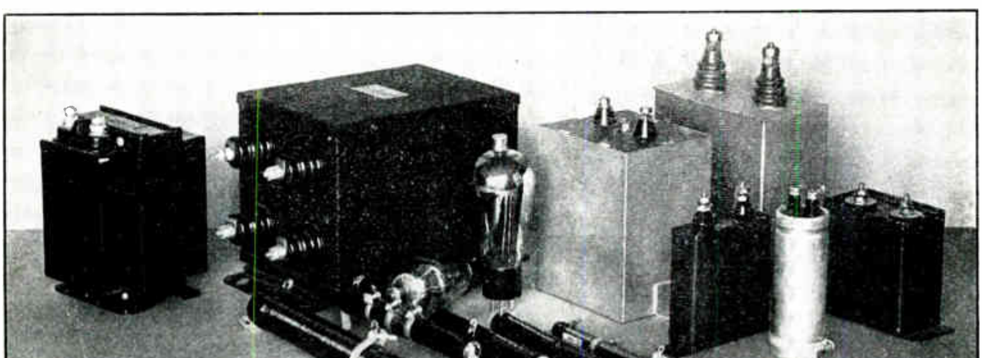


FIG. 1416 — CHOKES, TRANSFORMERS, CONDENSERS, RECTIFIERS AND RESISTORS — THE ESSENTIALS OF ALL POWER SUPPLY SYSTEMS

World Radio History

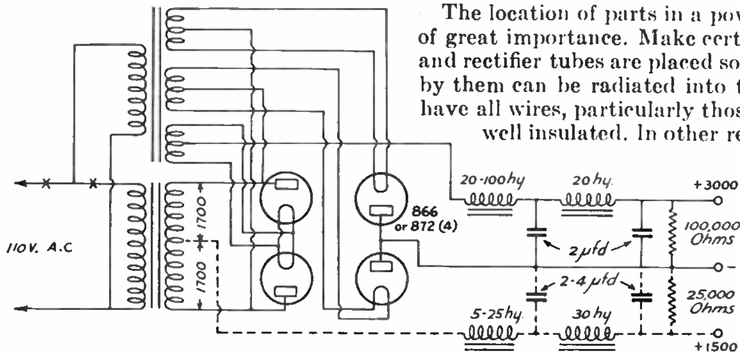


FIG. 1418 — HIGH-POWER BRIDGE RECTIFIER CIRCUIT DELIVERING TWO VOLTAGES PROVIDING THE PLATE TRANSFORMER IS CENTER-TAPPED

When the center tap filter shown in dotted lines is used, a tap at half maximum voltage with good regulation is provided. The current drawn from both taps should not exceed 540 ma. if 866's are used or 1600 ma. if 872's are used. The plate transformer must be rated for these respective currents.

should deliver not more than 350 volts on each side to avoid damaging the condenser.

The location of parts in a power-supply system is not of great importance. Make certain that the transformer and rectifier tubes are placed so that the heat generated by them can be radiated into the surrounding air, and have all wires, particularly those carrying high voltage, well insulated. In other respects the layout can be made anything convenient.

A Duplex Plate Supply for the Medium-Power Transmitter

To illustrate one of the many modifications that can be made to straight-forward power-supply design, a diagram of a two-voltage power supply suitable for operating a complete transmitter of medium power is given in Fig. 1425. Inexpensive Type 83 tubes are used in the bridge circuit to give a high voltage of 1000 volts; simultaneously one pair of the tubes acts as a center-tap rectifier in conjunction with the center-tap on the power transformers to furnish 500 volts for the low-power stages of the transmitter. A total of 250 milliamperes (or slightly

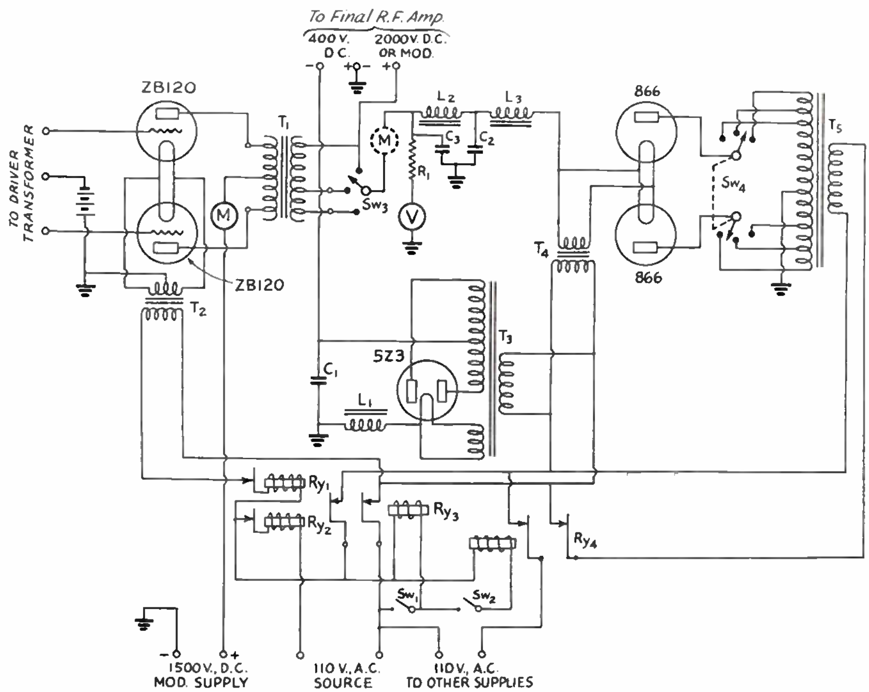


FIG. 1419 — CIRCUIT DIAGRAM OF COMPLETE PLATE SUPPLY, GRID BIAS SUPPLY, AND MODULATOR COMBINED INTO A SINGLE UNIT

Note that no bleeder resistor is shown connected across the bias supply; this function is performed by the r.f. amplifier grid-leak resistor, which acts as a portion of a voltage divider across the output terminals. Similarly, the bleeder of the high-voltage supply is made to serve two functions; with a milliammeter connected in series, it serves as a voltmeter series resistor as well. (Ohm's Law is used to compute the voltage applied to the final amplifier.)

World Radio History

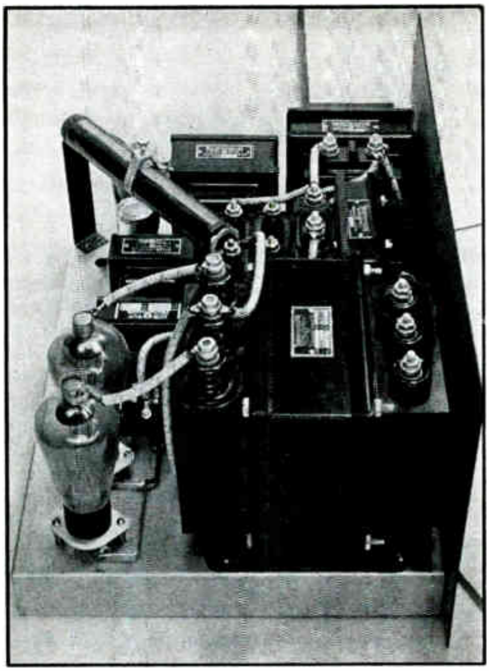


FIG. 1420 — HIGH-POWER POWER SUPPLY WITH 866 TUBES

On this chassis is a 2000-volt 450 ma. supply with voltage divider and a low-power supply for crystal stage.

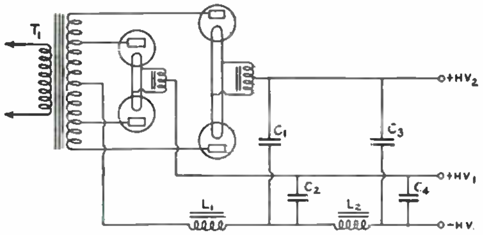
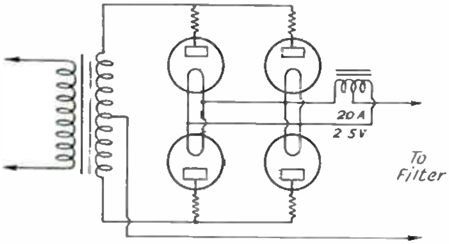


FIG. 1421 — A POWER SUPPLY CIRCUIT IN WHICH A SINGLE TRANSFORMER AND SET OF FILTER CHOKES IS MADE TO SERVE FOR DIFFERENT VOLTAGES

Each voltage has its own rectifier and filter condensers. Although only two voltages are indicated, others may be obtained provided the transformer has the necessary taps.



more, since both filters have choke input) may be taken from the power supply without exceeding the rectifier-tube ratings; a representative current division would be 100 ma. for the small tubes and 150 ma. for the final amplifier stage.

With the filter values indicated in Fig. 1425 the ripple in the 500-volt output will be less than .1% and in the 1000-volt output approximately .25%, so the power-supply will be well suited to use with the r.f. end of a 'phone transmitter. For c.w., the second filter section may be omitted from the 1000-volt section, in which case the ripple will be approximately 6%; increasing the remaining condenser capacity from 2 μfd. to 4μfd. will bring the ripple down to 3%. It is best to use the two-section

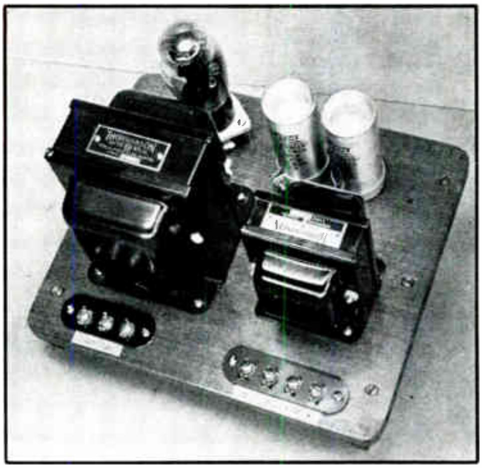


FIG. 1423 — THIS POWER SUPPLY WILL DELIVER 350 VOLTS AT 150 MA.

Low-cost receiving-type components are used. The rectifier used is an 83V. See Fig. 1424.

filter on the low-voltage output; the condensers and chokes are relatively inexpensive and low ripple is desirable on low-power stages.

An input choke having fixed inductance is recommended for the 500-volt output because the load on this section usually is continuous. If the load is to be variable, a swinging choke should be used, together with a bleeder of suitable value across the output. The bleeder may be used as a voltage divider to obtain still lower voltage — for instance, for a crystal oscillator.

Transformers and Rectifiers in Series

Under certain circumstances, it is sometimes possible to reduce the cost of a high voltage

FIG. 1422 — USING 866'S IN PARALLEL TO DOUBLE THE CURRENT RATING

In this arrangement 866's will deliver 1100 ma. providing the transformer and swinging choke used will handle the capacity. Note the low resistance equalizing resistors in the plate leads.

supply by connecting two similar lower voltage supplies or transformer-rectifier units in series. Such a circuit is shown in Fig. 1426. A pair of inexpensive 600 volt, 200 ma. transformers and type 83 rectifiers may be used in this manner to deliver a d.c. output voltage through the filter of about 1000 volts. Since the winding of the transformer on the positive side is at a higher potential than normal, some care should be taken to select a transformer with good in-

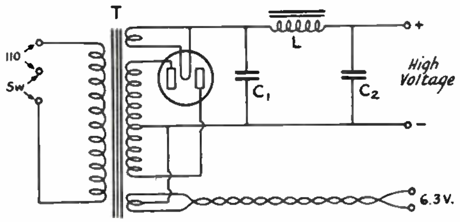


FIG. 1424 — LOW-POWER SUPPLY FROM RECEIVING PARTS

T — Power Transformer, 375 v. each side center-tap, with 6.3-volt and 5-volt windings (Thordarson T-70R62).
L — Filter choke; 8.75 henrys at 150 ma. (Thordarson T-17C00).
C_1, C_2 — 8-μfd. high-surge electrolytic condensers (Mallory UR-187).

sulation. Most transformers of reliable manufacture will have sufficient insulation, at least those with output voltage ratings of 600 volts or less each side of center-tap.

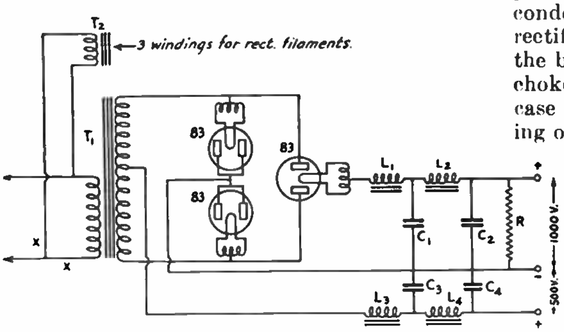


FIG. 1425 — DUPLEX PLATE SUPPLY CIRCUIT

This plate supply will deliver 500 and 1000 volts at a total of 250 milliamperes (sum of currents from both taps).

T_1 — Power transformer, 600 volts each side center tap; 350 VA.
T_2 — Rectifier filament transformer, three 5-volt 3-amp. windings.
C_1 — 2 μfd., 1250-volt rating.
C_2 — 4 μfd., 1250-volt rating.
C_3, C_4 — 2 μfd., 800-volt rating.
L_1 — Swinging choke, 8–40 henrys, 275 ma.
L_2 — Smoothing choke, 12 henrys, 275 ma.
L_3, L_4 — 10 henrys, 200 ma.
R — 40,000 ohms, 25-watt rating.

TRANSMITTER BIAS SUPPLIES

Low-voltage power packs make excellent substitutes for batteries as "C" bias supplies for certain types of r.f. power amplifiers. The "C" power pack, in fact, offers the same advantages as the combination battery-and-leak bias discussed in Chapter Eight. Not all power packs are suitable as bias supplies for transmitters, however.

The power pack for "C" bias use must have a low-resistance bleeder. Since the bleeder, or at least part of it, is connected to the r.f. amplifier grid circuit, it performs in just the same fashion as a grid leak; that is, the flow of amplifier grid current through the bleeder causes a voltage drop which may add considerably to the actual bias on the grid. For this reason, therefore, the part of the bleeder included in the biasing circuit (in case the bleeder provides taps for different voltages) should have a resistance no higher than that ordinarily required as a grid leak for the tube in use. The resistance of the bleeder then can be proportioned so that the voltage across the taps in use will be approximately equal to the cut-off bias of the tube when there is no excitation. This will give the protective feature of fixed bias and also provide the automatic biasing characteristic of grid leaks.

The transformer and rectifier for a bias supply will be identical with those used in receiver power packs. The filter may be somewhat simpler, however; it may, in fact, be found possible to get sufficient filtering with only a condenser connected across the output of the rectifier, since no current except that taken by the bleeder is drawn from the "C" supply. A choke and second condenser can be added in case actual tests show that a bias supply having only a condenser filter introduces modulation on the signal. The circuit diagram of Fig. 1427 is suggested for bias supplies; the method of calculating the bleeder resistance required also is shown.

Since the bias voltage varies with grid current, a "C" supply of this type often will be found to be somewhat unsatisfactory for biasing more than one stage, because the grid current for all stages must flow through the same resistor, thus causing all stages to be over-biased. This effect can be overcome to a considerable extent by using a low bleeder or voltage divider resistance so that voltage variations from grid-current flow are minimized, or by the use of one or more regulator tubes. If some form of regulation is not provided, the bleeder current in such a "C" supply should be just as great as the transformer and rectifier tube are capable of furnishing. The bleeder current for a 300-volt supply, for instance, would be approximately 100 mil-

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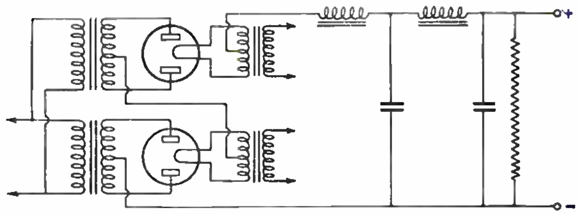

FIG. 1426 — TWO TRANSFORMERS AND RECTIFIERS CONNECTED IN SERIES TO GIVE HIGHER OUTPUT VOLTAGE

liamperes, calling for a resistor of about 3000 ohms.

For the reasons given above, "C" supplies without provision for regulation are usually unsatisfactory in applications where the bias voltage must remain constant under operating conditions, as in Class-B audio and r.f. amplifiers. For linear output from these types of amplifiers it is essential that the bias remain constant during operation.

Bias Voltage Regulation

As mentioned previously, a vacuum tube in a suitable circuit may be used to provide automatic voltage regulation for a biasing voltage power supply. A circuit which has been used successfully is shown in Fig. 1428. The stabilizer consists of a tube across the output of the power supply in a self-biasing arrangement. The resistor R_1 is on the order of several megohms, so that at no load the tube is biased practically to cut-off. The output voltage is then the total voltage of the supply minus the voltage required to bias the regulator tube to zero plate current. When current flows back through the regulator tube, as would happen if the power supply were being used to bias the grid of a tube which was being driven positive and was drawing grid current, the voltage across the regulator tube will tend to increase. This will cause the voltage across the biasing resistor, R_1, to decrease. Since the sum of the regulator tube drop and the drop through R_1 must equal the total supply voltage, as the voltage across R_1 decreases the bias on the regulator tube decreases, which causes the tube plate impedance to decrease so that the voltage across it tends to remain constant regardless of the current which is flowing back through it.

As the output voltage is lowered, it may be seen that it becomes necessary to increase the number of tubes in parallel to maintain good regulation, so that at low voltages it would be preferable to use batteries for bias, rather than an a.c. supply with this type of regulator.

The value of the resistor R_1 is not critical, so long as it is large enough to maintain the current drawn from the power supply at a very low value. Any value from a few hundred thousand ohms up to several megohms is satisfactory. The voltage divider R_2 can have practically any value, from a few thousand ohms up, as the current drawn is practically zero.

If additional taps are necessary, a regulator tube with its separate filament transformer will be required for each tap.

Power Supply Kinks

For protection of expensive equipment it is well to consider some method of breaking the high voltage should a short circuit occur or an accidental heavy surge take place. The simplest method is to insert high voltage fuses in the

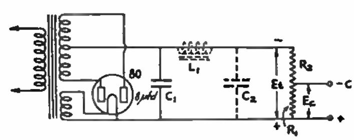

FIG. 1427 — A PRACTICAL CIRCUIT FOR THE "C" SUPPLY

A single 8-μfd. condenser often will suffice for the filter but if trial shows that more is needed, a choke and second condenser, shown in dotted lines, may be added. The condensers should be rated at 500 volts, especially if the "C" supply is to be used on a high-power stage where the excitation is likely to be large.

The bias voltage, Eĉ, should be approximately that value which will cut off the plate current of the tube at the plate voltage used (roughly the plate voltage divided by the voltage amplification factor of the tube). Resistor R_1 should be equal to the grid leak value ordinarily used with the tube. The required resistance for R_2 can be found by the formula

$$R_2 = \frac{E_t - E_c}{E_c} \times R_1$$

where E_t is equal to the peak value of the transformer-rectifier output voltage (r.m.s. voltage of one side of secondary multiplied by 1.4).

power supply as indicated in Fig. 1429. A more permanent method and one that can be adjusted from the front of the panel is by the use of an overload relay with an overload breaking the primary of the plate transformer.

—···—

Some amateurs still turn off all transmitter filaments between periods of transmission. When there are mercury vapor tubes in use as rectifiers it is necessary to wait 10 or 15 seconds for them to attain proper temperature before applying the high voltage. When two separate switches are used there is always the possibility of throwing the plate switch too soon, thus possibly damaging the rectifier tubes. Such a possibility can be avoided by the use of a switch as shown in Fig. 1430. This is a Mark Time switch that is mechanically a single throw unit but electrically it is a single throw double pole switch with a 15-second lag before

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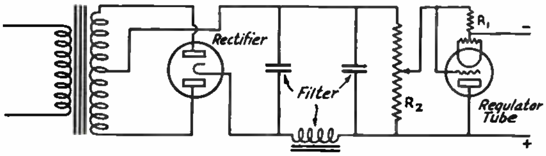


FIG. 1428 — CIRCUIT OF THE AUTOMATIC VACUUM-TUBE REGULATOR AS APPLIED TO A BIAS- OR PLATE-SUPPLY POWER PACK

R_1 is the regulator tube's bias resistor and R_2 is the power-pack output voltage divider. A separate filament winding should be used for the regulator. A type 45 tube will be satisfactory as the regulator tube.

the second pole closes. Any variety of timing may be had up to several hours. Such switches find various uses in the station.

—···—

Often the amateur finds it impossible to listen on the frequency of his transmitter without an annoying hum. This hum is only present when the final amplifier filament is on. If one is using a bias supply that only goes on with the plate voltage it can be cured by arranging the bias supply to be on whenever the filaments are on. If resistor bias alone is used it will be necessary to stop the minute flow of current through the grid return circuit when there is no excitation. This may be done by the use of a neon tube with its resistor in the base removed as shown in Fig. 1431. Another way of eliminating the hum would be to put a few volts of fixed bias in series with the resistor.

—···—

One way of getting fairly high voltage from the 110-volt mains is by using a quadrupling circuit as shown in Fig. 1433. The fundamental circuit is shown in the upper diagram and the practical circuit in the lower. Four 8-μfd. electrolytic filter condensers are used for building up the voltage. Additional filter could, of course, be incorporated in the circuit by adding a choke and putting an additional condenser section across the output. A test of this circuit showed a no-load d.c. voltage of 600; at a 40-ma. drain the terminal voltage was approximately 500 volts.

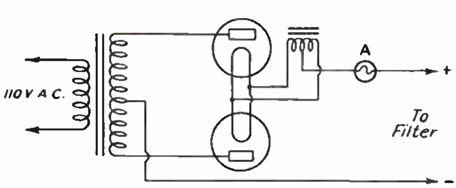


FIG. 1429 — HIGH-VOLTAGE FUSES SHOULD BE USED IN MEDIUM- AND HIGH-POWERED TRANSMITTERS

One way of insuring that the beginner doesn't burn out receiver filaments when using battery receivers by getting B-battery voltage across the filaments is by putting a resistor in series with the B battery right at its terminal. A value of 250 ohms per B battery of 45 volts will not greatly lower the voltage supplied but will prevent the passage of enough current to burn out receiving tubes by accidental connection.

Building Small Transformers

Power transformers for both filament heating and plate supply for all transmitting and rectifying tubes are available commercially at reasonable prices, but occasionally the amateur wishes to build a transformer for some special purpose or has a core from a burned out transformer on which he wishes to put new windings.

Most transformers that amateurs build are for use on 110-volt 60-cycle supply. The number of turns necessary on the 110-volt winding depends on the kind of iron used in the core and on the cross-sectional area of the core. Silicon steel is best, and a flux density of about 50,000 lines per square inch can be used.

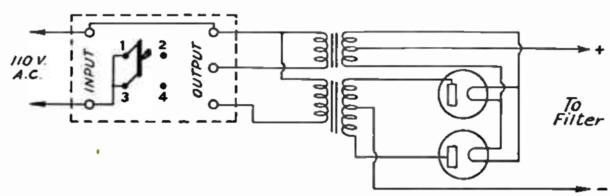


FIG. 1430 — SHOWING A DOUBLE POLE SINGLE THROW SWITCH THAT DELAYS BEFORE THROWING THE SECOND THROW AS DESCRIBED IN THE TEXT

This is the basis of the table of cross-sections given.

An average value for the number of primary turns to be used is 7.5 turns per volt per square inch of cross-sectional area. This relation may be expressed as follows:

$$\text{No. primary turns} = 7.5 \times \frac{E}{A}$$

where E is the primary voltage and A the number of square inches of cross-sectional area of the core. For 110-volt primary transformers the equation becomes:

$$\text{No. primary turns} = \frac{825}{A}$$

The size of wire to use depends on the current the winding will carry at full load. When a small transformer is built to handle a continuous load, the copper wire in the windings should have an area of 1500 circular mils for each ampere to be carried. (See Wire Table in

World Radio History

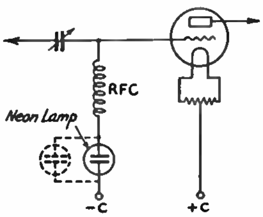


FIG. 1431 — NEON LAMP IN GRID CIRCUIT FOR CURING HUM FROM TRANSMITTER DURING RECEPTION

A three-watt lamp with base resistor removed is used. Where heavy grid currents are drawn, two or more lamps should be connected in parallel.

Appendix.) For intermittent use, 1000 circular mils per ampere is permissible.

A table is given showing the best size wire and core cross-section to use for particular transformers. The figures in the table refer to 60-cycle transformers. The design of 25-cycle transformers is similar but a slightly higher flux density is permissible. Because the frequency is much lower the cross-sectional area of the iron must be greater or the number of turns per volt correspondingly larger, otherwise the inductance will be too low to give the required reactance at the reduced frequency. If one builds the core so that its cross-section is 2.1 to 2.2 times the value of area worked out from the table, the same number turns of wire may be used in a primary coil for 25-cycle operation. If the same core and more turns of wire are used a larger "window" will be needed for the extra wire and insulation. Increasing both the number of turns per volt and the cross-section of the core gives the best-balanced design.

Most 60-cycle transformers will behave nicely on a 25-cycle supply if the applied voltage is sufficiently reduced. Up to 52 volts at 25 cycles may be applied to a 110-volt 60-cycle winding without harm. Knowing the transformer voltage ratio, the output voltage will be known. The current-carrying capacity will be the same as at 60 cycles. The KVA (kilovolt-ampere) rating will be about half the 60-cycle value.

Having decided on the core cross-section necessary to handle the power, the next step is to calculate the core window area required to accommodate the windings. The primary wire size is given in the table; the secondary wire size should be chosen according to the current to be carried, as previously described. The Wire Table in the Appendix shows how many turns of each wire size can be wound into a square inch of window area, assuming that the turns are wound regularly and that no insulation is used between layers. Figures are given for three different types of insulation. The primary winding of the 200-watt transformer, which has 270 turns of No. 17 wire, would occupy 270/329 or. 82 square inch if wound with double-cotton-covered wire, for example. This makes no allowance for a layer of insulation between the windings (in general, it is good practice to wind a strip of paper between each layer) so that the winding area allowance should be increased if layer insulation is to be

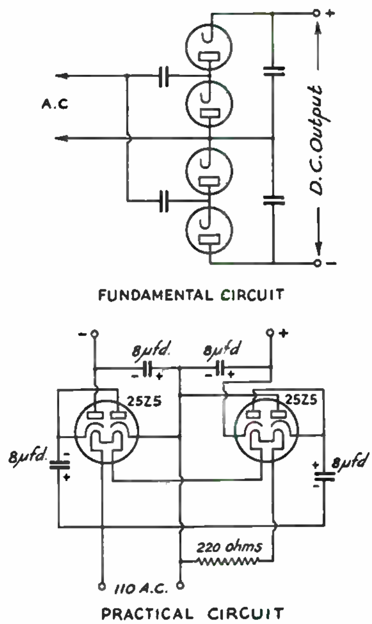


FIG. 1433 — VOLTAGE QUADRUPLING CIRCUIT USING 25Z5 RECTIFIERS WORKING FROM THE 110-VOLT LINE

This circuit will deliver about 500 volts under a load of 40 ma.

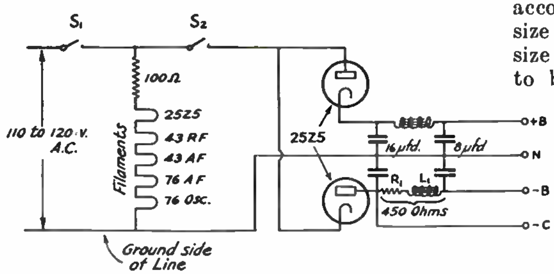


FIG. 1432 — A TRANSFORMERLESS POWER SUPPLY CIRCUIT

A total resistance of approximately 450 ohms was found correct for L_1 and R_1 in series, but it may be preferable to use a variable resistor for R_1 and adjust bias to make the d.c. voltage drops between plate and cathode of each 43 about equal when the final amplifier is excited and tuned but not modulated. The filaments in the transmitter as indicated are all in series.

World Radio History

used. The figures also are based on accurate winding such as is done by machines: with hand winding it is probable that somewhat more area would be required. An increase of 50% should take care of both hand winding and layer thickness. The area to be taken by the secondary winding should be estimated, as should also the area likely to be occupied by the insulation between the core and windings and between the primary and secondary windings themselves. When the total window area required has been figured — allowing a little extra for contingencies — laminations having the desired leg width and window area should be purchased. It may not be possible to get laminations having exactly the dimensions wanted, in which case the nearest size should be chosen. The cross-section of the core need not be square but can be rectangular in shape so long as the core area is great enough. It is easier to wind coils for a core of square cross-section, however.

Transformer cores are of two types, "core" and "shell." In the core type, the core is simply a hollow rectangle formed from two "L"-shaped laminations, as shown in Fig. 1434. Shell-type laminations are "E" and "I" shaped, the transformer windings being placed on the center leg. Since the magnetic path divides between the outer legs of the "E," these legs are each half the width of the center leg. The cross-sectional area of a shell-type core is the cross-sectional area of the center leg. The shell-type core makes a better transformer than the core type, because it tends to prevent leakage of the magnetic flux. The windings are calculated in exactly the same way for both types.

Fig. 1435 shows the method of putting the windings on a shell-type core. The primary is usually wound on the inside — next to the core — on a form made of fibre or several layers of cardboard. This form should be slightly larger than the core leg on which it is to fit so that it will be an easy matter to slip in the laminations after the coils are completed and ready for mounting. The terminals are brought out to the side. After the primary is finished, the secondary is wound over it, several layers of insulating material being put between. If the

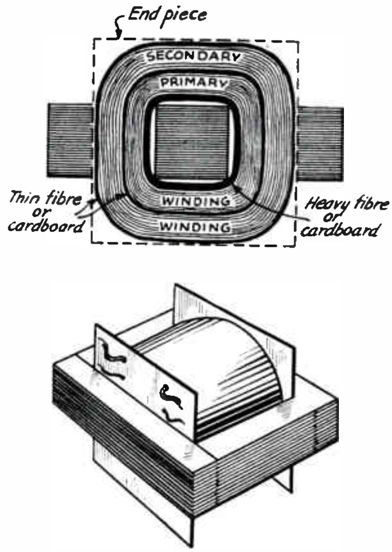


FIG. 1435 — A CONVENIENT METHOD OF ASSEMBLING THE WINDINGS ON A SHELL TYPE CORE

Windings can be similarly mounted on core-type cores, in which case the coils are placed on one of the sides. High-voltage core-type transformers sometimes are made with the primary on one core leg and the secondary on the opposite.

transformer is for high voltages, the high-voltage winding should be carefully insulated from the primary and core by a few layers of Empire cloth or tape. A protective covering of heavy cardboard or thin fibre should be put over the outside of the secondary to protect it from damage and to prevent the core from rubbing through the insulation. Square-shaped end pieces of fibre or cardboard usually are provided to protect the sides of the winding and to hold the terminal leads in place. High-voltage terminal leads should be enclosed in Empire cloth tubing or spaghetti.

After the windings are finished the core should be inserted, one lamination at a time. Fig. 1434 shows the method of building up the core. In the first layer the "E"-shaped laminations are pushed through from one side; the second "E"-shaped lamination is pushed through from the other. The "I"-shaped laminations are used to fill

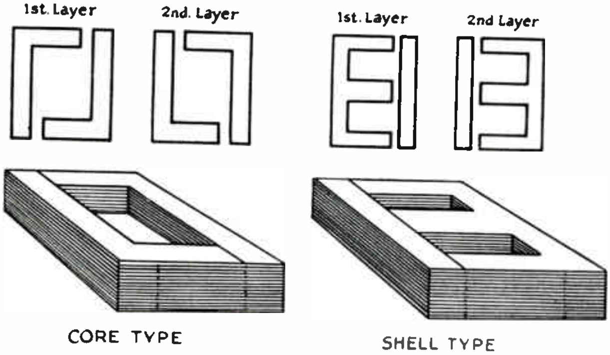


FIG. 1434 — TYPES OF TRANSFORMER CORES, SHOWING TYPES OF LAMINATIONS

the end spaces. This method of building up the core ensures a good magnetic path of low reluctance. All laminations should be insulated from each other to prevent eddy currents from flowing. If there is iron rust or a scale on the core material, that will serve the purpose very well —otherwise one side of each piece can be coated with thin shellac. It is essential that the joints in the core be well made and be square and even. After the transformer is assembled, the joints can be hammered up tight using a block of wood between the hammer and the core to prevent damaging the laminations. If the winding form does not fit tightly on the core, small wooden wedges may be driven between it and the core to prevent vibration. Transformers built by the amateur can be painted with insulating varnish or waxed to make them rigid and moisture proof. A mixture of melted beeswax and rosin makes a good impregnating mixture. Melted paraffin should not be used because it has too low a melting point. Double-cotton-covered wire can be coated with shellac as each layer is put on. However, enameled wire should never be treated with shellac as it may dissolve the enamel and hurt the insulation, and it will not dry because the moisture in the shellac will not be absorbed by the insulation. Small transformers can be treated with battery-compound after they are wound and assembled. Strips of thin paper between layers of small enameled wire are necessary to keep each layer even and to give added insulation. Thick paper must be avoided as it keeps in the heat generated in the winding so that the temperature may become dangerously high.

Keep watch for shorted turns and layers. If just one turn should become shorted in the entire winding, the voltage set up in it would cause a heavy current to flow which would burn it up, making the whole transformer useless.

Taps can be taken off as the windings are made if it is desired to have a transformer giving several voltages. The more taps there are, the more difficult becomes the problem of avoiding weakened insulation at the points where they are made. Taps should be arranged whenever possible so that they come at the ends of the layers. If the wire of which the winding is made is very small, the ends of the winding and any taps that are made should be of heavier wire to provide stronger leads.

After leaving the primary winding connected to the line for several hours it should be only slightly warm. If it draws much current or gets hot there is something wrong. Some short-circuited turns are probably responsible and will continue to cause overheating and possibly fireworks later.

Building Filter Choke Coils

Filter choke coils resemble transformers in construction, but only one winding is used. The core may be either of the core or shell type, but the corners should not be interleaved, a butt joint being used instead. This is done so that the core can be opened slightly to form an air gap in the magnetic path. An air gap actually increases the effective inductance of the choke when direct current is flowing through the winding by preventing magnetic saturation of the core. Since a low-reluctance magnetic path is not necessary, the shell-type of core has no particular advantages. The full page table of choke coil specifications is based on the core-type construction illustrated in Fig. 1436. The core may be built of straight pieces, as shown, or from L-shaped laminations of the type shown in Fig. 1434, but stacked to give an air gap.

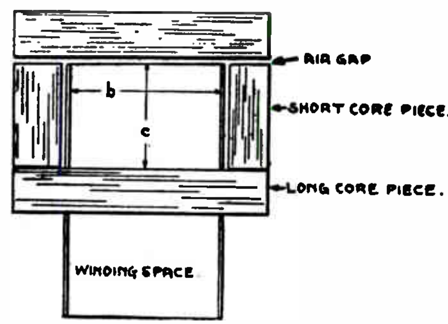


FIG. 1436 — CORE ARRANGEMENT FOR FILTER CHOKE COILS

The dimensions b and c refer to the full page table in the Appendix.

Input (Watts)	*Full-load Efficiency*	*Size of Primary Wire*	*No. of Primary Turns*	*Turns Per Volt*	*Cross-Section Through Core*
50	75%	23	528	4.80	1¼" x 1¼"
75	85%	21	437	3.95	1⅜" x 1⅜"
100	90%	20	367	3.33	1½" x 1½"
150	90%	18	313	2.84	1⅝" x 1⅝"
200	90%	17	270	2.45	1¾" x 1¾"
250	90%	16	248	2.25	1⅞" x 1⅞"
300	90%	15	248	2.25	1⅞" x 1⅞"
400	90%	14	206	1.87	2 " x 2 "
500	95%	13	183	1.66	2⅛" x 2⅛"
750	95%	11	146	1.33	2⅜" x 2⅜"
1000	95%	10	132	1.20	2½" x 2½"
1500	95%	9	109	.99	2¾" x 2¾"

World Radio History

The design table in the Appendix gives specifications for chokes that will meet most needs of the amateur in filter systems. Chokes of inductances between the values given in the table can be made by using less turns of wire in the winding. Inductance varies about as the square of the number of turns so that using half the number of turns specified gives one-fourth the inductance. More turns than those specified must not be used as the core will become saturated. Dimensions *b* and *c* given in the table can be understood by reference to Fig. 1436. The arrangement of core and winding should be that of the diagram, also. Chokes of the "swinging" type are considered beyond the scope of amateur construction because of special design features involved and the necessity for elaborate checking equipment. Danger from shorted turns or layers for transformers applies also to chokes.

FULL-WAVE RECTIFIER AND FILTER CHART FOR AMATEUR TRANSMITTERS

This chart should be used in conjunction with text and Fig. 1415.

Output Voltage $E_{d.c.}$	*Output Current (Ma.)* $I_{d.c.}$	*P. O. Watts*	$E_{a.c.}$* *(Approx.)*	L_1 *Opt. Crit. Swinging*	C_1	*% Rip.***	L_2 *Smoothing*	C_2	*% Rip.*	*Bleeder Resistance*	*Bleeder Current*	*Diag.*†
350	200	70	500	5–25	8	2.5	15	8	0.03	25,000	14	A
500	200	100	660	5–25	2	10.0	15	4	0.24	25,000	20	B
600	200	120	770	5–25	2	10.0	15	4	0.24	25,000	24	C
750	250	187	960	5–25	4	5.0	12	4	0.16	25,000	30	C
1000	200	200	1220	5–25	4	5.0	12	4	0.16	25,000	40	D
1000	400	400	1300	5–25	4	5.0	10	4	0.20	25,000	40	D
1250	200	250	1500	10–30	2	5.0	12	4	0.13	30,000	41	D
1250	400	500	1580	5–20	4	5.0	10	4	0.20	20,000	62	D
1500	200	300	1780	12–40	2	4.1	12	4	0.12	40,000	37	E
1500	400	600	1860	6–30	4	4.1	10	4	0.16	30,000	50	E
2000	250	500	2330	12–40	2	4.1	11	4	0.13	40,000	50	F
2000	500	1000	2410	5–25	4	5.0	10	4	0.20	25,000	80	F
2500	200	500	2880	20–100	2	2.5	12	2	0.16	100,000	25	G
2500	400	1000	2960	12–40	2	4.1	10	4	0.13	40,000	62	G

* Some manufacturers rate transformers as filter output when swinging choke is used. Others rate r.m.s. values. The figures here are r.m.s. values across one half the total secondary.

** Should a single section filter be used the figures in this column indicate the filter output ripple.

† Refers to Fig. 1415.

World Radio History

CHAPTER FIFTEEN

EMERGENCY AND PORTABLE EQUIPMENT

Emergency, Portable and Rural Applications — Power Supply Systems — Transmitting and Receiving Apparatus and Technique

EMERGENCY self-powered equipment is no longer a nice toy to play with when regular amateur activities pale; it has become the moral obligation of every amateur to be prepared in case of any communications emergency. Large-scale disasters during the past few years have demonstrated the tremendous value of amateur emergency stations in relaying relief messages when all other communication channels are closed. Aside from the all-important emergency phase, the use of portable equipment has lately been extended through organized activity in the annual "Field Day" activity, and the problem of providing equipment suitable for use in rural districts, where commercial power is not available, has always been with us. Recent developments have furnished approaches to the solutions of some of the problems, and it is the purpose of this chapter to analyze and summarize the general considerations involved in the self-powered field, and to offer certain suggestions.

The most vital need for self-powered equipment occurs in connection with emergency activity, and the basic design of all such equipment should be predicated on emergency use. The importance of this has been established by the amateur participation in such recent emergency work as the 1937 Ohio River valley flood, the 1938 southern California flood, and the 1938 eastern states hurricane. In each case hundreds of stations in the afflicted areas were forced into action at an instant's notice, many of them with power supply facilities completely disrupted. Without the general existence of adequate self-powered amateur equipment, relief communications in these crises would have been sadly hampered. As it was, public service of incalculable value was performed by amateur stations. And it is upon just such public service that amateur radio is dependent for its continued existence. Not only is this true in the case of flood, but wherever any other emergency — earthquake, sleet storm, hurricane — can occur. In short, every amateur, no matter where he may be located, can reasonably expect that sometime he may be called upon to perform emergency communications duty, and it is his responsibility to the public welfare, to himself, and to amateur radio as a whole to see that he is in some measure prepared.

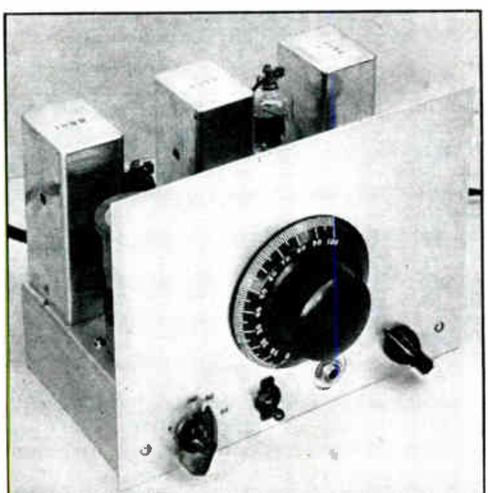


FIG. 1501 — THREE-TUBE SUPERHET FOR PORTABLE EMERGENCY USE

Filaments are heated by a 6-volt storage battery; "B" power is from one or two blocks of "B" batteries. The set is designed for the 1.75-, 3.5- and 7-mc. bands.

Choice of Power Supply

There is a wide gap between the present comparatively large variety of self-generating power sources and the situation of ten years ago when the amateur requiring independence from a.c. mains had only three alternatives: batteries, the use of a tricky, inefficient Ford spark coil arrangement, or the expenditure of hundreds of dollars for a gasoline-driven generator. Today it is possible to secure almost any conceivable type of power supply at rea-

World Radio History

BATTERY SERVICE HOURS

Estimated to 34-volt end point per nominal 45-volt section
Based on intermittent use of 3 to 4 hours daily
(For batteries manufactured in U. S. A. only)

Manufacturer's Type No.		Weight		Current Drain in Ma.												
Burgess	Eveready	Lb.	Oz.	2	5	10	15	20	25	30	40	50	60	75	100	150
—	386	14	—	—	2000	1100	690	510	400	320	200	170	130	100	50	30
21338[1]	—	15	12	—	1680	1220	765	560	433	325	—	154	113	76	47	25
—	486	13	5	—	1700	880	550	395	300	240	165	125	100	70	45	20
21308	—	13	—	—	1600	1100	690	490	—	300	200	—	—	—	—	—
—	586	12	2	—	1400	800	530	380	260	185	130	85	60	40	30	14
10338[1]	—	12	14	—	1150	750	550	440	375	300	—	160	125	95	57	29
1038	—	11	8	—	1300	800	520	350	—	185	115	—	—	—	—	—
22308	—	8	4	—	1200	640	400	250	—	130	69	—	—	—	—	—
2308	—	7	8	—	1100	540	330	180	—	83	47	—	—	—	—	—
—	485	9	3	—	1000	525	375	250	200	135	100	60	40	20	15	7.5
—	585	8	13	—	900	450	290	210	130	100	60	45	25	20	11	5
2338[1]	—	8	10	—	750	460	330	260	200	180	—	84	64	43	26	10
5308	—	3	4	—	350	170	90	50	—	21	8	—	—	—	—	—
—	762	3	3	—	320	140	81	54	37	27	—	—	—	—	—	—
33OBP[2]	—	3	2	700	305	140	75	52	39	30	—	16	11.5	7.3	4.2	1.0
A3OBP[3]	—	2	—	400	160	62	30	17	10	7	—	2	—	—	—	—
—	738	1	2	—	160	70	30	20	10	7	—	—	—	—	—	—
Z3ONX[4]	—	1	4	270	100	48	33	23	17	14	—	7.6	5.2	3.3	2	1
Z3ON[5]	—	1	4	240	94	37	17	9.5	6	4	—	1	—	—	—	—
X3OFL[6]	—	—	13	185	68	31	19	13	10	8	—	4.6	—	—	—	—
—	733	—	10	—	50	20	11	7	5.2	—	—	—	—	—	—	—
W3OFL[7]	—	—	10	112	43	19	12	8.5	6.6	5.4	—	2.2	—	—	—	—

[1] 50 volts.

[2] Also applies to 144-volt portion of 51116, which combines 3-volt "A" and 22½-volt "C." Wt. 16 lbs. 4 oz.

[3] Same life figures apply to A3OP, wt. 2 lbs., and A96P, 144-volt, wt. 8 lbs. 7 oz.

[4] Same life figures apply to Z30X, wt. 1 lb. 7 oz., and Z60X, 90-volt, wt. 2 lb. 7 oz.

[5] Same life figures apply to Z30BP, wt. 1 lb. 7 oz., Z60BP 90-volt, wt. 2 lb. 7 oz., and Z96P, 144-volt, wt. 4 lbs.

[6] Same life figures apply to X30BP, wt. 15 oz., X60X, 90-volt, wt. 1 lb. 14 oz., and X60BP, 90-volt, wt. 2 lbs. 1 oz.

[7] Same life figures apply to W30BP, wt. 11 oz., and W60BP, 90-volt, wt. 1 lb. 5 oz.

Estimated to .9-volt end point per 1.5-volt unit
Based on intermittent use of 3 to 4 hours daily
(For batteries manufactured in U. S. A. only)

Manufacturer's Type No.		Voltage	Weight		Current Drain in Ma.															
Burgess	Eveready		Lb.	Oz.	10	20	25	30	50	60	75	100	120	150	180	240	250	300	500	1000
—	7111	1½	2	2	—	—	—	—	—	700	—	—	300	—	200	120	—	85	—	—
4FA	—	1½	1	6	1250	1000	950	900	750	670	570	425	—	300	—	—	160	100	48	10
—	724	3.0	2	—	—	—	—	—	—	520	—	—	220	—	150	100	—	70	—	—
2F2H[1]	—	3.0	1	6	1200	800	660	600	400	340	270	185	—	102	—	—	47	33	12	3
—	723	3.0	1	—	—	—	—	—	—	250	—	—	100	—	70	40	—	30	—	—
F2BP	—	3.0	—	12	800	490	400	340	185	145	102	68	—	33	—	—	12	8.3	3	—
—	722	3.0	—	8	—	—	—	—	—	120	—	—	40	—	30	17	—	13	—	—
T2FL	—	3.0	—	8	420	250	200	170	96	77	60	44	—	21	—	—	8.8	6.5	—	—
F4BP	—	6.0	1	10	—	—	275	235	135	120	102	72	—	41	—	—	23	19	2	—

[1] Life figures also apply to 2F2BP, wt. 1 lb. 5 oz.

sonable cost. The only problem is to select the one which most adequately fulfils the need within the available budget.

An analysis of the numerous available types should disclose which are the most suitable for the various applications, based on the criteria of utility, efficiency, performance and cost.

Dry batteries: Dry-cell batteries are the standard primary electrical energy source. They are ideal for receiver and low-power transmitter supplies because they provide steady, pure direct current with almost zero regulation. Their disadvantages are weight, high cost and limited current capability. In addition, they will lose their power even when not in use if allowed to stand for periods of a year or more. This makes them uneconomical if not used more or less continuously.

The accompanying table shows the life to be expected from representative types under various current drains, based on intermittent service simulating typical operation. Continu-

World Radio History

ous service life will be somewhat greater at very low current drains and from one-half to two-thirds the intermittent life at the higher current values.

The life figures given in the table are based on an end-point of 34 volts. This is considered to be the normal limit in average equipment. With suitable design of the apparatus to enable it to operate satisfactorily on about half voltage, the end-point can be extended to 24 volts, adding approximately 50% to the life of the battery in average use.

The secret of long battery life at normal current drains lies in intermittent operation. The duration of "on" periods should be reduced to a minimum. The more frequent the rests given a dry-cell battery, the longer it will last. As an example, one standard type will last 50% longer if it is operated for intervals of one minute with five minutes rest in 24-hour intermittent operation than if it is operated continuously for four hours per day, although the actual wattage consumption in the 24-hour period is the same.

Although not a dry battery, the "Air Cell" comes under the same use classification. It is a primary battery which cannot be recharged. It has high current capacity and a flat discharge curve. Three types are now available, one having a capacity of 600 ampere-hours and a maximum current rating of 0.66 amperes, another having the same capacity but a maximum current rating of 0.75 amperes, and the third with a capacity of 300 ampere-hours and a maximum current rating of 0.66 amperes. The Air Cell has a basic potential slightly in excess of 2.4 volts, and the discharge curve is quite flat to about 2 volts.

Storage batteries: The most universally acceptable self-contained power sources is the

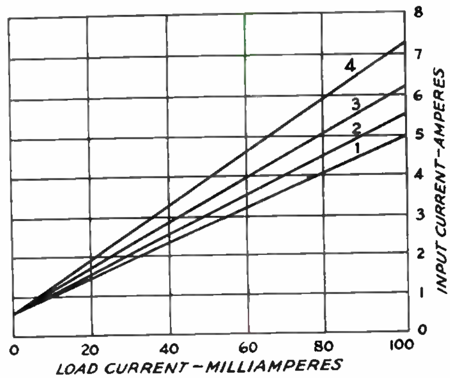


FIG. 1503 — CONVERSION EFFICIENCY OF VIBRATOR-TRANSFORMER AT VARIOUS LOADS

These curves are also for Mallory 300-volt Vibrapacks.

storage battery. It has high initial capacity and can be recharged, so that its effective life is practically indefinite. It can be used to provide filament or heater power directly, and plate power through associated devices such as vibrator-transformers, dynamotors and genemotors, and a.c. converters. For emergency work a storage battery is a particularly successful power source because no matter what the circumstances such batteries are almost invariably available — even if they have to be commandeered from parked cars!

For maximum efficiency and usefulness the power drain on the storage battery should be limited to 15 or 20 amperes from the ordinary 100- or 120-ampere-hour battery. This should provide a carrier power when transmitting of 20 to 30 watts, which is usually adequate. In connecting the battery, heavy leads of the automotive cable type should be used, to minimize the voltage drop; ordinary car-receiver leads are definitely not satisfactory. Similarly, heavy-duty low-resistance switches are required.

Vibrator-Transformers: The vibrator-transformer consists of a specially-designed transformer combined with a vibrating interrupter. When the unit is connected to a storage battery the circuit is made and broken rapidly by the vibrator contacts and the pulsating d.c. which flows in the primary of the transformer causes an alternating voltage to be developed in the secondary. This high-voltage a.c. is in turn rectified, either by a vacuum-tube rectifier or by an additional synchronized pair of vibrator contacts, and filtered, providing outputs as high as 300 volts at 100 ma. Tube rectifiers are ordinarily used only when the negative side of the circuit cannot be grounded, a requirement with the self-rectifying type. The high-voltage filter circuit is usually identical with that of an equivalent power source

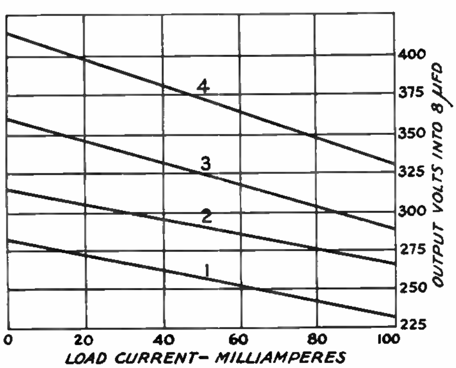


FIG. 1502 — VIBRATOR-TRANSFORMER REGULATION CURVES

These curves are for Mallory Vibrapacks VP-552 and VP-554, rated at 300 volts, 100 ma. They are typical of most vibrator supplies. The numbers indicate the voltage taps on the tapped transformer secondary, chosen by a selector switch.

World Radio History

operating from the a.c. line. Noise suppression equipment, serving to minimize r.f. disturbances, is usually incorporated in the manufactured unit.

Although vibrator-transformers are ordinarily used with 6-volt tubes, their use with 2-volt tubes is quite possible provided additional filament filtration is incorporated. This filter can consist of a small low-resistance iron-core choke, or the voice-coil winding of a speaker transformer. The field coil of a speaker designed to operate on 4 volts at the total filament current of the receiver may be used. The filaments are then connected in parallel, as usual, and placed in series with this winding across the 6-volt battery. On both 6- and 2-volt receivers "hash" can be reduced by heavily by-passing the battery at the vibrator supply terminals, using .25 to 1 μfd. or more. Noise will be minimized if a single ground, consisting of a short, heavy copper strap, is used.

Figs. 1502–1503 show the load current and regulation curves for representative vibrator-transformer units. The rated output voltages allow for filter drop; the filter resistance should, of course, be kept as low as possible. A 100- to 200-ohm series resistance is permissible.

Dynamotors and Genemotors: A dynamotor is a double-armature high-voltage generator, the additional winding operating as a driving motor. It is usually operated from a 6-, 12- or 32-volt battery, and may deliver voltages from 300 to 1000 or more. Dynamotors have been widely used in military work and most of those in amateur use derive from such origins. New dynamotors of high power capability are costly and are not generally available.

The genemotor is a refinement of the dynamotor designed especially for automobile receiver, sound truck and similar applications. It has found wide acceptance among amateurs as a source of transmitting power, having good regulation and efficiency combined with economy of operation. It is also used in connection with portable receiver installations, although a rather high inherent noise level limits this application in sensitive amateur high-frequency receivers.

Genemotors are made to fill almost every need, more than two dozen types being available. Their cost, at amateur net prices, runs from about eight to twenty-four dollars. Standard models range from 135 volts at 10 ma. to 300 volts at 200 ma. or 500 volts at 100 ma. Parallel and series operation of identical units to provide higher capacity is entirely practical. The normal efficiency averages around 40%, increasing to better than 50% in the higher-power units. The regulation is comparable to well-designed a.c. supplies; it is largely a result of external IR drops.

Successful operation of dynamotors and genemotors implies heavy, direct leads, mechanical isolation to reduce vibration, and thorough r.f. and ripple filtration (the purchase of manufactured filter units is recommended). The shafts and bearings should be thoroughly "run in" before regular operation is attempted, and the tension of the bearings should be checked occasionally.

A.c.-d.c. converters: In some cases it may be desirable to utilize existing equipment built for 115-volt a.c. operation in portable applications. To operate such equipment with any of the power sources outlined in the foregoing would require a considerable amount of rebuilding. This can be obviated by using a rotary converter capable of changing the d.c. from 6-, 12- or 32-volt batteries to 110-volt 60-cycle a.c. Such converter units are available from several manufacturers, with output ratings from 40 to 300 watts. Their cost runs from fifteen to fifty dollars at amateur prices.

The conversion efficiency of these units averages about 50%. In appearance and operation they are similar to genemotors of equivalent ratings, while the prices are approximately the same. The overall efficiency of the converter system will be lower because of the losses in the a.c. rectifier-filter circuits and the necessity for converting heater as well as plate power.

Generators: The plate supply systems outlined in the foregoing are, with the exception of the dry-cell batteries, designed to utilize the electrical energy stored in a storage battery. The problem then arises of securing the energy to be stored in the battery. If access to a.c.-operated chargers is not possible at times between actual use, some form of self-powered charging system is essential.

This need is ordinarily best met by a gasoline- or wind-driven generator. Water-power generators have been used, but their dependence on special circumstances is obvious, and they are not commercially available in small sizes.

The windcharger, although it originated but two or three years ago, has already received quite wide acceptance.[1] It consists of a small generator driven by a suitable impellor, mounted to take advantage of the free energy offered by the wind. The standard type costing in the neighborhood of twenty dollars will supply up to 16 amperes to a 6-volt battery. It will ordinarily keep fully charged a battery used to power a typical receiver and small transmitter operated from vibrator or genemotor supply in intermittent operation.

Gasoline-driven generators are also available for use in charging 6-volt or larger batteries. These ordinarily are rated at 150 or 200 watts and cost in the neighborhood of forty dollars. A ½ or ¾-h.p. single-cylinder four-cycle

World Radio History

engine is used, which will operate for twelve or fifteen hours on a gallon of gasoline.

In higher-powered installations the use of intermediate storage batteries may be dispensed with, and a gasoline-driven generator supplying 110-volt a.c. directly may be employed. Such generators are ordinarily rated at a minimum of 250 or 300 watts, and cost fifty or sixty dollars. They are available up to two kilowatts, or big enough to handle the highest-power amateur rig, at a cost of between three and four hundred dollars. Most are arranged to charge automatically an auxiliary 6-volt battery used in starting. Fitted with self-starters and adequate mufflers and filters, they represent a high order of performance and efficiency.

A variant on the generator idea is the use of fan-belt drive. The disadvantage of requiring that the automobile must be running throughout the operating period has not led to general popularity of this idea amongst amateurs, although in San Francisco and Oakland an amateur emergency unit relies on it heavily. Such generators are similar in construction and capacity to the small gas-driven units.

The home construction of generators of all the above types has been successfully attempted by amateurs at times, although the possession of a considerable knowledge of electric motor design is essential. One especially useful possibility is the re-winding of old automobile charging generators, several hundred watts capacity being obtainable from the largest sizes. Those originally used on the old 4-cylinder Dodge cars have been successfully adapted by amateurs.[2]

The Receiver

The weakest link in the portable or emergency communications chain usually is the receiver. An inadequate receiver, with poor selectivity, low sensitivity and insufficient stability can ruin a QSO even under favorable conditions, yet most so-called "portable" receivers can be thus described. When it is remembered that conditions in portable or emergency operation are often more severe than those at home, with poor antenna facilities, high noise levels, severe interference, etc., the fallacy of attempting to use an inferior portable receiver is apparent.

The best procedure of all is to use the home station receiver for portable work. The average communications super-heterodyne can be operated with storage battery "A" and dry cell "B" supply without difficulty, if 6-volt tubes are utilized. Of course, headphones should be used and the output tube removed, but this is no hardship. Headphones are far more satisfactory in such applications than the speaker in any event. This procedure should be followed not only because it ensures the availability of the high-performance receiver so vitally necessary, but because the practice that has been obtained by using the receiver at home is invaluable in the specialized operating techniques of portable or emergency work. It takes as much experience to learn to run a receiver properly as it does to drive a car, and the middle of a crisis is no time to gain that experience. Even on lowered plate voltage the home superhet will be better than a makeshift.

If a special portable/emergency receiver is to be built, it should be a superheterodyne. With present-day tubes and components, it is possible to build a simple superheterodyne as cheaply as a t.r.f. receiver, and there is no comparison between the two in performance. A regenerative receiver without an r.f. stage is completely out of the picture, since swinging antennas and blocking signals contribute so to instability that its use is not justified except under the most extreme circumstances. Small b.c. receivers can be converted into satisfactory ham-band receivers with a little ingenuity on the part of the amateur,[3] or a special receiver can be built with standard parts.

The receiver[4] in Figs. 1501, 1504–1506 was designed especially for portable and emergency work.[4] With only three tubes it has no more "A" and "B" battery drain than the usual t.r.f. receiver. Good selectivity is obtained by using a 460 i.f., with iron-core transformer coupling, and permeability-tuned transformers cut the cost of the i.f. transformers considerably. With no preselection, image response is bad on 14 Mc. and higher, but it was felt that the most-used bands would be 1.7, 3.5 and 7 Mc., where the images do not cause much trouble.

Basically, the receiver is conventional, and therefore reliable, in design. It consists of the 6K8 oscillator-mixer, a 6K7 i.f. amplifier at 460 kc., and the 6C8G combined second detector and beat oscillator. The audio output is taken from the plate of the second detector.

The complete circuit diagram of the receiver is given in Fig. 1505. To simplify construction and eliminate separate padders on each coil, the antenna circuit is not ganged with the oscillator. C_1 must, therefore, be separately tuned to resonance with the incoming signal if maximum signal strength is desired. Having the input tuning control separate permits its use as a volume control, thus eliminating the conventional bias-control resistor.

In the oscillator section, C_2 is the padding or band-setting condenser and C_3 the band-spread tuning condenser. On the 1.75- and 3.5-Mc. bands, C_3 is connected across the whole of the oscillator grid coil, with a jumper in the coil form to make the necessary connection. On the 7-Mc. coil, C_3 is tapped down as indicated in the coil table. To facilitate rapid and accurate

World Radio History

setting of C_2 for each band, a home-made gadget stops the condenser at the proper setting. A thin brass disc about the size of a penny, the rim smoothed down with steel wool, is soldered to the end of the condenser rotor shaft. A piece of half-inch wide thin brass strip is fastened to the mounting angle on the condenser by a machine screw and projects slightly to the rear of the disc. A U-shaped spring made of thin phosphor bronze strip about 1/16th inch wide is soldered to the brass piece. At the free end of the spring a V-shaped projection rides against the edge of the disc. When the proper setting of the condenser is found for a band, a small notch is filed in the disc so that the "V" fits into it. When the condenser is turned, the disc slides along the spring until the "V" slips into the notch and locates the desired setting.

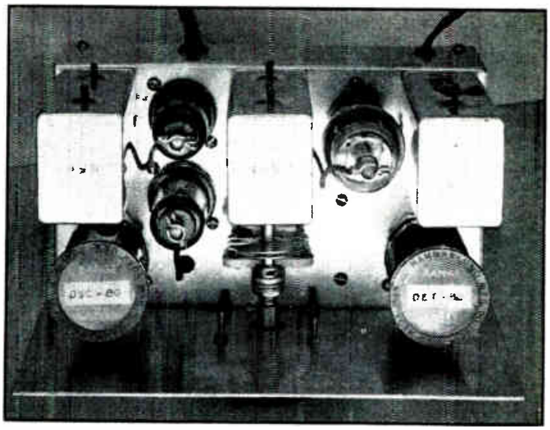


FIG. 1504 — TOP VIEW OF THE THREE-TUBE SUPER

The permeability-tuned i.f. and b.o. transformers are along the rear edge of the chassis. Plug-in oscillator and detector coils, with separate tuning controls, are used. The glass tube is the 6C8G; the metal tube nearest the panel is the 6K8 mixer-oscillator.

In the i.f. amplifier both transformers are the interstage type, since the output transformer works into a plate detector. The plate-type detector was used for several reasons, chief among them being the fact that it does not load its input circuit as does a grid-leak detector, thus making for better selectivity; the plate current is negligible, reducing battery drain; and it can handle fairly large signals so that reasonable audio output can be secured without additional audio amplification. The bias resistor, R_4, is by-passed by an electrolytic condenser, C_9. In the plate circuit a rather large by-pass, C_{10}, is used to cut down high-frequency response and thus reduce hiss and heterodynes. It has practically no effect on a

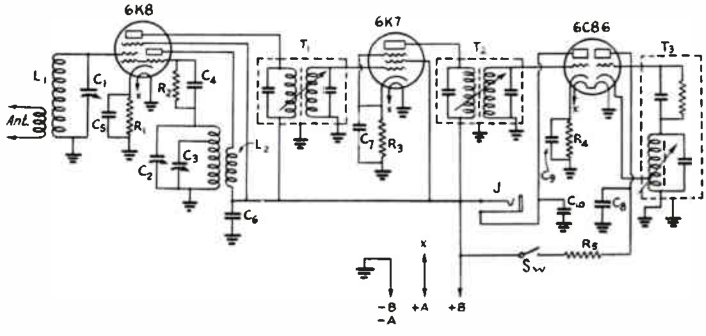


FIG. 1505 — CIRCUIT DIAGRAM OF THE PORTABLE 3-TUBE SUPERHET

C_1, C_2 — 100-μμfd. midget variable (Hammarlund HF-100).
C_3 — 35-μμfd. variable (Hammarlund MC-35-S).
C_4 — 100-μμfd. midget mica.
C_5-C_8, inc. — 0.1-μfd. paper.
C_9 — 10-μfd. 25-volt electrolytic.
C_{10} — 0.005-μfd. mica.
R_1 — 300 ohms, ½-watt.
R_2 — 50,000 ohms, ½-watt.
R_3 — 500 ohms, ½-watt.
R_4 — 10,000 ohms, ½-watt.
R_5 — 50,000 ohms, ½-watt.
T_1, T_2 — 460-kc. permeability-tuned i.f. transformer, interstage type (Sickles 6504).
T_3 — 460-kc. permeability-tuned b.o. transformer (Sickles 6577).
Sw — S.p.s.t. toggle switch.
J — Open-circuit jack.

L_1 — 1.75 Mc.: 70 turns No. 24 enamelled, close-wound, on 1½-inch form. Antenna coil 10 turns, ¼ inch from grid coil.
3.5 Mc.: 45 turns No. 22 enamelled, close-wound, on 1½-inch form. Antenna coil 6 turns, ¼ inch from grid coil.
7 Mc.: 18 turns No. 22 enamelled, close-wound, on 1½-inch form. Antenna coil 4 turns, ¼ inch from grid coil.

L_2 — 1.75 Mc.: 41 turns No. 22 enamelled, close-wound, on 1½-inch form. Tickler 13 turns, ⅛ inch from grid coil.
3.5 Mc.: 17 turns No. 22 enamelled, close-wound, on 1½-inch form. Tickler 6 turns, ⅛ inch from grid coil.
7 Mc.: 8 turns No. 22 enamelled, length ½ inch, diameter 1½ inches. Band-spread tap 6th turn from ground. Tickler 4 turns, close-wound, ⅛ inch from grid coil.

Note: L_1 coils wound on Hammarlund SWF-4 forms. L_2 coils on SWF-5 forms. Band-spread condenser, C_3, connected across whole of L_2 on 1.75 and 3.5 Mc.

World Radio History

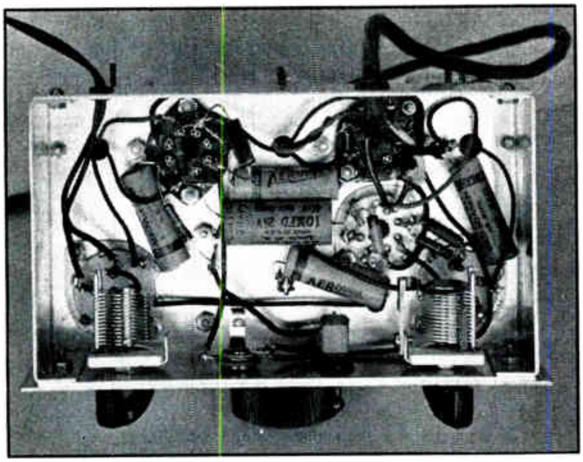


FIG. 1506 — A BOTTOM VIEW OF THE RECEIVER

The detector tuning condenser is at the left and the oscillator padding condenser, with its band-setting "stops," at the right. Antenna connections are the twisted leads going through the rear edge of the chassis at the left.

normal 1000-cycle beat-note, however, nor on the intelligibility of speech.

The second 6C8G section is the beat oscillator, using a permeability tuned transformer made for the purpose. The grid condenser and leak are built into the transformer. The plate is fed through the b.o. on-off switch and a 50,000-ohm dropping resistor, R_5, the latter serving both to reduce the current drain and to cut down the output of the oscillator to a value suitable for good heterodyning. Although not shown on the diagram, small capacitive coupling between the b.o. and the second detector is provided by a short length of wire, soldered at one end to the cathode terminal of the beat-oscillator section and with the other end twisted for a few turns around the lead from the 6K7 plate to T_2. This additional coupling is not strictly necessary, since there is some stray coupling between the two stages, but proves helpful in practice.

In the "A" battery circuit, one side of each heater is grounded; the others are connected in parallel and to the plus-A wire in the battery cable. Parenthetically, humless reception can be obtained with a 6.3-volt filament transformer instead of the battery. In the "B" circuit, screens and plates are operated at the same voltage. This not only gives best tube performance, but saves on resistors and by-pass condensers and simplifies the circuit.

There is no on-off switch on the set, either for the "A" or "B" batteries. It was considered that this switching can be grouped more conveniently with the transmitter switching in a coördinated design.

The receiver is built on a folded aluminum chassis 8″ wide, 4½″ deep and 2″ high. The panel is 8½ by 6½ inches: both chassis and panel utilize 1/16th-inch thick aluminum.

The i.f. is lined up in the normal fashion with a test oscillator or, lacking an oscillator, it can be lined up on the noise by turning on the b.f.o. and adjusting the i.f. transformers for maximum hiss. In actual operation, the b.f.o. is tuned off the intermediate frequency by about 1000 cycles or so, to give a slight single-signal effect.

With the i.f. aligned, the detector and oscillator coils for a band are plugged in. C_3 is set near minimum and C_2 slowly tuned from minimum until the high-frequency end of the band is reached. This point should be found with C_2 at about half capacity on 1.75 Mc., at about ⅝ capacity on 3.5 Mc., and very nearly at full capacity on 7 Mc. The band-spread may then be checked by tuning C_3 across its scale. The band-spread may be decreased by adding a turn or two to the oscillator grid coil in the case of the 1.75- and 3.5-Mc. coils, or increased by the reverse procedure. In either case a new setting must be found for C_2. On 7 Mc. the band-spread can be increased or decreased by moving the tap toward or away from ground.

Operation of the receiver is simple. With the band-setting condenser at the proper setting (the device previously described simplifies this adjustment), tuning is done with the main dial. For c.w. reception, snap the b.o. switch to the on position, tune in a signal, and adjust C_1 for maximum strength — or set the condenser at any point on the high-capacity side of resonance which gives the desired signal strength. The condenser gives adequate volume-control range, although it will not cut out a signal completely unless the signal itself is very weak. When using C_1 as a volume control, always set it on the high-capacity side of resonance so that image response will be reduced.

Resonance on C_1 is best detected by setting the main dial at a point where no signal is heard and then adjusting C_1 for maximum background noise. If two such settings can be found, use the one with the highest capacity; the other is in resonance at the image frequency. As C_1 is varied with a signal tuned in there will be a slight change in the beat-note frequency; this change will be gradual and always in the same direction until C_1 has passed through resonance and approaches the oscillator frequency. In the latter region the change will be considerably greater, so the detector tuning should be kept near actual

World Radio History

resonance or on the low-frequency side of it. The tuning is not really critical but, because of the relatively large-capacity condenser, shows a quite definite peak.

The Transmitter

Owing to the difficulty in securing power for emergency, portable and rural transmitters, their design will depend almost entirely upon the power supply available. Considering possible defects in hastily-improvised radiation systems, etc., it seems unwise to use less than 10 watts input to a power amplifier or 15 watts to an oscillator. However, powers greater than two or three times these values are not usually necessary, so selection of the power supply will depend almost entirely upon the pocketbook and other resources. The 300-volt, 100-ma. vibrator-transformers and genemotors represent a nice compromise unless it is possible to step into the 200- or 300-watt gasoline-driven generator class. The units to be described are designed for 25 to 30 watts input; larger designs will follow more or less conventional lines.

The best plan in providing for an emergency and portable transmitter is to utilize the basic exciter unit in the regular station. This not only ensures the availability of a reliable, efficient unit at all times but means a saving in parts and equipment. It represents no hardship to the permanent station to construct the exciter so it is compact, readily removable, and, above all, solidly and dependably assembled. If your present exciter is not adaptable to this use, plan the new one so it will be. Of course, provision for 6-volt tubes throughout is essential, with the heater circuit so arranged that it can be connected to a storage battery without change. A suitable plate supply using a vibrator or genemotor of similar system should be available separately, arranged for ready connection. The best method is to have a socket and plug connector assembly, with one plug built into the transmitter and another, wired identically, connected permanently to the emergency supply.

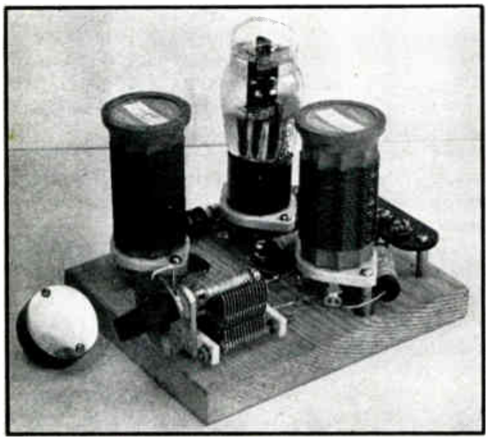


FIG. 1507 — SIMPLE AND PRACTICAL PORTABLE OR EMERGENCY TRANSMITTER

A receiving-type pentode (2A5, 42, 6F6, etc.) arranged for crystal control or a self-resonant-grid oscillator circuit can be used with any kind of power supply under most circumstances.

The basic design for a miniature emergency or portable transmitter is shown in Figs. 1507–1508. It is based on the use of a receiving type output pentode, such as the 2A5, 42 or 6F6. Such tubes are almost universally available because of their wide use in broadcast receivers. The normal requirement of crystal control can, if no crystal is available, be averted by the use of the tuned-plate untuned-grid circuit once general in amateur practice (but capable of emitting a now illegal signal and to be used only with suitable precautions).

The virtue of a transmitter of this type is that it can be readily and quickly constructed from junk-box parts. Indeed, in time of emergency it could be assembled in comparatively short time from the parts of a midget broadcast receiver. It is extremely versatile from the power supply standpoint, requiring only a storage battery for the heater and a few dry "B" batteries or equivalent for plate supply. Transmitters of this type have been successfully operated in actual emergencies for considerable periods using only 135 volts from dry cells for plate voltage. At the same time, 10 watts input can be secured if a 350- or 400-volt supply is available, enough for reasonably consistent work.

A milliammeter in the positive lead is desirable for tuning purposes, although listening on the receiver with the antennas disconnected should suffice. If it is difficult or impossible to secure oscillation, connect short lengths of insulated wire to the plate and grid contacts on the tube socket, and twist them together, producing a common feedback capacity.

The simple oscillator-transmitter should be used only if nothing else is available. If a permanent portable-emergency transmitter is planned, it is advisable to use some form of oscillator-amplifier combination, for its greater flexibility and better efficiency. One very logical combination utilizes a Pierce crystal oscillator (because it requires no tuning, regardless of crystal frequency) driving a beam-power tube. It makes a versatile combination — only one tuning control is necessary — and it can readily be used as the regular-station exciter. Two examples are given: one, a companion unit for the previously described receiver, utilizing a 6C5-6L6 combination, and the other a 6F6-807 lineup.

The 6C5-6L6 transmitter, Figs. 1509–1511, is built on a chassis identical to that used for the receiver. Provision is made for switch selection of any one of four crystals, and 1.7-, 3.5-, and 7-Mc. crystals all oscillate in the circuit with equal ease. Plug-in coils are used in the plate circuit of the 6L6, and no neutralization was found necessary on 1.7, 3.5 or 7 Mc. Fixed coupling coils were provided because the transmitter was built for use with

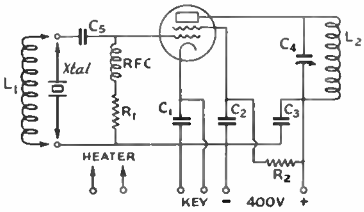


FIG. 1508 — CIRCUIT OF THE SIMPLE PORTABLE TRANSMITTER

L_1 — 80 turns No. 24 d.s.c. close-wound (this figure is only approximate; remove turns experimentally until plate current minimum occurs at desired frequency).
L_2 — 21 turns No. 20 enamel spaced the diameter of the wire, or to about 1½ inches.
C_1, C_2, C_3 — 0.01-μfd. 600-volt paper.
C_4 — 200-μμfd. midget variable (National STH-200).
C_5 — 500 μμfd. postage stamp mica.
R_1 — 7500-ohm 1-watt carbon.
R_2 — 50,000-ohm 2-watt carbon.
RFC — 2.5-millihenry r.f. choke (National R-100).

lamp-cord line feed. The transmitter is keyed in the cathode of both tubes to enable break-in work and afford maximum economy of the power supply. The coils may seem small for the bands on which they are used, but they are designed for the proper L/C ratio and are effective.

The transmitter should be tested by removing the 6L6 from the socket and closing the key, with the power on. Crystals from 1.7 to 7 Mc. should oscillate readily. The addition

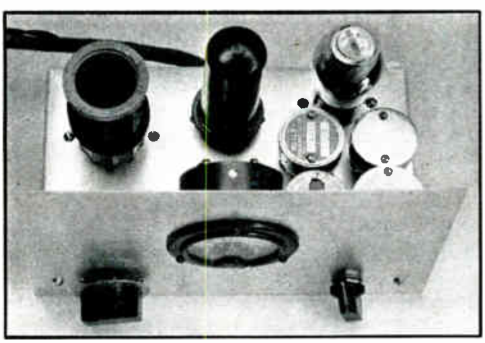


FIG. 1509 — TOP VIEW OF THE 6C5-6L6 TRANSMITTER

Provision is made for four crystals which are selected by the switch on the panel. Only one plug-in coil is required for this three-band oscillator-amplifier transmitter.

of condenser C_1 seems to keep the keying from being chirpy, and may need to be adjusted. However, values over 50 μμfd. seem to have no particular advantage. When first testing the transmitter, grid current should be checked by disconnecting R_2 from ground and inserting a low-range milliammeter. Grid current through the 100,000-ohm resistor should range between 1 and 2 ma. on 1.7, 3.5 and 7 Mc.

A somewhat similar unit,[3] but utilizing a 6F6-807 combination and built-in modulator, is shown in Figs. 1512–1514. The wiring diagram shows the essentials of the electrical design. It will be seen that a pi-section filter is used to couple the 807 to the antenna system used. When the switch arm is on the first tap, the antenna and coupler are completely disconnected from the final. This makes it possible to bring the final tank circuit to resonance, then cut in the network and antenna

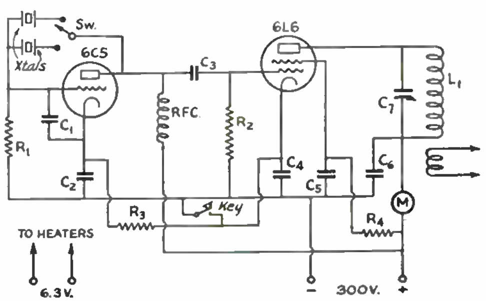


FIG. 1510 — WIRING DIAGRAM OF THE 6C5-6L6 TRANSMITTER

C_1 — 50-μμfd. postage stamp mica.
C_2 — 0.002-μfd. postage stamp mica.
C_3 — 250-μμfd. postage stamp mica.
C_4, C_6 — 0.005-μμfd. postage stamp mica.
C_5 — 0.01-μfd., 600-volt paper.
C_7 — 140-μfd. midget variable (Cardwell ZU-140-AS).
R_1 — 25,000-ohm, ½-watt.
R_2 — 100,000-ohm, 1-watt.
R_3 — 1000-ohm, ½-watt.
R_4 — 10,000-ohm, 2-watt.
RFC — 2.5-mh. r.f. choke.
M — 2″ 0-150 ma. meter.
Sw. — 4-position crystal switch (Yaxley 1316L).

L_1 — Band	Turns	Length	Coupling Coil Turns
1.7 Mc.	46 No. 24 d.s.c.	Close-wound	11
3.5	25 No. 18 enam.	1½″	7
7	13 No. 18 enam.	1¾″	4

Coupling coil is close-wound with push-back wire over lower end of L_1.

with the switch, adjusting for proper load and resonance with the taps and the network condensers as with any other Collins coupler.

The modulation transformer is a standard receiver-type universal output transformer rated at 20 watts audio, and will carry 60 ma. d.c. each side. The plate load impedance of the 6L6 modulator tube working Class-A is ap-

World Radio History

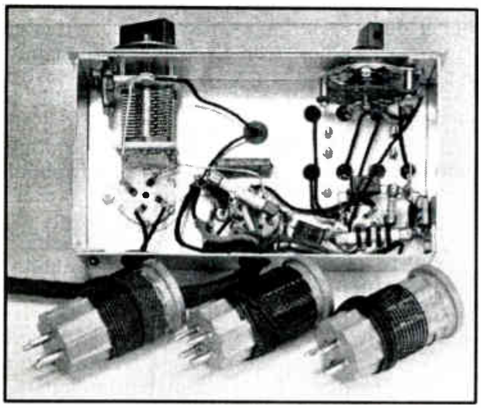


FIG. 1511 — UNDERNEATH THE CHASSIS OF THE PORTABLE TRANSMITTER

Wiring is straightforward and very simple. The antenna twisted-pair feed line is connected to the twisted pair coming out the back of the set. Coupling coils are wound over the lower end of each coil.

proximately the same as the r.f. load impedance at 25 watts input. The primary of the transformer, connected as an auto-transformer, gives a good match and is large enough to handle the power nicely. The voice coil windings are not used.

Still another arrangement, using a 6V6G Tritet oscillator to drive a 6A6 neutralized

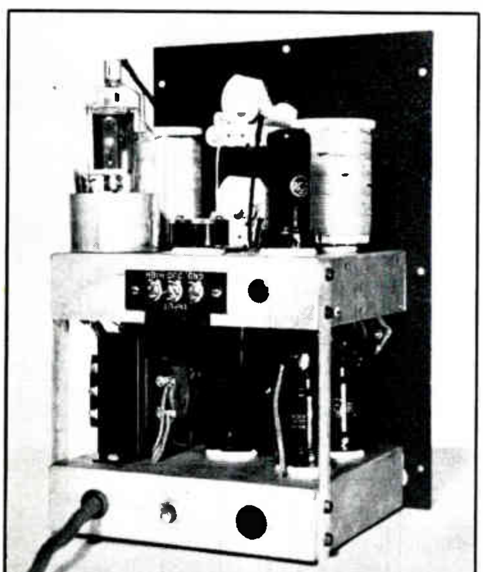


FIG. 1512 — A COMPLETE 25- TO 35-WATT TRANSMITTER AND MODULATOR

The r.f. section is on the upper chassis, audio on the lower. Circuits and construction are simple but highly practical for the job. A complete case has been removed to show the details of the rig.

final amplifier, is shown in Figs. 1515–1517. At 300 volts it is a bit easier to run 100 ma. to the final amplifier, with good efficiency, than in the other units, but the 6V6G oscillator will draw slightly more current. Crystal switching facilitates frequency changing within an amateur band. Fixed cathode tuning eliminates one control and, because of the fact that there is more than sufficient excitation, does not hamper performance.

Inductive coupling between stages is not only a convenient and efficient form, but in this layout improves the neutralization. This is due to the fact that it permits the grid circuit to be operated "floating" without a ground return. Even without coil shielding there is no perceptible feedback.

An antenna tuning unit is provided which is simple and yet sufficiently universal to accommodate any type of end- or center-fed antenna or tuned transmission line. A large majority of portable antennas are of these types. The circuit diagram shows how a parallel or series connection is made. An external link made of insulated hookup wire provides a simple and effective means of varying the coupling.

The single meter is switched between grid and plate circuits by means of SW2. This is the only refinement in the way of parts that are not absolutely essential; in all other elements the layout has been pruned to the bare minimum compatible with adequate performance. That no unnecessary sacrifices have been made is evidenced by the overall efficiency and clean signal of the completed unit. Outputs of 20 to 25 watts are readily obtainable. On c.w. the keying is sharp and clean-cut, while on 'phone there is no trace of frequency modulation.

Keying can be accomplished in a variety of ways. Individual requirements will dictate the final choice. If break-in is essential, the cathode of the 6V6G can be keyed, for the high-mu 6A6 does not draw excessive plate current. Center-tap keying of the 6A6 is satisfactory. A good method is to open the grid circuit of the 6A6; this is positive, and almost clickless. The system shown in Fig. 901 in Chapter Nine also works very well.

Antenna Systems

It is difficult to specify standard antenna systems for emergency or portable applications, because in all cases the location is the determining factor. As with most things, the simplest antenna is ordinarily the best.

One of the simplest systems is the end-fed antenna. A single half-wave on the lowest frequency to be used will radiate plenty of energy, providing a good part of its length is well above ground. If it is cut reasonably close to resonance efficient coupling is assured by

World Radio History

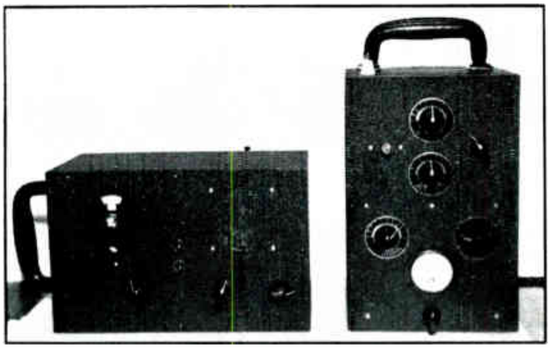


FIG. 1514 — THE 6F6-807 TRANSMITTER IN ITS CASE (RIGHT)

The receiver on the left has been revamped from a small b.c. superheterodyne especially for portable-emergency work.

connecting directly to the plate (through a variable condenser) or to a supplementary link-coupled tuned circuit.

If a transmission line is essential, it should be as well-constructed as possible. The single-wire-fed type is ideal if the feed line can be brought off the antenna at right angles. The feeder should be tapped on the plate coil (through a 0.002-µfd. fixed condenser) at the point where the desired loading occurs, making sure that the tank circuit is tuned to resonance. The tables shown in Chapter Thirteen for this type of antenna should be followed closely.

A low-impedance two-wire line is excellent if the antenna is to be an integral

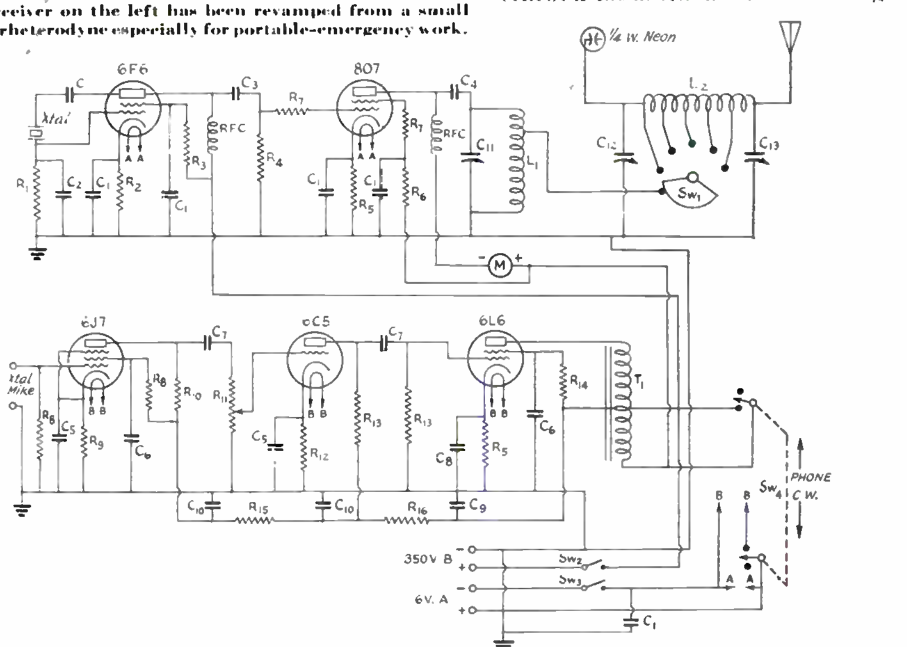


FIG. 1513 — CIRCUIT DIAGRAM OF THE 6F6-807 PHONE-C.W. TRANSMITTER

C_1 — 0.005-µfd. mica, 500-volt.
C_2 — 150-µµfd. mica, 500-volt.
C_3 — 100-µµfd. mica, 500-volt.
C_4 — 0.002-µfd. mica, 1000-volt.
C_5 — 10-µfd. electrolytic, 25-volt.
C_6 — 0.1-µfd. paper.
C_7 — 0.02-µfd. paper.
C_8 — 25-µfd. electrolytic, 25-volt.
C_9 — 8-µfd. electrolytic, 450-volt.
C_{10} — 4-µfd. electrolytic, 450-volt.
C_{11} — 200-µµfd. variable (Hammarlund MC-200-M).
C_{12} — 320-µµfd. variable (Hammarlund MC-325-M).
C_{13} — 260-µµfd. variable (Hammarlund MC-250-M).
R_1 — 50,000 ohms, ½-watt.
R_2 — 1000 ohms, 1-watt.
R_3 — 75,000 ohms, 1-watt.
R_4 — 15,000 ohms, 2-watt.
R_5 — 250 ohms, 10-watt.
R_6 — 6000 ohms, 10-watt.
R_7 — 100 ohms, 1-watt.
R_8 — 1 megohm, ½-watt.
R_9 — 1000 ohms, 1-watt.
R_{10} — 250,000 ohms, ½-watt.
R_{11} — 5-megohm potentiometer.
R_{12} — 3000 ohms, ½-watt.
R_{13} — 100,000 ohms, ½-watt.
R_{14} — 10,000 ohms, 10-watt.
R_{15} — 50,000 ohms, 1-watt.
R_{16} — 10,000 ohms, 1-watt.
Sw_1 — 6-point tap switch (Centralab F-K-121).
Sw_2, Sw_3 — S.p.s.t. switch.
Sw_4 — D.p.d.t. switch.
T_1 — Output transformer (see text) (Thordarson T-13S41).
L_1 — 1.75 and 3.5 Mc.: 42 turns No. 18 d.c.c., tapped 7th turn from plate end, close-wound on 1¾-inch diameter plug-in form.
7 and 14 Mc.: 9t. No. 16 d.c.c. occupying 1½" on 1¾" form. Ant. tap 4th from plate.
L_2 — 46 turns No. 18 d.c.c. wire, close-wound on 1¾-inch form, tapped every 9 turns for four taps, 10 turns last tap.

World Radio History

part of the portable station, since if it is too long it can be coiled-up out of the way. Rubber-covered lamp cord will make a fair feed line, the slight mis-match accounting for only a small loss of power. For the meticulous, one of the special 72-ohm lines can be used.

The familiar tuned transmission line, of either the Zepp or center-fed types, is next in preference. It is dependable in performance but somewhat more complicated to erect. The antenna coupling system should be extremely flexible with this type, with tapped coils and choice of series and parallel connections to accommodate any feeder length. The feeders should be kept short and direct.

Emergency antennas may be erected with insulation of dry hard wood, glass towel bars, porcelain ware, etc., with wire salvaged from broken communications (not power!) lines or similar sources. If it is impossible to erect resonant lengths of wire, impedance-matching systems such as that shown in Fig. 1513 can be used. Tuning can be accomplished by plate milliammeter, neon bulb, or a flashlight bulb in series with the antenna.

Probably the most straightforward prepara-

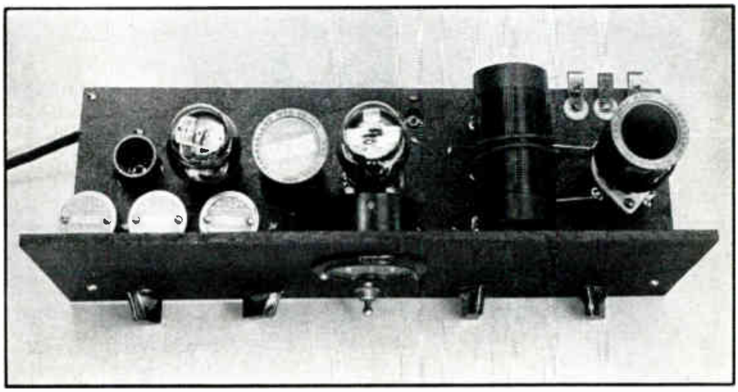


FIG. 1515 — LAYOUT VIEW OF THE OSCILLATOR-AMPLIFIER PORTABLE

Beginning with the crystal socket panel and cathode coil at left, the layout follows the circuit diagram. The Fahnestock clips at the right rear, insulated by steatite bushings, are the antenna output terminals.

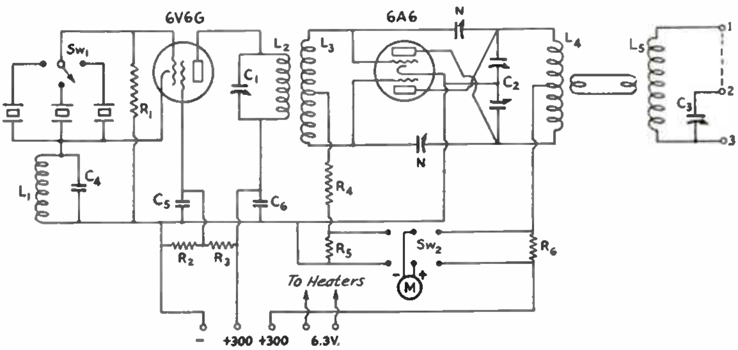


FIG. 1516 — CIRCUIT OF THE 6V6G-6A6 TRANSMITTER

C_1 — 50-μμfd. midget (Cardwell ZR-50-AS).
C_2 — 100-μμfd. (each section) split-stator midget (Cardwell EU-100-AD).
C_3 — 140-μμfd. midget (Cardwell ZU-140-AS).
C_4 — .00025-μμfd. midget mica.
C_5 — .006-μμfd. midget mica.
C_6 — .002-μμfd. midget mica.
N — 15-μμfd. midget (Cardwell ZR-15-AS).
R_1 — 100,000-ohm ½-watt carbon.
R_2 — 50,000-ohm 1-watt carbon.
R_3 — 15,000-ohm 10-watt wire-wound.
R_4 — 1500-ohms 2-watt carbon.
R_5, R_6 — 50-ohm ½-watt carbon.
SW_1 — 7-pole single-throw rotary switch (only three points used).
SW_2 — Double-pole double-throw toggle switch.
M — 0-150 ma.
L_1 — For 3.5-Mc. crystals: 14 turns No. 18 enam. on 1" diam. form to occupy L" winding length.
L_2 — 3.5 Mc.: 33 turns No. 24 d.c.c., close-wound.
7 Mc.: 20 turns No. 24 d.c.c., close-wound.
L_3 — (wound on same form as L_2):
3.5 Mc.: 60 turns No. 30 d.s.c., close-wound, ¼" from L_2.
7 Mc.: 32 turns No. 28 d.c.c., close-wound, ¼" from L_2.
L_4 — Wound on 1¾" diam. bakelite or National XR13 coil form.
3.5 Mc.: 46 turns No. 20 enam., spaced to occupy 2½" length.
7 Mc.: 28 turns No. 18 enam., spaced to occupy 2" length.
L_5 — Wound on 1½" diam. coil forms. Links are two turns each, wound loose for adjustment.
3.5 Mc.: 34 turns No. 20 enam., spaced to occupy 1¾" length.
7 Mc.: 21 turns No. 18 enam., spaced to occupy 1½" length.

World Radio History

tion for different conditions is to include several lengths of rope with the portable antenna, so that a line may be thrown into a tree or dropped out of a window. Portable masts can be built but involve rather serious constructional difficulties.

Modulators

When power is limited and conditions bad, the proportionately higher communications efficiency and greater operating territory of c.w. often make its use preferable to 'phone. Yet in some instances, notably in emergency work where instructions and general traffic must be handled rapidly and in quantity, the greater speed of voice over code makes modulated transmission desirable.

Audio systems suitable for modulating the 6C5-6L6 and 6V6G-6A6 transmitters are described elsewhere in the *Handbook*, in Chapter Twelve. The 6C5-6L6 unit can be modulated, at 300 volts, by a modulator unit giving 8 to 10 watts of audio, and a 15-watt modulator will completely modulate the 6V6G-6A6 unit running at full input. Separate power supplies for modulator and transmitter are almost essential in such assemblies when vibrators or genemotors are used.

Regulations

The F.C.C. regulations covering amateur portable and emergency work have been revised, and should be studied thoroughly by every amateur. See Appendix.

Bibliography

[1] *QST*, March, 1934, p. 28; *QST*, April, 1935, p. 48. [2] *QST*, November, 1937, p. 26. [3] *QST*, September, 1938, p. 8 [4] *QST*, August, 1938, p. 8.

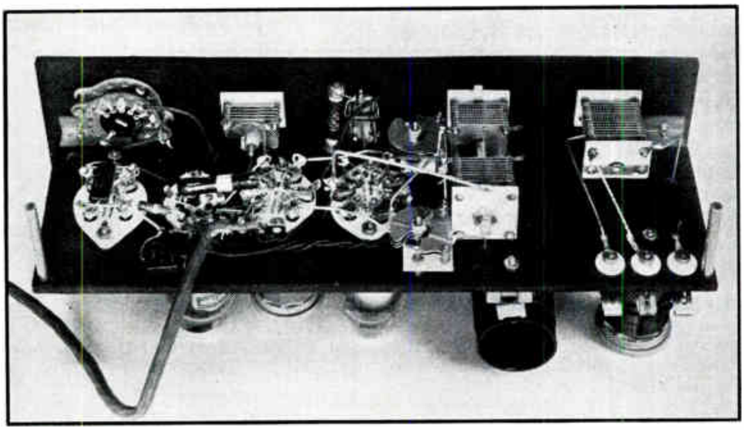


FIG. 1517 — BOTTOM VIEW OF THE 6V6G-6A6 PORTABLE

All parts are identifiable by reference to the circuit diagram. Positioning of the neutralizing condensers to allow for adjustment from the top permits permanent installation in a box of suitable size.

World Radio History

CHAPTER SIXTEEN

INSTRUMENTS AND MEASUREMENTS

The Amateur's Laboratory — Monitors — Frequency Meters — Voltmeters and Milliammeters — Ohmmeters — Oscillators — V.T. Voltmeters — Field Strength Meters — Oscilloscopes

The proper operation of all but the very simplest of transmitters and receivers calls for the use of a certain number of instruments of various types. While the amateur station can be operated successfully with nothing more than a means for checking transmitter plate input and frequency — and for proper modulation, in the case of a 'phone transmitter — the progressive amateur is interested in instruments and measurements as an aid to better performance. The measure of the perfection of an amateur station, once a satisfactory transmitter and receiver have been provided, is the extent and utility of the auxiliary measuring and checking apparatus provided.

THE AMATEUR'S LABORATORY

The following is a list of those instruments which every amateur might well strive to include in his equipment:

Absorption frequency meter.

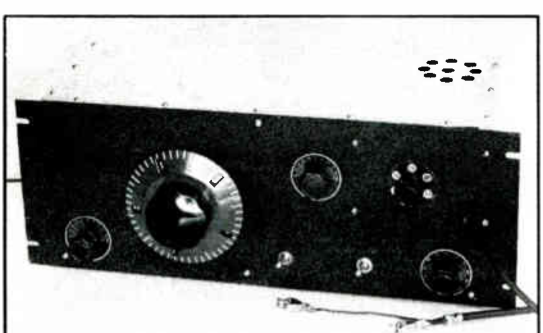


FIG. 1601 — FREQUENCY-CALIBRATED SIGNAL GENERATOR

Combining a stable frequency meter, modulating oscillator, output amplifier and attenuator, this unit fills the need for accurate frequency measurement and a variable-level test signal source.

The controls are: Lower left, inductive calibration re-set trimmer; main dial, frequency; next, modulation and power on-off switches; lower right, attenuator; top left, output tuning, and top right, output band-switching.

Heterodyne frequency meter and signal generator.
100-kc. oscillator.
Modulation meter.
Field-strength meter.
Audio oscillator.
Cathode-ray oscilloscope.
Multi-range voltmeter.
Ohmmeter.
Vacuum-tube voltmeter.
Condenser checker.

Of course, the usual assortment of milliammeters is assumed, as are neon bulbs and flashlight bulbs with pick-up coils, for transmitter adjustment. Ordinary light bulbs of various sizes with attached flexible leads should be at hand to make power output comparisons.

Representative instruments from the above list will be described in this chapter. Some of these can profitably be combined into multi-purpose instruments; the manner and extent to which this is done is left to the ingenuity of the individual amateur. It should be realized, however, that multi-purpose equipment is never as useful as its equivalent in separate instruments, and the latter are nearly always to be preferred.

If additional equipment is desired, the following instruments will also be found useful in the fully-equipped ham shack:

Beat-frequency oscillator.

Frequency-sweep circuit for oscilloscope.

A.f. power output meter.

R.f. power output meter (consisting of light bulbs of graduated sizes whose luminosity per watt input has been calibrated against a light-sensitive cell actuating a milliammeter).

Tube checker.

Test amplifier (for checking microphones, speakers, etc.).

Calibrated voltage divider (heavy-duty potentiometer or decade box calibrated in db or units, tens, etc.).

Resistance and capacity bridges.

World Radio History

Monitors for C.W.

Aside from current-indicating instruments, which must be purchased, one of the most useful instruments the station can have is a monitor, used for checking the quality of the emitted signal.

A monitor is a miniature receiver, usually having only a single tube, enclosed with its batteries in some sort of metal box which acts as a shield. It need not be a costly or elaborate affair. The circuit shown in Fig. 1602 illustrates the simplicity of a typical monitor.

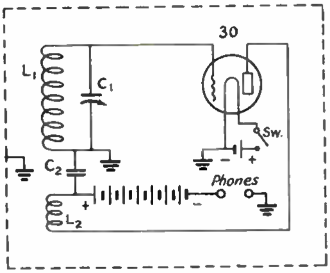


FIG. 1602 — SIMPLE MONITOR

C_1 — 50-μμfd. midget variable condenser.
C_2 — .002-μfd. midget mica condenser.
Sw — Single-pole toggle switch.
L_1, L_2 — Wound on 1½-inch 4-pin forms with No. 30 d.s.c. wire. The number of turns is given in this table:

Band	L_1	L_2
1750 kc.	70	20
3500 kc.	35	10
7000 kc.	15	6
14,000 kc.	5	4

The monitor can be built in any metal container large enough to hold it, a small-size 22½-volt "B" battery, and a flashlight cell.

The requirements for a satisfactory monitor for checking c.w. signals are not difficult to satisfy. It should oscillate steadily over the bands on which the station is to be active; the tuning should not be excessively critical, although the degree of band-spreading ordinarily considered desirable for receivers is not essential; the shielding should be complete enough to permit the monitor to be set near the transmitter and still give a good beat note when tuned to the fundamental frequency of the transmitter (this is often impossible with the receiver because the pick-up is so great); and it should be constructed solidly enough so that it can be moved around the station without the necessity for retuning when listening to a fixed signal.

A more elaborate instrument offering these qualities to a greater degree is shown in Figs. 1603–04. The dual triode provides both an oscillating detector and an audio amplifier. Plugging the receiver headphones into the jack turns the monitor on. Rugged construction affords stability, good-sized batteries give long life, and the audio stage provides a usefully strong headphone signal.

The grid leak, R_1, can be increased in value if the monitor shielding is good and the transmitter of low power. Larger values give better sensitivity, but cause blocking in strong r.f. fields.

Monitors for 'Phone

Any type of simple detector circuit with a means for picking up a small amount of r.f. from the transmitter can be used as a 'phone monitor. The pickup coil need not even be tuned, although the monitor will be considerably more sensitive when tuned.

A satisfactory type of 'phone monitor, using a Type 55 or equivalent tube as a diode detector and audio amplifier, is shown in Fig. 1605. The circuit *LC* is tuned to the transmitter frequency; any constants which satisfy this requirement can be used.

Because of the tuned pickup and audio amplification, a monitor of this type will be quite sensitive. Besides its primary use for audio quality checks, it can be used for checking hum and other carrier noises.

The 'phone monitor usually must be used with a headset, since a loud-speaker will cause audio feed-back through the microphone.

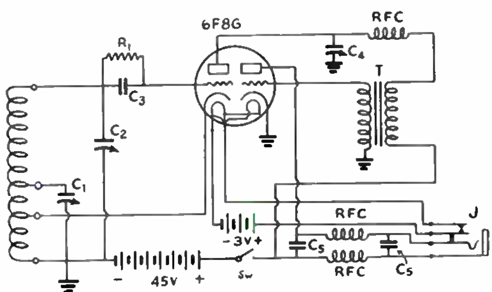


FIG. 1603 — TWO-STAGE MONITOR

C_1 — 15-μμfd. tuning condenser (Hammarlund HF15).
C_2 — 25-μμfd. padding condenser (Hammarlund APC25).
C_3 — 100-μμfd. midget mica condenser.
C_4 — 100-μμfd. regeneration condenser (Hammarlund HF100).
C_5 — 250-μμfd. midget mica condensers.
R_1 — 100-000-ohm. ½-watt fixed resistor (see text).
T_1 — Audio transformer, 3:1 ratio (Thordarson T-13A34).
RFC — 2.5-mh. r.f. chokes.
J — Two-circuit 'phone jack.
L — Coils wound for various bands on 1½-inch plug-in forms (Hammarlund SWF-4):

Band	No. Turns	Wire Size	Winding Length	Cathode Tap	Band-Spread
3.5	40	No. 24 d.s.c.	1⅛"	4	38
7	27	No. 20 e.	1⅝"	3	9
14	13	No. 18 e.	1⅛"	2	4½

World Radio History

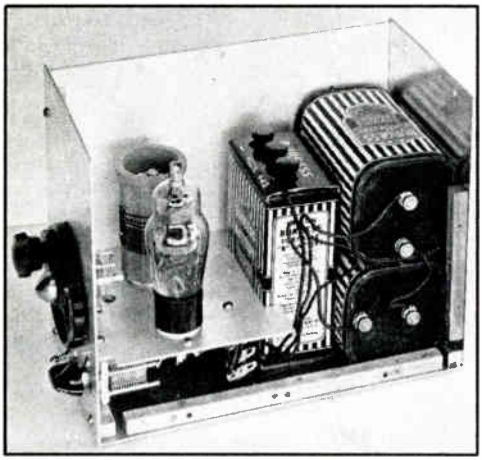


FIG. 1604 — TWO-STAGE MONITOR WITH SELF-CONTAINED BATTERY SUPPLY

CHECKING THE TRANSMITTER FREQUENCY

In the absence of more elaborate frequency-measuring equipment, the receiver may be used to give at least some idea of transmitter frequency. To do this it is necessary to calibrate the receiver dial settings in terms of frequency. A quite accurate idea of band limits can be obtained by listening to other amateur stations, noting where amateur activity stops at each end of the band.

If operation near the edges of the band is contemplated, however, present amateur regulations require more precise methods. The receiver may be checked against A.R.R.L. Standard Frequency Transmissions, schedules for which appear regularly in *QST*. If the receiver is well-made and has good inherent stability, this calibration may be relied on to within perhaps 0.1 per cent. Alternatively, the calibration may be transferred to the monitor by tuning the latter to "zero beat" — the silent space between the two beat notes — with the standard frequency signal in the receiver. Calibration should not be attempted until either the receiver or monitor has been thoroughly "warmed up," i.e., operating for at least two hours.

The transmitter frequency can be checked by listening to the oscillator alone in the receiver, with the power amplifier off. If even this signal is too strong and blocks the receiver, listen first on the monitor until the transmitted signal is heard, and then listen for the monitor on the receiver with the transmitter off. The frequency of the transmitter will, of course, be that of the monitor.

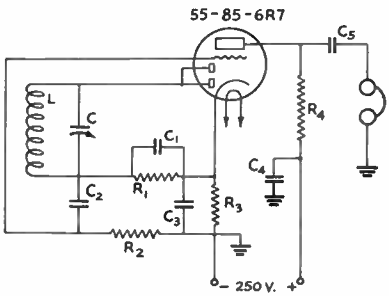


FIG. 1605 — SIMPLE 'PHONE MONITOR

C_1 — 250-μμfd. mica.
C_2 — 0.01-μfd. 200-volt.
C_3 — 0.1-μfd. 200-volt.
C_4 — 0.002-μfd. 400-volt.
C_5 — 1-μfd. 400-volt.
R_1 — .5 megohm ½-watt.
R_2 — 2-megohm ½-watt.
R_3 — 3500-ohm ½-watt.
R_4 — .1-megohm ½-watt.

Absorption Frequency Meters

The simplest type of frequency meter consists of a coil and condenser, tunable over the frequency range desired. A frequency meter of this type, when tuned to the frequency of the transmitter and loosely coupled to the tank coil, will extract a small amount of energy from the tank. The energy thus extracted can be used to light a small flash-light lamp, connected as shown in Fig. 1606. Maximum current will flow in the lamp when the frequency meter is tuned exactly to the transmitter frequency, hence the brightness of the lamp indicates resonance. A more accurate indication may be obtained by substitution of a thermo-galvanometer for the lamp. Better yet, a vacuum-tube voltmeter can be used as the indicator. Although this type of frequency meter is not well adapted to precise measurement of frequency, it is useful in a variety of ways.

Figs. 1607–09 show an absorption-type frequency meter equipped with a diode-rectifier vacuum-tube voltmeter as an indicator. The sensitivity of the indicator depends on the range of the meter. Any instrument from 0–200 microamperes to 0-5 milliamperes may be used, with 0–1 ma. the most successful for average amateur work.

Calibration of the absorption frequency meter calls for a receiver of the regenerative type to which the coil in the meter can be coupled. With the detector oscillating weakly, the frequency meter should be brought near the detector coil and tuned over its range until a setting is found which causes the detector to stop oscillating. The coupling between meter and receiver should then be loosened until the stoppage of oscillations occurs at only one spot on the meter tuning dial. The meter is then tuned to the frequency at which the receiver is

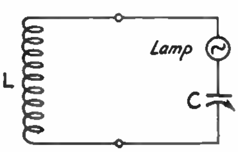


FIG. 1606 — BASIC ABSORPTION FREQUENCY METER CIRCUIT

World Radio History

set. If the receiver is set on several stations of known frequency, a number of points for a calibration curve can be obtained for each frequency-meter coil.

The absorption frequency meter is particularly useful for checking the tuning of a transmitter stage (to ensure that the stage is not tuned to a harmonic instead of the desired frequency, for instance), for determining the frequency of parasitic oscillations in the transmitter, for finding the frequency range covered by regenerative receiver coils, etc.

For transmitter work, a flash-light lamp or other indicator is not at all necessary, since resonance will be indicated by a flicker in plate current of the stage being checked as the meter is tuned through resonance.

The absorption frequency meter can also be used for comparative measurements of transmitter harmonic output under various adjustments.

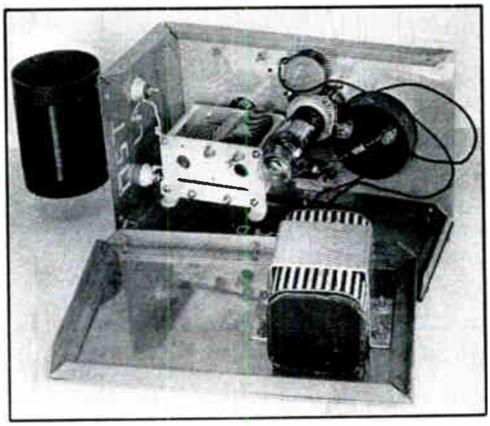


FIG. 1609 — JACK-TYPE FEED-THROUGH INSULATORS PROVIDE COIL MOUNTINGS IN THE ABSORPTION FREQUENCY METER

All parts are mounted on the panel and end wall of the 6 x 4½ x 10-inch aluminum box. The battery is renewed by removing the rear plate.

Heterodyne Frequency Meters

The heterodyne frequency meter somewhat resembles the monitor in that it is a small oscillator, completely shielded, but the refinement and care in construction is carried to a high degree so that the frequency meter can be accurately calibrated and will retain its calibration over long periods of time. The oscillator used in the frequency meter must be very stable; that is, the frequency of oscillation at a given dial setting must be practically the same under any conditions. No plug-in coils are used in the frequency-meter; one solidly built and firmly mounted coil is permanently installed in it, and the oscillator covers one band only. A low-frequency band is used for this purpose, and when the meter is to be used on the higher-frequency bands its harmonics instead of the fundamental oscillation are used.

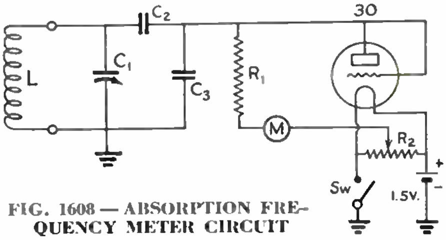


FIG. 1608 — ABSORPTION FREQUENCY METER CIRCUIT

C_1 — 500-μμfd. variable (National EMC-500).
C_2, C_3 — 50-μμfd. midget mica.
R_1 — 40,000-ohm, ½-watt.
R_2 — 100-ohm potentiometer (Centralab WW).
L — Plug-in inductances, wound (except L_1 and L_6) on 1¾-inch National XR-13 forms. L_1 on 3-inch bakelite form. Winding length app. 2¾ inches.

Coils	Approx. Range	No. Turns	Wire Size
L_1	170–500 kc.	180	No. 28 e.
L_2	500–1500 kc.	100	No. 24 d.c.c.
L_3	1.5–4.5 Mc.	33	No. 14 tinned
L_4	3–9 Mc.	15	No. 14 "
L_5	8–25 Mc.	6	No. 14 "
L_6	20–60 Mc.	½	¼" c.t.

1.5-volt dry cell (Burgess 4FA).

The frequency meter must possess a dial which can be read precisely to fractions of divisions. To obtain accuracy it is necessary to read the scale to at least one part in 500; ordinary dials such as are used for receivers are not capable of such precision. The National 4" Type N and 6" Type N and NW dials are provided with vernier scales for reading to a tenth of a scale division (one part in 1000) and are well suited to this work, as is also the type PW. The General Radio 704 and 706 series dials also are excel-

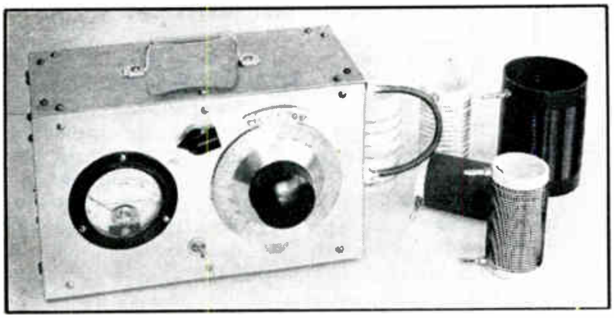


FIG. 1607 — ABSORPTION FREQUENCY METER WITH VACUUM-TUBE VOLTMETER RESONANCE INDICATOR

Plug-in coils cover the range of approximately 170 kc. to 60 Mc. A dial reading to 1 part in 1000 affords over-all calibration precision of about 0.25 per cent.

World Radio History

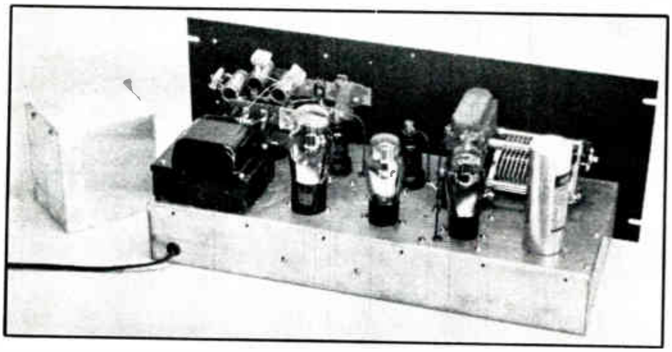


FIG. 1610 — DOUBLE SHIELDING REDUCES STRAY RADIATION IN THE FREQUENCY-CALIBRATED SIGNAL GENERATOR

The square shield shown on the end normally covers the Browning output tuning assembly. A bottom plate and dust cover complete the shielding.

lent. There are a few other good dials on the market. Care should be used to select one which has fine lines for division marks, and which has an indicator very close to the dial scale so that the readings will not be different when the dial is viewed from different angles.

The heterodyne frequency meter also can be used as a monitor if desired.

One of the most stable oscillator circuits, and therefore most suitable for the frequency meter, is the electron-coupled circuit. The oscillation frequency is practically independent of moderate variations in supply voltages, provided the plate and screen voltages applied to the screen-grid tube used are properly proportioned. Furthermore, because of the nature of the circuit it is possible to take output from the plate with but negligible effect on the frequency of the oscillator. A third feature is that strong harmonics are generated in its plate circuit so that the meter is useful over an extremely wide range of frequencies.

Mechanical considerations are most important in the construction of a frequency meter. No matter how good the instrument may be electrically, its accuracy cannot be depended upon if it is flimsily built. Mount everything solidly; make connections with stiff wire and place all leads so they cannot be moved in the course of ordinary handling.

Frequency-Calibrated Signal Generator

An instrument designed to meet several needs around the amateur station including that of accurate frequency measurement is pictured and diagrammed in Figs. 1601 and 1610–12.

The unit comprises an electron-coupled type of frequency meter, harmonic amplifier and attenuator, modulating audio oscillator, and power supply.

The 6J7 has its grid circuit tuned over the range 870 to 1030 kc., the harmonics covering all existing and prospective amateur bands. Especial care has been taken to build an oscillator of high inherent stability for permanence of calibration and high re-set accuracy.

Since the greatest source of frequency drift in a tuned circuit is the inductance, care should be taken to isolate the coil from thermal variations. Its location is therefore as remote as possible from heat sources. The coil is wound on a 3-inch length of ⅞-inch hard wood dowel (preferably of mahogany), thoroughly dried and heavily doped. The coil form is mounted in a National PB-10 coil shield with spade lugs. Around the shield a heat-insulating box is constructed from ⅜-inch thick pieces of balsa wood (obtainable from any model-builders' supply house), assembled with cellulose nitrate cement.

The calibration re-set control is of the inductive type, since variations will be largely from this source. It consists of a shorted 3-turn loop of heavy wire about 1 inch in diameter, rotated over a 90° angle at the ground end of the coil. With the loop closely coupled to the coil an appreciable change in inductance occurs, while at right angles the coil maintains approximately its true inductance. The loop is soldered to the end of a ½-inch shaft in a panel bearing mounted on the coil shield. This shaft also goes through another bearing on the panel, giving additional rigidity.

Further stabilization of the oscillator frequency is provided by (1) the Colpitts electron-coupled oscillator circuit, (2) the heavily-built tuning condenser with double-spaced plates, (3) the use of low-drift impregnated silver-plated padding condensers, and (4) voltage stabilization of the d.c. plate-and-screen supply by the VR-105 regulator tube.

The output of the oscillator is impedance-resistance coupled to a 6K7 harmonic amplifier. A manufactured band-switching assembly in the plate circuit of this amplifier provides tuned output relatively free from harmonics throughout the five low-frequency amateur bands. Since the tuner is supplied equipped for grid-circuit use, it must be revamped by removing the grid condenser and leak, etc. Taps on the output coils provide low-impedance signal output through a shielded coupling lead. Applying negative bias to the 6K7's suppressor grid enables effective attenuation of the output signal. This provides the equivalent of a reliable test oscillator for general receiver alignment work, etc. The power supply output of approximately 350 volts d.c. is divided in half to provide this bias, about 175 volts remaining for plate voltage.

Since a modulated signal is useful for much receiver test work, a sine-wave audio oscillator which suppressor-grid modulates the oscillator to about 30 per cent at roughly 400 cycles is included. For precise calibration work, the oscillator should be calibrated and used with the modulator switch off.

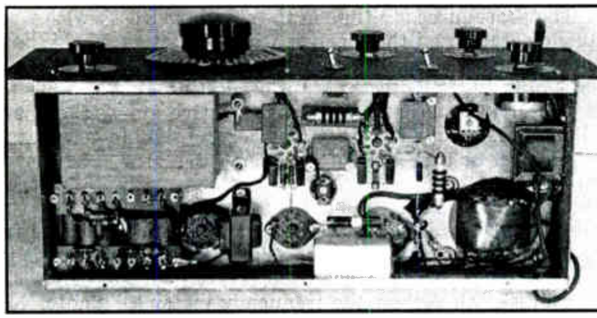


FIG. 1612 — THE BALSA-WOOD HEAT-INSULATING BOX FOR THE FREQUENCY-METER OSCILLATOR INDUCTANCE IS SEEN AT THE UPPER LEFT

The wood surrounds an aluminum coil shield. Just below is the audio oscillator group, with condensers and resistors strung between insulated terminal strips for wiring convenience.

Calibrating the Frequency Meter

When the frequency meter is finished it must be calibrated before it can be put into service. First its tuning range should be checked to be certain that it covers the band with a little overlap at each end. This can be done by checking against a receiver covering 1750–2050 or 3500–4000 kc.

After the coverage has been checked, the current issue of *QST* should be consulted for information as to the next transmission by A.R.R.L. Standard Frequency Stations for calibration purposes.

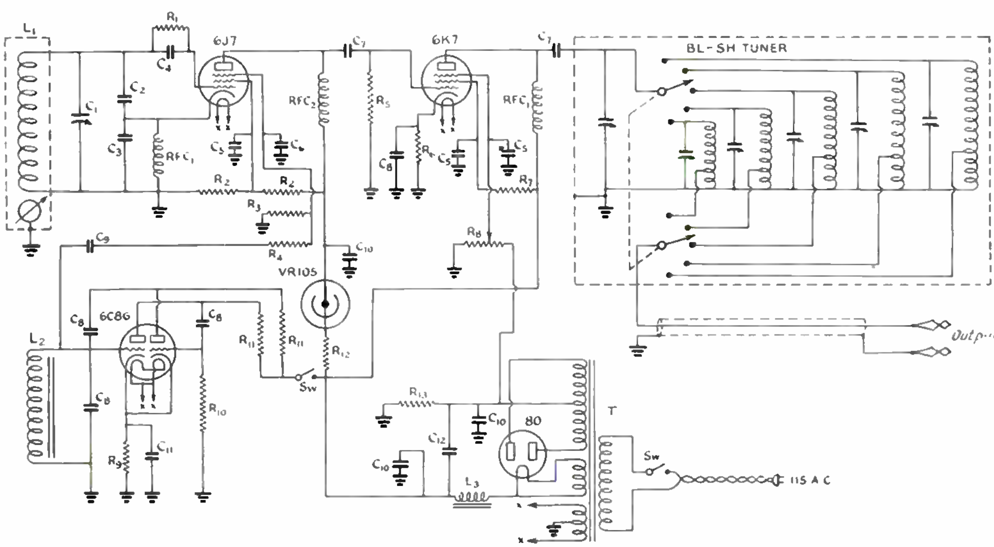


FIG. 1611 — CIRCUIT OF THE FREQUENCY-CALIBRATED SIGNAL GENERATOR

C_1 — 125-μμfd. variable (National PW-1, double-spaced).
C_2 — 350-μμfd. low-drift condenser (Sickles Silver-Cap).
C_3 — 1100-μμfd. low-drift condenser (Sickles Silver-Cap).
C_4 — 100-μμfd. fixed mica (Aerovox 1455).
C_5 — 0.005-μfd. midget fixed micas.
C_6 — 0.001-μfd. midget fixed mica.
C_7 — 0.002-μfd. fixed micas (Cornell-Dubilier 4-602).
C_8 — 0.1-μfd. 400-volt tubular paper.
C_9 — 0.25-μfd. 200-volt tubular.
C_{10} — 8-μfd. 450-volt electrolytic.
C_{12} — 16-μfd. 450-volt electrolytic.
R_1 — 50,000-ohm, 1-watt (IRC metallized).
R_2 — 10,000-ohm, ½-watt.
R_3 — 5000-ohm, ½-watt.
R_4 — 7500-ohm, ½-watt.
R_5 — 1-megohm, ½-watt.
R_6 — 500-ohm, ½-watt.
R_7 — 50,000-ohm, ½-watt.
R_8 — 100,000-ohm, 2-watt, wire-wound pot.
R_9 — 800-ohm, ½-watt.
R_{10} — 0.5-megohm, ½-watt.
R_{11} — 50,000-ohm, ½-watt.
R_{12} — 6000-ohm, 10-watt.
R_{13} — 30,000-ohm, 10-watt.
L_1 — 95 turns No. 28 d.s.c., close-wound on ⅞-inch hardwood dowel (see text).
L_2 — 0.75-henry iron-core reactor (Thordarson T-81C15).
L_3 — 10-henry filter choke (Thordarson T-13C27).
RFC_1 — 2.5-mh. r.f. chokes.
RFC_2 — 10-mh. universal-wound RF choke (Sickles SC-102).
T — 700-volt c.t. power transformer, with 6.3-volt 1-amp. fil. (Thordarson T-70R21).

The procedure is to tune in the standard frequency station on the receiver with the detector oscillating, then back off the regeneration control until the detector stops oscillating but is still giving a great deal of regenerative amplification. With a superhet receiver the signal would first be tuned in with the beat oscillator on; after setting the receiver to zero beat with the incoming signal the beat oscillator should be shut off. The dial on the frequency meter should then be turned until the signal from the meter is heard to beat with the standard frequency signal. Adjust the frequency meter to give zero beat and note the dial reading. A number of these points will give a complete calibration and make possible the drawing of a curve on graph paper.

Caution must be employed when using a heterodyne frequency meter in conjunction with a superheterodyne receiver, since signals may be heard on at least two spots on the receiver dial; one is where the meter-frequency equals the receiver frequency, the other where the meter-frequency equals that of the h.f. oscillator in the receiver. Sometimes an image frequency is also received. To check, detune the receiver slightly from zero beat (with the b.f.o. turned off). If the meter is not on the signal frequency a varying audio note will be heard; if it is correctly located, tuning the receiver slightly will cause no change in the beat note.

100-Kc. Oscillator

Another accurate method of frequency calibration, especially useful when the calibration is applied directly to the receiver and must be checked frequently, is that employing a 100-

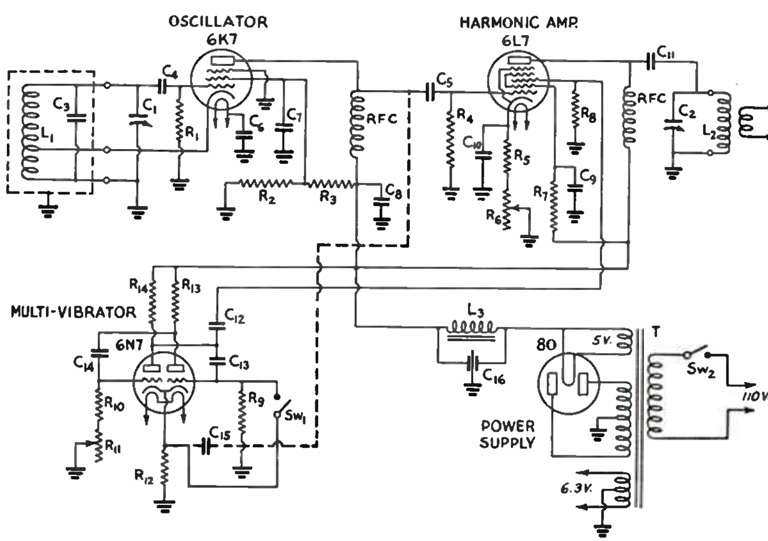


FIG. 1613 — CIRCUIT DIAGRAM OF THE 100-KC. OSCILLATOR, HARMONIC AMPLIFIER AND MULTI-VIBRATOR COMBINATION

C_1 — 100-$\mu\mu$fd. variable (National ST-100).
C_2 — 140-$\mu\mu$fd. variable (Hammarlund HF-140).
C_3 — 0.0011-μfd. fixed mica, low-drift (Sickles Silver-Cap).
C_4, C_5 — 250-$\mu\mu$fd. mica.
C_6, C_7, C_8, C_9 — 0.1-μfd. paper, 400-volt.
C_{10} — 0.01-μfd. paper, 400-volt.
C_{11}, C_{12}, C_{13}, C_{14} — 0.002-μfd. mica.
C_{15} — 10- to 25-$\mu\mu$fd. mica, if used.
C_{16} — Dual 8-μfd. electrolytic, 450-volt.
R_1 — 250,000 ohms, 1-watt.
R_2 — 50,000 ohms, 1-watt.
R_3 — 25,000 ohms, 1-watt.
R_4 — 100,000 ohms, 1-watt (I.R.C. F-1).
R_5 — 500 ohms, ½-watt.
R_6 — 25,000-ohm volume control.
R_7 — 15,000 ohms, 1-watt.
R_8 — 50,000 ohms, ½-watt.
R_9 — 30,000 ohms, ½-watt.
R_{10} — 20,000 ohms, ½-watt.
R_{11} — 15,000-ohm volume control.
R_{12} — 300 ohms, ½-watt.
R_{13}, R_{14} — 2500 ohms, 1-watt.
RFC — 2.5-mh. r.f. choke (National R-100).
Sw_1, Sw_2 — S.p.s.t. toggle switch.
T — Power-transformer, 250 v. d.c. at 40 ma. with 6.3- and 5-volt windings (Thordarson T13R11).
L_3 — 7-henry, 40-ma. choke (Thordarson T13C26).
L_1 — 100 kc. — National R-100 choke with cathode tap connected between 1st and 2nd pies from ground.
1000 kc. — 130 turns No. 30 enameled, tapped 30th turn from ground; on 1½-inch form.
L_2 — 550–1200 kc. — 130 turns No. 30 enameled.
1200–3300 kc. — 70 turns No. 22 enameled.
7500–3300 kc. — 22 turns No. 22 enameled, length 1 inch.
15–6.8 Mc. — 11 turns No. 22 enameled, length 1 inch.
32–13.5 Mc. — 5 turns No. 22 enameled, length 1 inch.
56 Mc. — 2 or 3 spaced turns on 1-inch form, or air wound.
All except 56-Mc. coil wound on 1½-inch forms (Hammarlund).
Output links may be adjusted to give desired signal strength in receiver.

World Radio History

kc. oscillator. Such an oscillator can be made very simply and inexpensively. To check the frequency of an oscillator operating at 100 kc. it is not necessary to set up elaborate calibrating apparatus nor is it necessary to use a crystal, for the frequency of the oscillator may be set by beating one of its harmonics against one of the many broadcast signals of stations operating at exact multiples of 100 kc. These signals, which are accurate to better than 50 cycles (usually within 10), are commonly available at all but a few of the twenty-four hours at most points in this country and Canada. The b.c. signal need be only strong enough to make identification possible. Once set, the oscillator provides accurately calibrated signals every 100 kc. from 100 kc. upwards in frequency.

The most dependable direct frequency check can be obtained from the mid-day standard-frequency transmissions of WWV. Detailed schedules are published in *QST*. In addition, this station is generally audible on 5000 kc. from 4 P.M. to 2 A.M. E.S.T. Mondays through Fridays, with modulation at 440 cycles interspersed with voice announcements.

Such an oscillator is shown as the upper-left-hand section of Fig. 1613. It can be built separately or in conjunction with the other units shown.

First considering the oscillator alone, initial calibration is quite simple provided only that at least two b.c. stations operating on multiples of 100 kc. may be heard. In most cases it will not be necessary to connect the oscillator to the b.c. receiver. The procedure of setting the oscillator to 100 kc. is as follows: First, tune in a b.c. signal at a multiple of 100 kc. such as 700, 800, 900, or 1000 kc., etc. Be sure of the identity of the station, since a difference of one channel (10 kc.) will mean an error of about 250 kc. at 14 Mc. Reduce the beat to zero, being very careful of the adjustment. For greatest accuracy, listen for the slow beats on modulation. Now tune the receiver to a second signal at a multiple of 100 kc. If the oscillator is operating at 100 kc., it should zero beat with all signals at exact multiples of 100 kc. If the oscillator is not operating at 100 kc. it may be adjusted to zero beat with the first signal but at the same setting will not zero-beat with other signals at 100-kc. multiples. In this case, capacity or inductance must be adjusted. As a matter of fact, if any beat note at all is obtained, it will probably be the correct one since the nearest other frequencies which would produce a beat with a signal at say 700 kc. would be 116.6 or 87.5 kc. which would require an appreciable departure in capacity or inductance from the correct values.

After the oscillator has become thoroughly warmed up, it should hold its calibration over periods of several hours. Continuous operation is not necessary, however, because it is a simple matter to check against a b.c. signal whenever a high-frequency check is desired.

FIG. 1614 — THIS UNIT WILL GENERATE SIGNALS FOR FREQUENCY CHECKING AT INTERVALS OF 10 KC. AT ANY POINT IN THE HIGH-FREQUENCY SPECTRUM

With continuous checking against a standard-frequency signal, the accuracy is limited only by the accuracy of the standard and the precision with which the oscillator can be adjusted to zero beat with it.

The usefulness of such an oscillator is limited by the fact that it affords calibration points only at 100-kc. intervals. By the addition of a locked-in 10-kc. multivibrator type of oscillator, coverage almost to within beat-note range can be achieved.

This multivibrator occupies the lower left corner of Fig. 1613. At the upper right is a 6L7 harmonic amplifier driven by the 100-kc. oscillator. The multivibrator output is fed to the injection grid of the 6L7 and thereby modulates the 100-kc. carrier at 10-kc. intervals by its own fundamental and harmonics.

Initial adjustments are made with SW_1 closed, cutting out the multivibrator. The 100-kc. oscillator is set as described above. The proper coil — L_2 — for the band in use is plugged in, and C_2 is adjusted for maximum strength in the receiver. If overloading results, the gain control, R_6, is backed off or the link coupling to the receiver input reduced. Pick up several 100-kc. points on the receiver dial and note their location.

World Radio History

Then open SW_1. A whole series of signals should appear across the receiver dial, those originally noted at the 100-kc. settings being the loudest. Tune from one of these settings to the other, counting the number of beats in between. If the number is other than nine (denoting 10-kc. intervals), adjust the frequency control, R_{11}, until the right number occurs.

If sufficient care has been used in calibration, frequencies at 10-kc. intervals throughout the radio spectrum will be available with an accuracy from day-to-day of perhaps 0.03 per cent (about 5 kc. at 14 Mc.). For good accuracy the instrument should be thoroughly warmed up and all controls should be set for the desired conditions and left unchanged (including multivibrator and amplifier controls). Immediately after calibrating, an accuracy of perhaps 0.01 per cent or better can be expected if sufficient care is used.

As an alternative to the 100-kc. e.c. oscillator shown, a 100-kc. crystal oscillator could readily be used. With temperature control or a low-drift crystal such as the Bliley SOC-100 unit, a highly satisfactory secondary frequency standard can be constructed.

Beyond their customary uses — calibrating receivers and other instruments, checking transmitter frequency, etc. — such instruments as the 100-kc. oscillator-multivibrator and the frequency-calibrated signal generator can also be used as direct transmitter frequency controls. It is usually necessary merely to run a coupling link to the grid circuit of the crystal oscillator stage in the transmitter, replacing the crystal. A stable, dependable e.c.o. results.

U. H. F. Frequency Checking — Lecher Wires

The methods described for checking transmitter frequency on the lower frequency bands are often unsuited for use on the ultra-high frequencies. The methods that are simplest and most satisfactory in this region are based on direct measurement of the physical characteristics of resonant linear circuits.

The simplest method is to cut the antenna wire to 95 per cent of the actual wavelength desired, then tuning the transmitter until the antenna is operating most effectively. This is, of course, extremely approximate and would serve only as a preliminary measure.

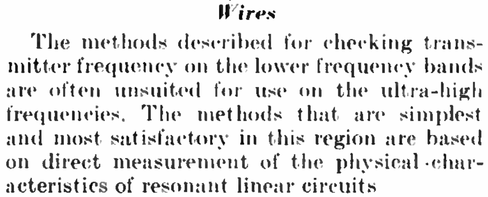


FIG. 1615 — LECHER WIRE SYSTEM

The next simplest scheme is to compare the frequency of one's own transmitter by tuning it on the receiver and comparing the setting with other stations of known wavelength. This is readily possible in districts where plenty of signals are available for the purpose, but at present would be impractical on the 2½- or 1¼-meter bands. On the latter bands, or even on 5 meters, the problem is readily solved if a linear type oscillator is used. With this type of oscillator (described in Chapter Twelve) the wavelength can be measured directly from the rods which constitute the tuning circuit.

For the very short waves, probably the most practical method involves the use of two parallel wires — known as Lecher wires — on which standing waves may be measured directly. Such a Lecher system may be set up readily and forms a valuable addition to the ultra-high frequency worker's equipment.

A typical Lecher system (Fig. 1615) consists of two No. 18 bare copper wires spaced about three inches and mounted on stand-off insulators on a length of board. The wires should be several wavelengths long. The wires are left free at one end while at the other they are connected to a one- or two-turn coupling coil of about the diameter of the tank coil of the transmitter. This coupling coil is placed near the transmitter coil. In operation, a sliding bridge — consisting of a piece of stiff bare wire on the end of a two-foot wooden dowel — is run slowly down the length of the wires until a point is reached where the oscillator plate current makes a sudden fluctuation. The point is marked. The bridge is then moved farther down the wires until a second node is located. This also is marked. The same procedure is then followed to locate a third node. At this stage, the distance between each pair of marks is measured. If the Lecher system is operating correctly and if it is mounted well clear of surrounding objects, the distances will all be the same and will represent quite accurately one half of the wavelength being measured. An alternative sliding bridge — useful when the oscillator has plenty of output — is a flash-lamp bulb with wires soldered to its contacts. These wires are hooked over the wires of the Lecher system and the lamp moved along until the various points are located at which the lamp lights brightest. The points will be extremely critical.

The same general procedure may be used to calibrate a receiver — the indication in this case being obtained by the receiver going out of oscillation as the bridge passes over the various nodes.

Once the approximate calibration has been obtained in this way, it can be checked by

World Radio History

comparing harmonics produced by oscillators on harmonically-related lower frequency bands.

The oscillator-multivibrator combination can be used for u.h.f. checking by using 1000-kc. and 10-Mc. coils in the oscillator. For accurate work, the receiver should first be set accurately on 10,000 kc. with the 100-kc. coil in the oscillator. The 10,000-kc. coil is then inserted in the oscillator and it is retuned to zero beat. The oscillator frequencies will then be spaced at 10-Mc. intervals, making it easy to count from 30 Mc. or any other reference frequency. With 50, 60 and 70 Mc. identified, the 1000-kc. coil can be plugged into the oscillator, whereupon 1-Mc. intervals are available. If necessary, even the 100-kc. and 10-kc. points can be found, with the same percentage of accuracy as on the lower frequencies.

D.C. INSTRUMENTS

Throughout this *Handbook* reference has been made to the use of direct-current instruments for measurement of current and voltage. Voltmeters and milliammeters are basically identical instruments, the difference being in the method of connection. A voltmeter measures the current through a high resistance connected across the source to be measured; its calibration is in terms of voltage drop in the resistance, or *multiplier*. A milliammeter is connected in series with the circuit and measures the current flow. The ranges of both voltmeters and milliammeters can be extended by the use of external resistors, connected in series with the instrument in the case of a voltmeter, or in shunt in the case of a milliammeter. A low-range milliammeter also can be used as a voltmeter by connecting a resistor of suitable value in series.

The ways in which multipliers and shunts are connected to voltmeters and milliammeters are shown in Fig. 1616. To calculate the value of multiplier or shunt it is necessary to know the resistance of the meter; this information can be obtained from the maker. If it is desired to extend the range of a voltmeter, the value of resistance which must be added in series is given by the formula:

$$R = R_m\,(n-1)$$

where R is the multiplier resistance, R_m the resistance of the voltmeter, and n the scale multiplication factor. For example, if the range of a 10-volt meter is to be extended to 1000 volts, n is equal to 1000/10, or 100.

If a milliammeter is to be used as a voltmeter, the value of series resistance can be found by Ohm's law, or

$$R = \frac{1000\,E}{I}$$

where E is the desired full scale voltage and I the full-scale current reading of the instrument in milliamperes.

To increase the current range of a milliammeter, the resistance of the shunt, Fig. 1616-B, can be found from the formula:

$$R = \frac{R_m}{n-1}$$

where the letters have the same significance as before.

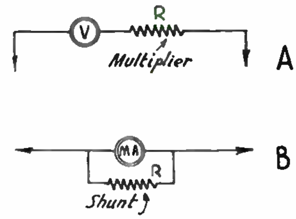


FIG. 1616 — HOW VOLTMETER MULTIPLIERS (A) AND MILLIAMMETER SHUNTS (B) ARE CONNECTED

Multi-Range Voltmeters and Ohmmeters

A combination voltmeter-milliammeter having various ranges is extremely useful for experimental purposes and for trouble-shooting in receivers and transmitters. As a voltmeter such an instrument should have high resistance so that very little current will be drawn in making voltage measurements. A voltmeter taking considerable current will give inaccurate readings when connected across a high-resistance source, as is often the case in checking voltages at various parts of a receiver circuit. For such purposes a 1000-ohms-per-volt instrument is customarily used; a 0–1 milliammeter or 0–500 microammeter (0–0.5 ma.) is the basis of most multi-range meters of this type. Microammeters having a range of 0–50 μa., giving a sensitivity of 20,000 ohms-per-volt, are also used.

The various current ranges on a multi-range instrument can be obtained by using a number of shunts individually switched in parallel with the meter. Great care should be taken to minimize contact resistance.

It is often necessary to check the value of a resistor or to find the value of an unknown resistance, particularly in receiver servicing. For this purpose an "ohmmeter" is used. An ohmmeter is simply a low-current d.c. voltmeter provided with a source of voltage (usually dry cells), connected in series with the unknown resistance. If a full-scale deflection of the meter is obtained with the connections to the external resistance shorted, insertion of the resistance under measurement will cause the reading to decrease in proportion to the amount of resistance inserted. The scale can therefore be calibrated in ohms. If a voltmeter not calibrated

World Radio History

directly in resistance values is used, the following formula can be applied:

$$R = \frac{eR_m}{E} - R_m$$

where R is the resistance under measurement,
E is the voltage read on the meter,
e is the series voltage applied, and
R_m is the internal resistance of the meter (full-scale reading in volts $\times$ ohms-per-volt).

A combination ohmmeter, multi-range d.c. milliammeter, and multi-range a.c. and d.c. voltmeter is shown in Fig. 1617. As an ohmmeter it consists of a 0–1 ma. d.c. instrument, a 9-volt battery, and associated fixed and variable resistors to enable precise zero adjustment There are two measurement ranges, 0–10,000 and 0–100,000 ohms.

As a voltmeter, as many ranges as may be desired can be provided by suitably tapping the series resistors selected by the rotary switch. Seven a.c. and eight d.c. ranges are shown. These ranges are, of course, linear with and exactly proportional to the d.c. and a.c. scales, the latter being secured either on the meter or through a separate calibration chart of the a.c. rectifier.

As a multi-range d.c. milliammeter four ranges are diagrammed, 0–1, 0–10, 0–100, and 0–1000 ma. Additional ranges could be provided if desired. Heavy a.c. toggle switches are recommended, to reduce inaccuracies due to contact resistance.

The use of a multi-purpose meter of this type necessitates precautionary examination before each measurement to make sure that the respective controls are properly adjusted; otherwise, the instrument will quite likely be seriously damaged. When measuring unknown voltages or currents it is an excellent idea to begin with the highest range, thus identifying the proper range for most accurate measurement. As an ohmmeter, the instrument should never be connected across a circuit in which current is flowing; that is, the receiver power should be turned off when resistance measurements are maed.

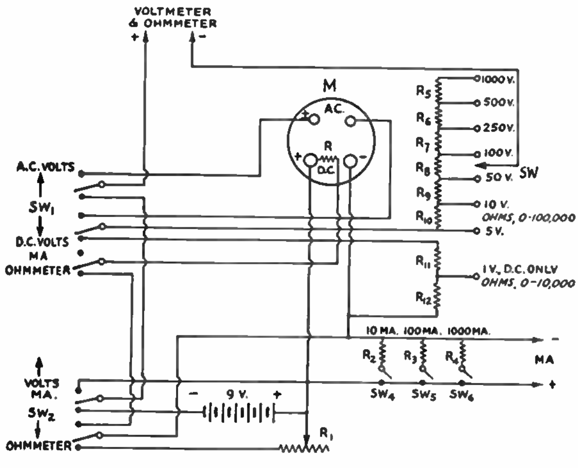


FIG. 1617 — COMBINATION MULTI-RANGE OHMMETER, MILLIAMMETER AND A.C.-D.C. VOLTMETER

R — Shunt to compensate for resistance of rectifier (integral with meter when self-contained rectifier is employed).
R_1 — 650-ohm rheostat.
R_2 — 5-ohm precision fixed resistor (10-ma. shunt) if 50 mv. meter, comparable value for other meters.
R_3 — 0.5-ohm precision fixed resistor (100-ma. shunt).
R_4 — 0.05-ohm precision fixed resistor (1000-ma. shunt).
R_5 — 500,000-ohm precision fixed resistor.
R_6 — 250,000-ohm precision fixed resistor.
R_7 — 150,000-ohm precision fixed resistor.
R_8 — 50,000-ohm precision fixed resistor.
R_9 — 40,000-ohm precision fixed resistor.
R_{10} — 5,000-ohm precision fixed resistor.
R_{11} — 4,000-ohm precision fixed resistor.
R_{12} — 950-ohm precision fixed resistor.
SW_1 — Triple-pole double-throw jack switch.
SW_2 — Double-pole double-throw jack switch.
SW — 8-point rotary switch.
SW_4, SW_5, SW_6 — Single-pole single-throw toggle switches (see text).
M — 0-1 milliampere (Weston Model 301 Universal meter).

VACUUM-TUBE VOLTMETERS

In the measurement of audio-frequency and radio-frequency voltages, where the use of a power-consuming measuring device is unsatisfactory because of the small power in the circuit, the vacuum-tube voltmeter finds wide application. Most vacuum-tube voltmeters used by amateurs measure peak voltages. The voltmeter tube, which may be a triode or screen-grid type, is biased nearly to plate-current cut-off, a current of a fraction of a milliampere being taken as a reference, called the "false zero." When a voltage is applied between grid and cathode the plate current will rise; the grid bias voltage is then increased until the plate current returns to the false zero. The additional bias voltage required to bring the plate current back to the reference value will be equal to the peak value of the signal being measured. Because the measurements of the peak voltmeter are substantially independent of wave-form, this type of voltmeter is useful in audio and radio-frequency measurements since the capacities of vacuum tubes are determined by the peak voltages and currents which must be handled. A simple but entirely practical voltmeter

World Radio History

of this type is shown in Fig. 1618. It is known as the "slide-back" type. In operation, R_1 is turned all the way to the right, with zero reading on the voltmeter V. R_2 is then adjusted until the desired "false zero" point is read on the milliammeter M. The voltage to be measured is then applied, causing the milliammeter reading to increase. R_1 is then adjusted until false zero again is read on M, whereupon the voltmeter will read the voltage being measured. If the voltage to be measured is greater than 9 volts, additional bias can be placed at the point marked X, the exact value being read by an auxiliary voltmeter.

Field-Strength Meters

An item in the equipment of the advanced radio amateur that is increasing in importance and general use is the field-strength meter. Its uses are numerous, the more important being the ability it lends to correctly adjust antenna and transmitter characteristics under actual *radiating* conditions. This facility is of particularly great importance on the ultra-high frequencies, where an effective field-strength meter represents about the only reliable method of adjustment, especially on low-power equipment or with directive antennas.

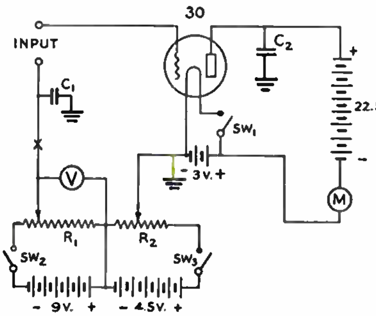


FIG. 1618 — SIMPLE PEAK-TYPE VACUUM-TUBE VOLTMETER

C_1 — 500-μμfd. mica fixed condenser.
C_2 — 0.01-μfd. mica fixed condenser.
R_1 — 2,000-ohm wire-wound potentiometer.
R_2 — 1,000-ohm wire-wound potentiometer.
$SW_{1,2,3}$ — Battery on-off switches; may be ganged.
M — 0–1 milliammeter (any low-range milliammeter or microammeter may be used).
V — 0–10 voltmeter, 1000 ohms per volt.

A simple field strength meter particularly suitable for work in the ultra-high frequency region is shown in Figs. 1619–20. Essentially, the meter consists simply of an acorn triode operated with very low plate voltage and biased to cut-off, constituting a linear detector. When the signal under observation is tuned in, rectification occurs, and the plate current increment is read on the microammeter. Among

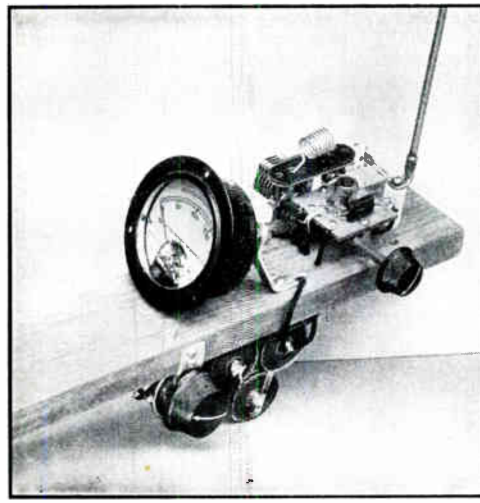


FIG. 1619 — SIMPLE FIELD-STRENGTH METER USING ACORN TUBE

The board-type construction facilitates construction and provides a convenient handle, minimizing body-capacity effects when making observations.

the uses to which this meter can be put are: (1) Measuring comparative transmitter outputs under different adjustments. (2) Neutralizing amplifiers (using only a pick-up coil, without the antenna). (3) Measuring comparative antenna radiation under different adjustments. (4) Deriving field-strength patterns of, and adjusting, u.h.f. beam antennas.

A more sensitive field-strength meter of use in examining the field strength patterns of lower-frequency antenna systems is shown in Figs. 1621–22. It consists of a diode rectifier and d.c. amplifier in the same envelope. The initial plate current reading is in the neighborhood of 1.4 milliamperes; with signal input, the current dips downward. The scale reading is linear with signal voltage, a characteristic that is advantageous in making certain types of comparative measurements. Radiated power variations will, of course, be as the square of the field voltage indication. With a 1.5-milliampere meter, field strengths of fractional millivolts register on the meter, if a copper-rod antenna two or three feet long is used.

Modulation Meter

The federal regulations require the use of some form of overmodulation indicator in the amateur 'phone transmitter. This bare legal minimum can be complied with quite easily, as discussed in Chapter Ten. To be assured of correct adjustment without possibility of error, however, some sort of direct-reading percentage-modulation meter and carrier-shift indicator should be employed. A cathode-ray

World Radio History

oscilloscope will serve, but in its absence a variation of the type of modulation monitor used at broadcast stations can be built.

The circuit of such a modulation meter is shown in Fig. 1623. It consists of a pick-up circuit, a diode rectifier, a "carrier" meter and a "modulation" meter.

The carrier meter has two functions. First, it is used to indicate the reference carrier level at which the monitor is to operate; and second, it shows carrier shift during modulation which is an indication of inequalities in the positive and negative peaks. This meter, as shown in the diagram, is connected in the cathode of the 56 tube. This tube is a linear diode rectifier and gives an instantaneous output voltage proportional to the carrier envelope. This output voltage is fed through a low-pass filter to an audio output transformer. The modulation indicator meter is across the output winding of this transformer. This meter reads the average of both sides of the full-wave peaks. Since the modulation meter reads in db instead of percentage of modulation, a conversion table follows:

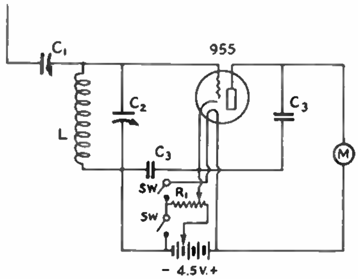


FIG. 1620 — CIRCUIT OF THE SIMPLE FIELD-STRENGTH METER

C_1 — 30-μμfd. adjustable mica trimmer condenser.
C_2 — 35-μμfd. midget air trimmer condenser.
C_3 — 250-μμfd. midget mica fixed condensers.
R_1 — 1000-ohm midget potentiometer.
L — 50–80 Mc.: 7 turns No. 14 tinned wire, ½-inch dia. 1-inch long.
25–40 Mc.: 10 turns No. 14 tinned wire, ¾-inch dia. 1-inch long.
12–20 Mc.: 20 turns No. 16 enamel wire, close-wound on ¾-inch diameter bakelite tubing.
6–10 Mc.: 37 turns No. 22 enamel wire, close-wound on ¾-inch tube.
3–5 Mc.: 75 turns No. 30 d.s.c. wire, close-wound on ¾-inch tube.
1.5–2.5 Mc.: 75 turns No. 30 d.s.c. wire, close-wound on 2-inch tube. (The above ranges are only approximate.)
M — 0–200 microamperes (a higher-range meter, although not as satisfactory, can be used if necessary).

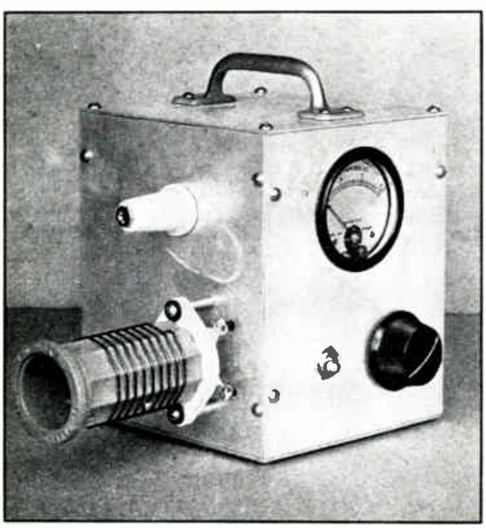


FIG. 1621 — SENSITIVE FIELD-STRENGTH METER

This meter is particularly useful on the lower-frequency amateur bands; it can be used for both transmitter and antenna adjustment, and in making field-strength patterns.

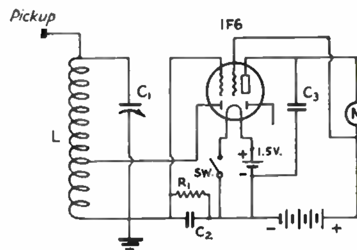


FIG. 1622 — THE TWO-STAGE FIELD-STRENGTH METER CIRCUIT DIAGRAM

C_1 — 50-μμfd. midget variable condenser.
C_2 — 250-μμfd. midget mica fixed condenser.
C_3 — 0.002-μfd. midget mica fixed condenser.
R_1 — 1-megohm ½-watt fixed resistor.
L — Wound on 1½-inch coil forms, winding length 1½ inches, diode tap in center of coil:
1.5–3 Mc.: 58 turns No. 28 d.s.c. wire, close-wound.
3–6 Mc.: 29 turns No. 20 enamel wire, close-wound.
6–12 Mc.: 15 turns No. 20 enamel wire, spaced.
11–22 Mc.: 8 turns No. 20 enamel wire, spaced.
20–40 Mc.: 4 turns No. 20 enamel wire, spaced. (Above ranges are approximate only.)
M — 0–1.5 milliamperes.

The filament battery consists of two flashlight cells wired in parallel. The plate battery is a small portable "B" battery, Burgess type Z30P.

Care should be taken to connect the diode plate on the negative filament leg, otherwise an initial bias will be placed on the rectifier and it will not function properly.

db	*% Modulation*
* 1.8	120
* 0.9	110
0.0	100
− 0.9	90
− 1.8	80
− 3.0	70
− 4.0	63
− 5.0	56
− 6.0	50
− 7.9	40
− 11.0	30
− 14.0	20
− 20.0	10

* Overmodulation.

The peak modulation indicator may be any fast-acting copper-oxide rectifier-type meter. Triplett, Weston and General Radio make meters suitable for this purpose. They should have very little overswing. There are three types, a slow speed, a medium speed and a fast-acting meter. The latter should be used. The output transformer should be of good quality.

The adjustment and calibration of the monitor is most important. This may be done by taking the monitor to a broadcast or amateur 'phone station equipped with a modulation monitor or cathode ray oscilloscope. Attach an antenna of sufficient length to cause at least ½ scale deflection on the carrier meter with the shunt condenser C_1 all the way in. Note the amount of swing on the modulation meter. It will be less than 0 db for 100% modulation as read on the station monitor. Gradually decrease the resistance R_1 and at the same time turn the shunt condenser C_1 out, keeping the carrier meter at ½ scale. Continue this adjustment until the modulation meter kicks 0 db when the station monitor shows 100% modulation. Lock R_1 at that setting, as that value should remain fixed. Now check the monitor against the station monitor on voice modulation so as to simulate as nearly as possible the type of modulation of amateur stations. If it does not show 0 db on 100% modulation on voice, adjust R_1 and C_1 until it does. The monitor is now calibrated and can be used on any transmitter regardless of the frequency without loss of accuracy provided the carrier meter reads up to the calibrated value. Tubes may be replaced without upsetting the calibration.

With the monitor in operation there should be no indication of carrier shift on the carrier meter when the modulation meter shows 100%. If there is any, it indicates improper operation of the transmitter. The signal from the transmitter may be heard on 'phones plugged into the listening jack and is an exact picture of what is going on the air. However, the 'phones should be out when calibrating and checking percentage of modulation.

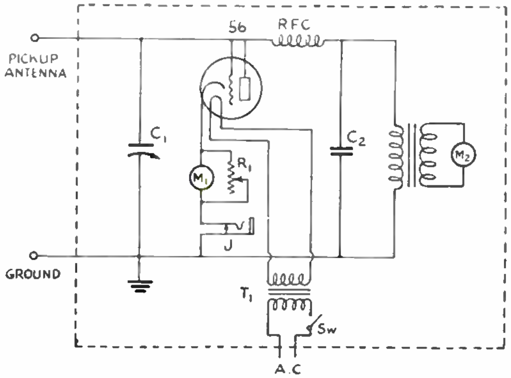


FIG. 1623 — MODULATION METER CIRCUIT

C_1 — 100-$\mu\mu$fd. midget.
C_2 — 0.002-μfd. mica.
M_1 — 0-1 ma.
M_2 — Db meter (See text).
R_1 — 30-ohm rheostat.
J — Closed-circuit jack.
T_1 — 2½-v. fil. trans.
T_2 — 5000-5000 ohm transformer.
SW — S.p.s.t. toggle switch.

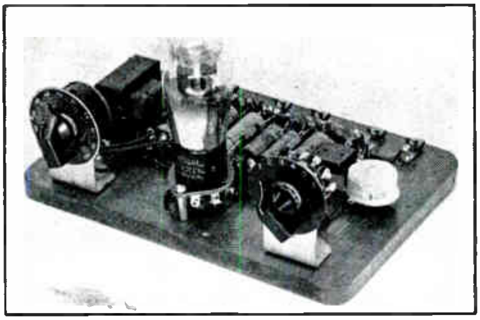


FIG. 1624 — TWIN-TRIODE AUDIO OSCILLATOR FOR ADJUSTING 'PHONE TRANSMITTERS AND AUDIO SYSTEMS

Construction is simplified by attaching all condensers and resistors to tie strips and wiring between terminal lugs.

Audio Test Oscillator

For most adjustments on 'phone transmitters it is desirable to have some form of constant-voltage, adjustable-frequency sine-wave source of a.f. voltage.

A simple and inexpensive device fulfilling these requirements is shown in Figs. 1624 and 1625. A dual triode is used as a simple sine-wave audio oscillator of the capacity-feedback type. Six frequencies are provided — roughly 100, 400, 1000, 3000, 5000 and 10,000 cycles — with standard capacities and inductances. An output control varies the level from zero to the maximum (depending on loading and plate voltage) of several volts.

CATHODE-RAY OSCILLOSCOPES

PERHAPS the most useful of all measuring and testing devices is the cathode-ray oscilloscope. Although relatively expensive, its applications are so numerous that it can be used to replace a number of other less satisfactory types of measuring equipment. It is particularly suited to r.f. and a.f. voltage measurements because it does not consume power from the source being measured.

The circuit diagram of a simple cathode-ray oscilloscope is given in Fig. 1626. In building such a unit one precaution, in particular, must be observed: the tube must not be placed so that the alternating magnetic field from either of the transformers has any

World Radio History

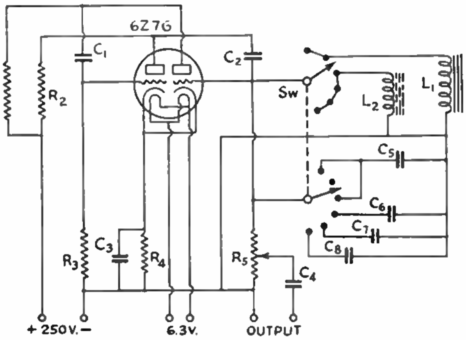


FIG. 1625 — AUDIO SIGNAL GENERATOR CIRCUIT DIAGRAM

C_1, C_2, C_4, C_5, — 0.1-μfd. 400-volt tubular paper.
C_3 — 10-μfd. 25-volt tubular electrolytic.
C_6 — 0.01-μfd. 400-volt tubular paper.
C_7 — 0.002-μfd. midget mica.
C_8 — 0.0005-μfd. midget mica.
R_1, R_2 — 50,000-ohm, ½-watt.
R_3 — 0.3-megohm, ½-watt.
R_4 — 1000-ohm, ½-watt.
R_5 — 50,000-ohm potentiometer.
L_1 — 7-henry iron-core reactor (Thordarson T-13C26).
L_2 — 125-mh. iron-core r.f. choke.

effect upon the electron beam. A second essential, especially important where the oscilloscope is to be used for checking a powerful transmitter, is to prevent stray r.f. voltages from getting into the supply circuits via the a.c. line. Two 0.01-μfd. or 0.1-μfd. condensers (C_1), connected in series across the line with the midpoint grounded to the cabinet, will usually be effective. The condensers must be mounted inside the cabinet where they will not be in the field from the transmitter.

Supplementing the voltage controls indicated in Fig. 1626, it is desirable to make provision for rotating the cathode-ray tube socket so that the horizontal and vertical sweep lines actually are horizontal and vertical. The whole instrument should be enclosed in a metal box, preferably steel or iron, to shield it from stray fields.

In this oscilloscope the horizontal sweep voltage can be obtained either from an audio-frequency source (such as the modulator stage of a transmitter) or from the 60-cycle line. Using an a.f. horizontal sweep, the pattern appearing on the screen will be in the form of a trapezoid or triangle (depending on the percentage of modulation) when checking transmitter performance. Practical application of this method is outlined in Chapter Ten.

Although for many amateur applications the use of a sweep circuit having a linear time base is not essential, for actual studies of wave form the linear time axis is necessary. The sweep circuit proper usually employs a grid-controlled gaseous discharge tube, the 885 (especially designed for this purpose), operating as a relaxation oscillator. In order for the time axis to be linear a condenser in the output circuit is caused to charge at a uniform rate. To accomplish this a pentode-type current-limiting tube is connected in series with the power supply. In operation, the sweep circuit is connected to the vertical plates of the existing oscilloscope. The voltage under observation is connected to the horizontal plates, and the resulting picture is an accurate representation of the wave shape of the voltage being examined.

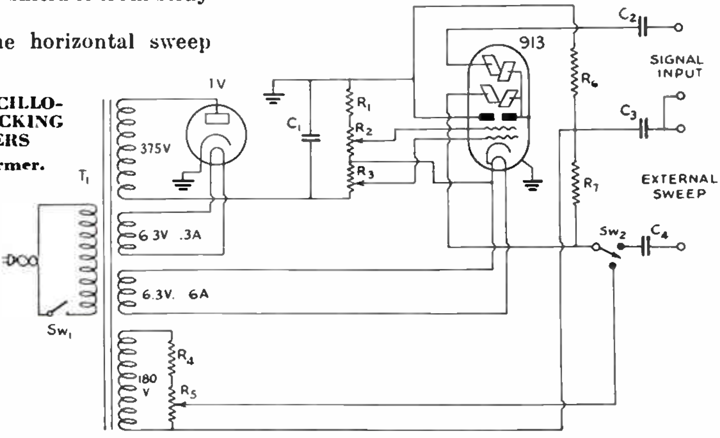
External amplifiers, usually of the resistance-coupled type to provide high gain with wide frequency range and low distortion, are useful in most applications. The 1-inch cathode-ray tube, with a sensitivity of perhaps 100 volts per inch, is not suitable for use with potentials of less than several volts.

An oscilloscope incorporating these features, together with a variable-frequency audio oscillator, is shown in Figs. 1627–28–29. The circuit diagram shows the 913 1-inch cathode-ray tube, its associated 1-V rectifier, the 6K7-885 sweep circuit combination, the 6N7 a.f. oscillator, 6J7 amplifier, and their 1-V rectifier.

Looking at the front view, the top controls are, from left to right:

FIG. 1626 — SIMPLE OSCILLOSCOPE CIRCUIT FOR CHECKING AMATEUR TRANSMITTERS

T_1 — Kenyon type 307 transformer.
C_1 — 8-μfd. 600-volt electrolytic.
C_2, C_3, C_4 — .1-μfd. 600-volt paper.
R_1 — 130,000-ohm 2-watt.
R_2 — 40,000-ohm potentiometer.
R_3 — 30,000-ohm potentiometer.
R_4 — 25,000-ohm ½-watt.
R_5 — 50,000-ohm potentiometer.
R_6, R_7 — 1-megohm ½-watt.



World Radio History

1. Sweep amplitude control, R_{24}. This control varies the width of the pattern when, as normally used, the sweep voltage is applied to the horizontal plates.

2. Amplifier gain control, R_1. When the amplifier is in use, the height of the pattern is controlled by setting resistor.

3. Intensity control, R_{18}. This control should be adjusted for suitable pattern brilliance and need not be touched thereafter during a given set of measurements.

4. Focusing control, R_{17}. Adjusted to give uniform spot or line thickness, making the line as fine as possible. There is always some interlocking between settings for intensity and focus, so the two controls should be adjusted back and forth to give the most sharply-defined pattern.

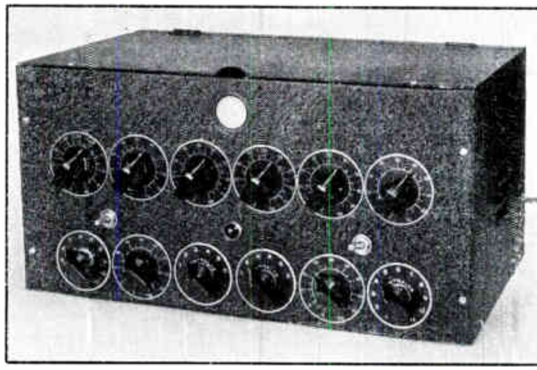


FIG. 1628 — PANEL VIEW OF THE 913 OSCILLOSCOPE

Twelve controls give ample flexibility for all kinds of measurements about the ham transmitter and receiver or in service work.

5. Audio oscillator feedback control, R_8. This control changes the generated frequency to some extent, and also affects the purity of the output wave-shape. Once set to give the nearest possible approach to a sine wave (as judged by comparison to 60 cycles, for example) it may be left alone.

6. Synchronizing control, R_{11}. Used to lock the sweep-circuit frequency to that of the signal under observation, or to a sub-multiple of the signal frequency.

In the bottom row, the controls are as follows:

7. Coarse sweep-frequency adjustment, Sw_5. By selecting condensers of different capacities in the 885 relaxation-oscillator circuit, this switch changes the sweep frequency in roughly harmonic steps. The total frequency range is approximately 4 to 21,000 cycles per second. Lowest frequency will be found with the largest condenser cut in circuit, and *vice versa.*

8. Fine sweep-frequency adjustment. R_{13}. For adjustment to desired frequency between the coarse steps provided by Sw_5.

9 and 10. Input switches for deflecting plates, Sw_6 and Sw_7. By means of these switches, either set of plates can be connected to (a) sweep-oscillator output, (b) either of the external binding posts marked "horizontal input" and "vertical input," (c) amplifier output, (d) off. It is therefore possible to reverse the horizontal and vertical deflections, thus shifting the pattern by 90 degrees, at an instant's notice, as well as to use either pair of plates for the sweep voltage or the voltage being scanned.

11. Audio oscillator output control, R_6. The oscillator on-off switch, Sw_2, is mounted on this control.

12. Synchronizing transformer switch, Sw_4. This control selects the transformer ratio from the several available with the particular type of transformer used. Normally, the switch is set so that the whole transformer secondary is in use.

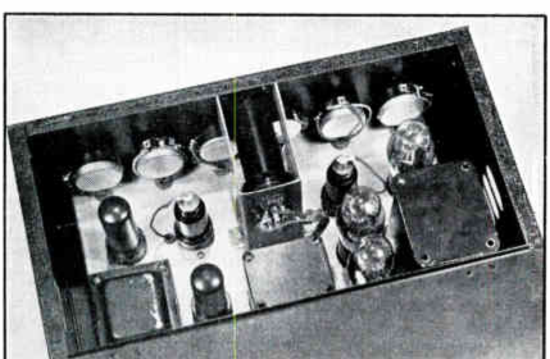


FIG. 1627 — LOOKING INTO THE OSCILLOSCOPE FROM THE REAR

The transformers in the rear are, l. to r., T_1, T_3 and T_2. Between T_1 and T_3 is the 5Z4; the 1-V's are between T_3 and T_2. The other tubes are, in the same order, 6J7, 6N7, 913, 6K7 and 885. The signal input circuit should be wired with short leads well spaced from all other parts if r.f. work is contemplated.

To operate, first set the focusing and intensity controls, R_{17} and R_{18}, at maximum and close the line switch. Sw_6 and Sw_7 should be set to the "off" position. After the tubes heat, a luminous dot should appear in the center of the screen. The intensity and focusing controls may then be manipulated to make the dot small and sharp and of suitable brightness.

Next, connect the output of the sweep oscillator to the horizontal plates by setting Sw_7 (or Sw_6, whichever may be connected to the set of plates actually giving horizontal deflection) to the approximate tap. The dot should change into

World Radio History

a line extending across the screen horizontally. To change the length of the line, adjust R_{24}. If the sweep-frequency switch, Sw_5, should happen to be set at the low-frequency end of the scale, there will not be a continuous line but a slowly-moving dot. The remedy is to increase the sweep frequency.

Now apply the signal to be observed to the "vertical input" terminals and connect Sw_6 to the same terminal. If the signal amplitude is of the order of 25 to 50 volts r.m.s., a pattern of usable size should appear on the screen. To get a stationary figure, connect the signal source also to the "synchronizing input" terminals (a direct connection between the two sets of binding posts on the oscilloscope is all that is necessary) and adjust the synchronizing control, R_{11}, to lock the sweep circuit to the external frequency. Adjustment of Sw_5 will determine the number of cycles that appear on the screen; with the oscillator on the same frequency as that of the signal one cycle will appear, on harmonics only part of a cycle, and on subharmonics a number of cycles depending upon the ratio of signal frequency to oscillator frequency. For example, with the sweep oscillator on 200 cycles locked by a 1000-cycle signal under observation, five cycles will appear on the screen.

Do not allow a bright spot to stay at one place on the phosphorescent screen, since the coating material will be burned. Keep the spot moving; in other words, always have a sweep of some sort applied to at least one set of deflecting plates.

The use of oscilloscopes for alignment and testing of receivers involves additional equipment. To show the resonance characteristic of the receiver it is necessary not only to show the response at the carrier frequency but at all ad-

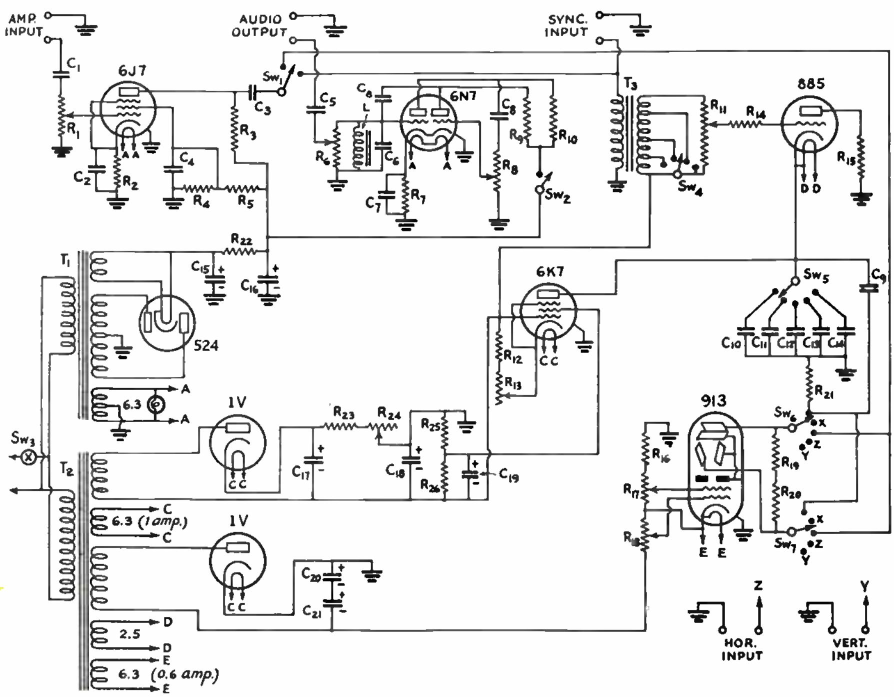


FIG. 1629 — CIRCUIT DIAGRAM OF THE OSCILLOSCOPE

L — 125-mh. iron-core choke.
C_1, C_3, C_4, C_5, C_6, C_8, C_9, C_{10} — 0.1-μfd. 400-volt.
C_2, C_7 — 16-μfd. 35-volt.
C_{11} — 0.025-μfd. 400-volt.
C_{12} — 0.005-μfd. 400-volt.
C_{13} — 0.001-μd. 400-volt.
C_{14} — 40-$\mu\mu$fd. 400-volt.
C_{15}, C_{16}, C_{17}, C_{18}, C_{19}, C_{20}, C_{21} — 8-μfd. 400-volt electrolytic.
R_1, R_8 — 500,000-ohm pot.
R_2 — 300-ohm, 1-watt.
R_3, R_5 — 250,000-ohm, ½-watt.
R_4, R_9, R_{10} — 50,000-ohm, ½-watt.
R_6, R_{13}, R_{17}, R_{24} — 50,000-ohm pot.
R_7, R_{15} — 1000-ohm, 1-watt.
R_{11} — 10,000-ohm pot.
R_{12} — 1500-ohm, ½-watt.
R_{14} — 300,000-ohm, ½-watt.
R_{16} — 125,000-ohm, ½-watt.
R_{18} — 30,000-ohm pot.
R_{19}, R_{20}, R_{21} — 5-meg., ½-watt.
R_{22} — 15,000-ohm, 1-watt.
R_{23} — 7500-ohm, ½-watt.
R_{25} — 40,000-ohm, ½-watt.
R_{26} — 6000-ohm, ½-watt.
T_1 — Small power transformer giving 700 volts, c.t., 6.3 volts 1.8 amps., 5 volts 2 amps.
T_2 — Kenyon Type 207.
T_3 — Kenyon Type 1.
Sw_1 — S.p.d.t. toggle switch.
Sw_2 — S.p.s.t. switch cover for R_6.
Sw_3 — S.p.s.t. toggle switch.
Sw_4, Sw_5, Sw_6, Sw_7 — 6-position switches.

World Radio History

jacent frequencies through the pass-band. To accomplish this, a motor-driven variable condenser, or "wobbler", is often incorporated in the signal generator, automatically tuning the oscillator frequency over the desired range (usually about 20 kc.) at a fixed rate of speed. An auxiliary set of contacts on the motor shaft serve to provide an external synchronizing voltage for the horizontal plates; an iron bar rotating the field of a horseshoe magnet is often used, pickup coils on the magnet connected to the horizontal plates providing the alternating sweep voltage. The vertical plates of the oscilloscope are connected to the second detector or first audio stage through a suitable amplifier.

The uses of an oscilloscope are not limited to those mentioned above. It is, in fact, so versatile an instrument as to be an adequate substitute for almost every other type of electrical measuring equipment.

As a voltmeter, measurement is accomplished by applying the potential in question to either pair of deflecting plates and measuring the length of the resulting trace. Checking this against the tube sensitivity (Table XI, Chapter Five) will give the approximate voltage. If an amplifier is used, its actual gain must, of course, first be known. This can be learned by applying a stable test signal with the amplifier both off and on and comparing the resulting traces.

As a low-frequency meter, the frequency under observation is applied to one set of plates and compared with a known frequency which is applied to the other pair. This known frequency may be obtained from a beat-frequency oscillator, tuning fork standard, a.c. line (60 cycles), or similar source. The comparison of two widely-separated frequencies (within ratios of 20 to 1 or so) is accomplished by the use of Lissajou's figures. Such figures show frequency ratios in terms of recurrent patterns. The interpretation of these patterns is explained in any of the standard cathode-ray texts (RCA's *Cathode-Ray Tubes*, Rider's *The Cathode-Ray Tube at Work*, etc.).

The measurement of phase relationships is also facilitated by the use of an oscilloscope, showing as it can the linear amplitude of an a.c. potential plotted against time. Since the time base can be made relatively short, small phase displacements can be observed even with comparatively high frequencies.

In addition to its use at the transmitter proper for modulation checking, etc., the oscilloscope may be connected to the receiver for visual monitoring of received signals. The connections are simple. One horizontal deflecting plate is connected to the plate of the last i.f. stage through a 0.002-μfd. fixed condenser (the i.f. transformer must be re-aligned to allow for the added shunt capacity), and a 2-megohm resistor connected to ground. One vertical plate is connected to a 60-cycle sweep source. The remaining plates are grounded. If sufficient i.f. voltage is available, a regular trapezoidal pattern will result when a 'phone signal is tuned in.

However, if the receiver does not have sufficient i.f. voltage output to give a useful pattern, an i.f. amplifier stage should be interposed between receiver and oscilloscope. This amplifier can consist of a single tube similar to the other i.f. tubes in the receiver, with its grid circuit coupled to the receiver i.f. output through a midget variable condenser and 2-megohm grid leak to ground. An i.f. transformer in the plate circuit is tuned to the same frequency as the receiver, the secondary being connected to the horizontal deflecting plates.

Such an accessory is not only an asset to one's own station, but may be of assistance to stations being worked, as well.

World Radio History

CHAPTER SEVENTEEN

ASSEMBLING THE AMATEUR STATION

Location and Arrangement of Station — Control Systems — Receiver Protection — Lead-in Arrangement — Break-in and Remote Control

THE element of danger to the operator and others of the household from high voltages, as well as convenience, should be considered seriously in planning the arrangement of station equipment.

LOCATION OF STATION

WHERE space is at a premium, the transmitter may be built into a desk or radio console. If conveniently located, a spare closet makes a very good spot for the transmitter and may be arranged as shown in Fig. 1701. If necessary, the transmitter may be located in the basement or attic, in a closet or even in a weatherproof box outside the house and operated by remote control. Apartment-house dwellers sometimes build up a compact arrangement on wheels which may be stored under the kitchen range or sink and brought out to the operating position whenever desired.

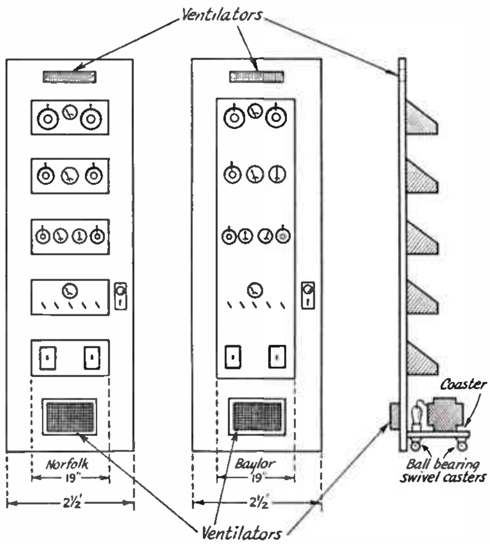


FIG. 1701 — TRANSMITTER MOUNTED ON CLOTHES-CLOSET DOOR

Standard rack construction may be followed. Weight of heavy units is taken up by rollers at bottom. The door may be replaced at little expense.

Arrangement of Equipment

If the transmitter is to be built into a floor rack (construction described in Chapter Six) or a frame, an operating table with a top of 24″ by 36″ has sufficient space for a receiver of good size, key or microphone, control switches and room for writing. A drawer will take care of plug-in coils, small tools and writing materials. An operating table of somewhat greater length will afford space for additional apparatus such as the monitor or small transmitter. The construction of two different types is described in Chapter Six.

The transmitter should be located near a window where the antenna or transmission line may be brought in most conveniently and also near the operating position where frequency changes which may be made by adjustment of tuning controls on the front of the panel may be made without leaving the operating position. One good arrangement is shown in Fig. 1702. The transmitter rack is within easy reach of the operator. Since the lowest controls of the average rack transmitter come above the table level, it might be placed against the end of the operating table with controls facing either the operator or the center of the room. Space between the wall and transmitter should be left to permit passage to the side and rear for coil changing.

If the transmitter is built up in breadboard style, it may be placed upon a second table in the position in which the rack is shown. Sometimes breadboard units are assembled, one above the other, on a series of shelves emulating rack construction. Power-supply equipment may be assembled upon a heavy board and placed under the transmitter table. A suitable screen should be fastened to the legs of the table to prevent approach to the high-voltage apparatus, and high-voltage wiring should be brought up at the rear of the table to the transmitter. While the receiver power supply may be placed upon a shelf under the operating

World Radio History

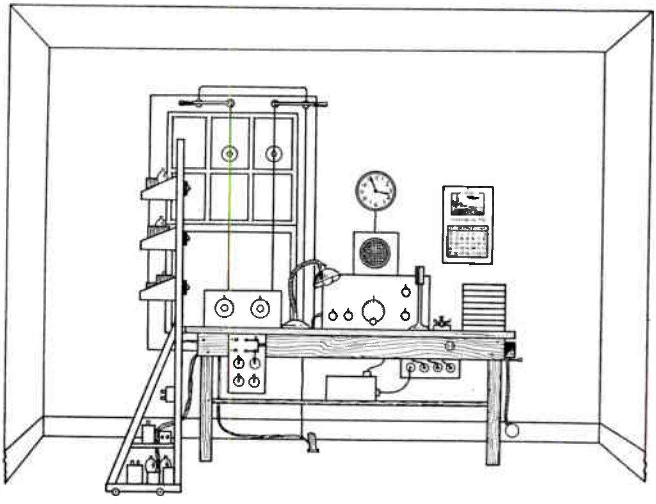


FIG. 1702 — A CONVENIENT ARRANGEMENT FOR STATION

The rack transmitter panel is within easy reach of the operator. On the table are the antenna tuner, lamp, receiver and loudspeaker, microphone, key and stationery file. The entrance switch is fastened to the right-hand end of the table. Transmitter controls are mounted on a board fastened to the table at the left of the operator with foot-operated control switch underneath the table. Receiver power supply is on shelf underneath. Service outlets are mounted on board fastened to rear of table. Lightning switches at top of window with ground wire running down right side of window.

table, under no circumstances should the transmitter power supply be placed there unless completely enclosed. In cases where the power-supply equipment is too bulky to be placed in the operating room, it is sometimes placed in the basement and wired up to the operating room. If this is done, the wiring should be suitably insulated and the apparatus fenced off to prevent anyone coming in contact with it.

Control Circuits

Proper arrangement of controls is fully as important as convenient arrangement of apparatus. If the transmitter is to be of fairly high power, it is desirable to provide a special service line directly from the meter board to the operating room. This line should be run in conduit or BX cable with conductors of ample size to carry the load without undue voltage drop. The line should be terminated with an enclosed entrance switch properly fused.

Fig. 1703 shows the wiring diagram of a simple control system. It will be noticed that, because the control switches are connected in series, none of the high-voltage supplies may be turned on until the filament switch has been closed and that the high-power plate supply cannot be turned on until the low-power plate supply switch has been closed, and also, that the modulator power cannot be applied until the final-amplifier plate-voltage has been applied. SW_5 places a 100- to 300-watt lamp (L_p) in series with the primary winding of the high-voltage plate transformer for use during the process of preliminary tuning and for local c.w. work. The final amplifier should be tuned to resonance first at low voltage and then SW_5 is closed short-circuiting the lamp. Experience will determine what the low-voltage plate-current reading should be to have it increase to full-power value when SW_5 is closed so that the proper antenna coupling and tuning

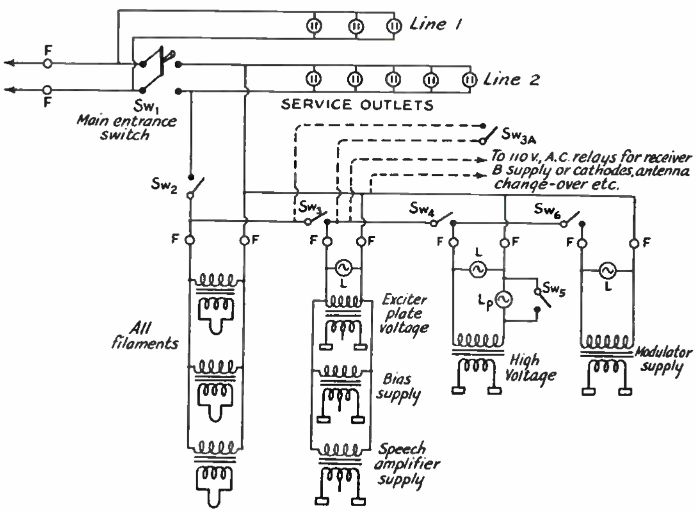


FIG. 1703 — STATION CONTROL SYSTEM

With all switches except SW_3 closed, SW_3 serves as the main control switch. SW_1 — Enclosed entrance switch. SW_2 — Filament switch. SW_3 — Low plate-voltage and main control switch. (See text.) SW_4 — High plate-voltage switch. SW_5 — Low-power and tune-up switch. (See text.) SW_6 — Modulator plate-voltage switch. F — Fuse. L — Warning light. L_p — Voltage-reducing lamp. (See text.)

World Radio History

adjustments may be made at low voltage.

Preferably, SW_3 should be of the push-button type which remains closed only so long as pressure is applied. A switch of this type provides one of the simplest and most effective means of protection against accidents from high voltage. In the form which is usually considered most convenient, it consists of a switch which may be operated by pressure of the foot

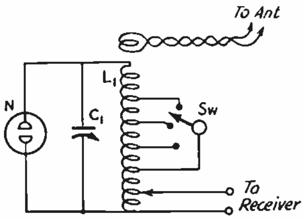


FIG. 1704 — SIMPLE PROTECTIVE DEVICE FOR RECEIVER

When the voltage induced across L_1C_1 by transmitter becomes too great, the neon tube breaks down, short-circuiting the tuned circuit. L_1 and C_1 are any coil and condenser which will tune over the required range. Bare wire is suggested for L_1 so that adjustment of the taps will be simplified.

and is located underneath the operating table. When used in this manner, it means that the operator must be in the operating position, well removed from danger, before high voltage may be applied. If desired, SW_{3a} may be placed on the *front* of the transmitter panel so that it may be used while tuning the transmitter. SW_{3a} should, of course, be of the push-button type also.

In more elaborate installations, and in remote control systems, similarly arranged switches control relays whose contacts serve to do the actual switching at the transmitter.

Two strings of utility outlets are connected, one on each side of the entrance switch, for operation of the receiver and such accessories as monitor, lights, electric clock, soldering iron etc. Closing the entrance switch should close those circuits which place the station in readiness for operation. SW_2 and SW_4 are normally closed and SW_3 open. When SW_1 is closed upon entering the operating room, the transmitter filaments are turned on as well as the receiver which should be plugged into line No. 2. With SW_4 closed (also SW_5 and SW_6), SW_3 performs the job of turning all plate-supplies on and off during periods of transmission and reception. Continuously operating accessories, such as the clock, should be plugged into line No. 1 so that it will not be turned off when SW_1 is opened. Line No. 1 is also of use for supplying a soldering iron, light, etc. when it is desired to remove all voltage from the transmitter by opening SW_1.

Receiver Protection

Unless certain precautions are taken, operation of a transmitter in close proximity may cause damage to the receiver. Low-power transmitters seldom cause trouble unless both transmitter and receiver are unshielded and the output circuit of the transmitter is so close to the input of the receiver as to provide appreciable coupling between the two. Higher-power transmitters may induce voltages so great in the input circuits of the receiver that, even though the receiver plate supply is turned off during periods of transmission, grid current is sufficient to ruin the input tube and sometimes burn out the cathode resistance. Well shielded receivers are much less susceptible to damage and frequently are used with more or less success without protection of any form, although it may be necessary to replace the input tube at intervals. It is always advisable, however, to make some provision for protecting the receiver against possible damage.

Short-circuiting of receiver input terminals by means of a switch or a relay operated from the transmitter control switch is only partially effective, especially at the higher frequencies. A simple precaution, which is often found adequate, is to provide a switch which opens the cathode circuit of the input tube, preventing the flow of grid current, although a considerable d.c. potential may exist between heater and cathode.

Another simple arrangement, suggested by W3BES, involves the use of a neon tube to short-circuit a high-impedance antenna tuner. It is shown in Fig. 1704. Probably the most effective and logical scheme is one provided by W8JMI, shown in Fig. 1705, in which a separate rectifier with external pick-up is used to bias the first or first and second r.f. tubes of the receiver.

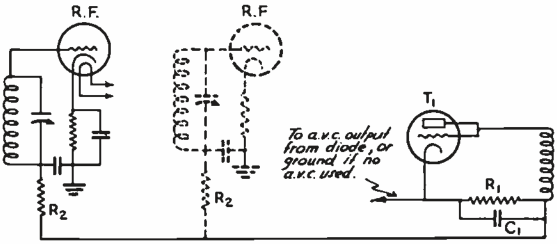


FIG. 1705 — ANOTHER PROTECTIVE DEVICE FOR RECEIVER

L_1 is a pick-up coil coupled to the transmitter output tank circuit. Size of coil must be determined by experiment. C_1 — .002 μfd. R_1 — 100,000 ohms suggested for first trial. Experiment with particular set-up will be necessary. R_2 — Decoupling resistors in receiver AVC system.

T_1 — Any tube with grid and plate tied together.

World Radio History

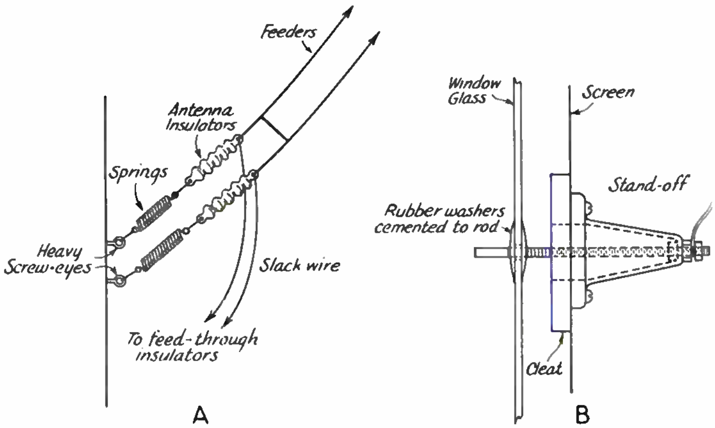


FIG. 1706 — BRINGING THE FEEDERS IN

A — Anchoring feeders to take strain from feed-through insulators or window glass. B — Going through a full-length screen. The cleat is fastened to frame of screen on inside of screen. Clearance holes are cut in the cleat and also in the screen. The rubber washers keep the weather out.

Bringing the Antenna or Transmission Line into the Station

In bringing the antenna or transmission line into the station, the line should first be anchored to the outside wall of the building, as shown in Fig. 1706, to remove strain from lead-in insulators. When permissible, holes cut directly through the walls of the building and fitted with feed-through insulators of suitable size are undoubtedly the best means of feeding the antenna into the station, for the job can be done with little difficulty and can provide greater mechanical permanence than other schemes. It involves no interference to screening or storm windows. The holes should have plenty of air clearance about the conducting rod, especially when tuned lines, which develop high voltages, are employed. Probably the best place to go through the walls, from the standpoint of appearance is the trimming board at the top or bottom of a window frame which provides flat surfaces for tightening lead-in insulators. Cement or rubber gaskets may be used to water-proof the exposed joints.

Where such a procedure is not permissible, the window itself usually offers the best opportunity. One satisfactory method is to drill holes in the glass near the top of the upper sash. If the glass which is to be drilled is replaced by plate glass, a stronger job will result. Plate glass may be obtained reasonably from automobile junk yards and may be drilled before placing in the frame. The glass itself provides the necessary insulation and the transmission line may be fastened to bolts fitting the holes. Rubber gaskets cut from inner tube will render the holes water-proof. The lower sash should be provided with stops at a suitable height to prevent damage when it is raised. If the window is fitted with a full-length screen, the scheme shown in Fig. 1706-B may be used.

In a less permanent method, the window is raised from the bottom or lowered from the top to permit the insertion of a board three or four inches wide which carries the feed-through insulators. This arrangement may be made weather-proof by making an overlapping joint between the board and window sash, as shown in Fig. 1707, and covering the opening between upper and lower sashes with a sheet of soft rubber cut from an inner tube.

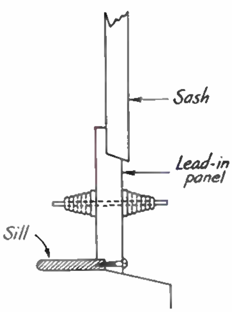


FIG. 1707 — ANTENNA LEAD-IN PANEL

It may be placed over the top sash or under the lower sash of window. The overlapping joint makes it weather-proof. The single thick board may be replaced by two thinner boards fastened together.

When the transmitter must be located at a considerable distance from the point at which the antenna transmission line enters the building, the most practical way of feeding the antenna is by means of a low-impedance transmission line which may be fastened along the picture moulding near the ceiling. If multi-band operation is desired, a separate antenna for each band will be required; otherwise, it will be necessary to place the antenna tuner at the point at which the feeders enter the building and couple the antenna tuner to the transmitter by means of a low-impedance line. This arrangement is very awkward to tune with the antenna and final-amplifier tank circuits separated so widely.

Antenna Switching

As pointed out in Chapter Thirteen, it is desirable, particularly in DX work, to use the same antenna for transmitting and receiving. This requires switching of antenna from transmitter to receiver. One of two general systems may be employed. In the first, the transmitter and receiver are each provided with an antenna tuner and the antenna transmission line is switched from one to the other. In the second system, one antenna tuner is provided for each antenna and the switch is in the low-impedance coupling line. Several arrangements are shown in Fig. 1708. The high voltages which develop on tuned lines require switches and wiring with good insulation. Frequently relays with low-capacity contacts are substituted for the hand-operated switches.

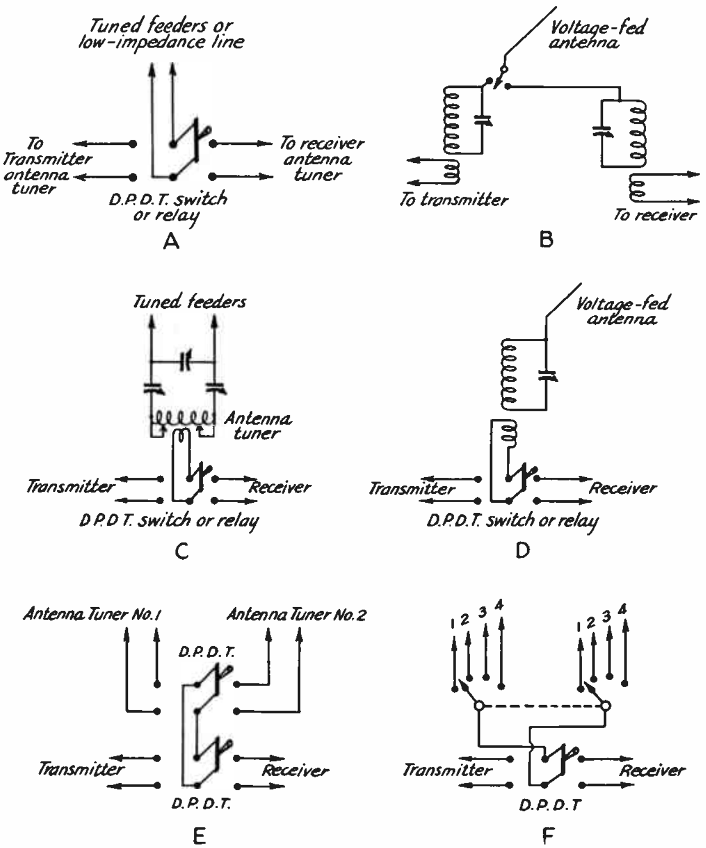


FIG. 1708 — ANTENNA SWITCHING SYSTEMS

A — For tuned lines with separate antenna tuners or low impedance lines. B — For voltage-fed antenna. C — For tuned line with single tuner. D — For voltage-fed antenna with single tuner. E — For two tuned-line antennas with tuner for each antenna or for low-impedance lines. F — For several two-wire lines.

Remote Control

When it becomes necessary to locate the transmitter at some point remote from the operating position, it is usually more feasible to control the transmitter by means of relays rather than to attempt to carry power wiring between the transmitter and operating position. Not only must the wiring be more carefully executed, but considerable drop in voltage may develop unless wire of large size is used. Relays require little current and low-voltage types require wiring with a relatively small amount of insulation. Wiring for a large transmitter may be bonded into a small cable occupying but little space. A typical arrangement for remote control is shown in Fig. 1709. In 'phone installations, it is common practice to place the modulator and driver with the transmitter and speech amplifier at the operating position, coupling the two with a low-impedance line.

Where distance between control point and the transmitter makes it important, the number of control lines may be reduced by a scheme shown in Fig. 1710. Relays 1, 2 and 3 are adjusted to close at progressively increasing values of current. In operation, SW_1 is closed and, with R_1 and R_2 in series, the line current is sufficient to close only Relay No. 1 which will turn on filaments and bias supply. When SW_2 is closed, R_1 is cut out of the circuit and the line current increases to a value sufficient to close relay No. 2 which turns on the high voltage, but not No. 3. The key short-circuits R_2 and again the line current increases closing relay No. 3, the keying relay. The system requires rather careful adjustment and values will depend upon relay characteristics and line voltage. Those interested in a more extensive circuit for frequency changing, modulation checking as well as power control by means of a single pair of wires are referred to page 37 of *QST* for July 1938.

Break-in

The advantages of break-in operation are many and are described in Chapter Eighteen. If the station is provided with a stable, shielded superheterodyne receiver, it may be necessary only to use a separate antenna for the receiver. This should be located as far as possible from the transmitting antenna and at right angles to it. Sometimes a short receiving antenna will reduce interference from the transmitter and yet permit reception from stations at quite some distance. Use of the external rectifier of Fig. 1705, described in connection with

World Radio History

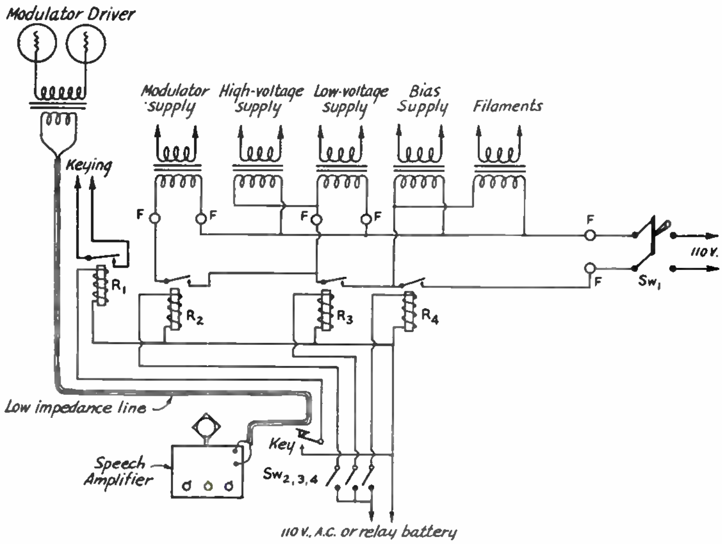


FIG. 1709 — REMOTE CONTROL SYSTEM

This system is essentially the same as that shown in Fig. 1703 except that the switches control relays at the remote transmitter which do the switching. The speech amplifier and modulator driver are coupled with a low-impedance line.

receiver protection, is recommended where break-in operation is desired. With unshielded or regenerative receivers, it may be necessary to provide a relay which opens the headphone circuit when the key is closed to prevent racket in the headphones which might paralyze the ear for the weaker break-in signal. In this case, an output transformer between receiver and headphones with the relay breaking the connection between headphones and transformer secondary winding is recommended. In extreme, cases, an additional relay short-circuiting the receiver input may be required. All of these relays should be connected so as to operate with the key.

If the same antenna is used for receiving as well as transmitting, a change-over relay operating from the keying circuit must be added.

Unless the transmitter oscillator is very well shielded, it will be impossible to use break-in operation with a station on the frequency of the transmitter or frequencies immediately adjacent unless the oscillator is keyed. Most break-in systems employ keyed oscillators with the following amplifier stages provided with sufficient fixed bias to prevent plate-current flow with excitation removed.

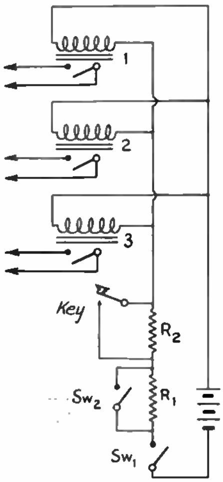


FIG. 1710—THE NUMBER OF CONTROL WIRES MAY BE REDUCED BY THIS METHOD FOR LONG REMOTE LINES

Relays are adjusted to close on different currents controlled by resistances.

'Phone Break-in—Push-to-Talk

Break-in operation with' phone becomes more complicated and less practicable because of the increased difficulty in distinguishing the wanted signal from others. A method of electronic control of the carrier is described in detail in *QST* for November 1936. The voice signal operates a relay which cuts the carrier off if there is a short pause in speech, the carrier resuming whenever speech is resumed.

A more commonly used system is the "push-to-talk" method. In this system, a convenient "push" switch, such as the foot-operated switch mentioned in connection with Fig. 1702 is used to cut the carrier, and also the oscillator, on and off. With this arrangement and the receiver precautions recommended for break-in operation, phone conversations may be speeded up and made more pleasurable.

UNDERWRITERS' REGULATIONS —LIGHTNING PROTECTION

AN UNGROUNDED radio antenna, particularly one large and well-elevated, is a lightning hazard. When well grounded, it provides a measure of protection; therefore grounding switches should be provided not only to comply with insurance underwriters' requirements but also to prevent loss of property. Grounding switches are shown in Fig. 1702. Anyone contemplating the installation of a station should get in touch with his insurance agent and city inspection department to ascertain requirements. He should also send ten cents to the Superintendent of Documents, Government Printing Office, Washington, D. C., for the booklet *Safety Rules for Radio Installations,* Handbook of the Bureau of Standards No. 9.

World Radio History

CHAPTER EIGHTEEN

OPERATING A STATION

The transmitter should be adjusted for satisfactory, stable, operation. Do not try to work too near the edge of an amateur band. Keep well *within* the estimated accuracy of your frequency measuring equipment and means of measurement. Check frequency often. Crystal control provides a certain degree of "frequency insurance" but do not omit checks for harmonics and parasitics that may be present with the signal, as well as for frequency changes due to quartz temperature or circuit element capacities if near a band edge. Other control methods require *tremendously increased precautions*. F.C.C. monitoring stations are on the job of checking notes, frequency and other possible discrepancies, so it pays to be watchful.

Method in operating is important, and in this Chapter we shall discuss the common practices. The *good* operator does not sit down and send a long call when he wants to work someone. He *listens in.* He covers the dial thoroughly. The fellow that is admired for his good operating is the one who is always calling some particular station instead of using CQ. Because he *listens* until he hears someone to work and *then* goes after him, our good operator gets his man nearly every time. A good operator chooses the proper time to call, he makes plain signals, and he does not call too long. A short call is sufficient because if a station does not get the call it is likely that he is listening to another station. A long call makes the receiving operator lose patience and look for someone else.

Pride in technique is the earmark of the successful amateur among his fellows. Code proficiency sets apart the real seasoned operator from the one who builds equipment only to tear it apart again. Engineering or applied common sense are essential to both the operator and experimenter. Operating ability is just as essential and important in radiotelephone operating as in code work — perhaps it is more essential and more rare, for understanding of phonetics must contribute to conciseness with careful system, as in the airways service, for effective two-way work. The penalty for not having "what it takes" in operating is ineffectiveness in results, as well as to win the name of "lid" by bungling.

Too often the beginner-operator operates his set like a plaything; the aim should be to operate with a serious and constructive purpose, not for novelty or mere entertainment. It must be remembered that radio communication is not an individual plaything but the interference one causes may affect many others. It may cause pleasure or expressions of annoyance depending on the care and thoughtfulness with which one operates. All of this merely to introduce the plea that time be given to the brief study of operating technique before going on the air.

Many the amateur who complains about his results or blames his equipment when the real fault was with proper timing of calls and failure to do enough intelligent listening. Patience and judgment, and familiarity with tuning methods and ways, and standard procedures are absolutely essential to full success and enjoyment.

The operator who sends forty or more CQ's and signs two or three times in a slipshod manner gains the respect of no one. His call may be impossible to identify. His lack of operating judgment seriously impairs and handicaps *his own success and enjoyment* in addition to causing other amateurs to form an unfavorable opinion of his work and the uncalled-for interference he creates. *By proper* procedure the number of two-way contacts (QSO's) and the enjoyment and profit in each will be a maximum.

The adjustment on the receiver has much to do with successful operation, too. The good receiving operator notes the dial setting and when he has completed calling in proper fashion, he waits a moment and then tunes above or below the logged dial setting just in case something has shifted slightly in the receiver or transmitter. The best operator has patience and waits a few minutes in case of delay at the transmitter or in case fading signals make a second answer necessary. Upon the station and its *operation* depend the possibility of good communication records.

An operator with a clean-cut, slow, steady method of sending has a big advantage over the poor operator. Good sending is partly a matter of practice but patience and judgment are just as important qualities of an operator as a good "fist."

Accuracy is of first importance. Then *speed* must be considered. Very often, transmission at moderate speeds moves traffic or insures

World Radio History

understandable conversation better than fast sending. A great deal depends on the proficiency and good judgment of the two operators concerned. Fast sending is helpful only when two fast operators work together.

Communication

Communication has as its object the exchange of thought. Sometimes individuals concerned converse at length and exchange their thoughts freely. At other times the individuals are miles apart and the thoughts must be condensed to just a few words. Then these words must be relayed or passed on from operator to operator. When they reach their ultimate destination someone can interpret them fully only if they have been properly and carefully handled by the intermediate operators.

Time is involved in making any exchange of thought. Because every man's life and experience is measured by time, this factor becomes important in everything we do or say. The number of messages handled, the number of distant stations worked, the number of records made at our station, all depend in some degree on the time available for our hobby. The more time we spend at the set, the more well known our station becomes and the more extensive will be the sum total of our results in amateur radio.

As time is a factor, uniform practices in operating are necessary to insure a ready understanding. So proficiency in the commonly-used abbreviations and in knowledge of uniform operating practices is to be desired. Proficiency comes with practice. In the Appendix are the "Q" signals and some abbreviations used by amateur operators.

Procedure

Official A.R.R.L. Stations observe the rules regarded as "standard practice" carefully. Any actively-operating stations will do well to copy these rules, to post them conspicuously in the station, and to follow them when operating.

Calls shall be made by transmitting *not more than three times* the call signal of the station called, and DE, followed by one's own call signal sent *not more than three times*, thus: VE2BE VE2BE VE2BE DE W1AW W1AW W1AW. In amateur practice this form is repeated completely once or twice. The call signal of the calling station *must* be inserted at frequent intervals for identification purposes. Repeating the call signal of the called station five times and signing not more than twice has proved excellent practice in connection with break-in operation (the receiver being kept tuned to the frequency of the called station). The use of a break-in system is highly recommended to save time and reduce unnecessary interference.

The A.R.R.L. method of using the general inquiry call (CQ) is also that of calling three times, signing three times, and repeating three times. CQ is not to be used when testing or when the sender is not expecting or looking for an answer. After CQ, the dial should be covered thoroughly for two or three minutes looking for replies.

The directional CQ: To reduce the number of useless answers and lessen QRM, every CQ call shall be made informative when possible. Stations desiring communication shall follow each CQ by an indication of direction, district, state, continent, country or the like. International prefixes (Appendix) may be used to identify a particular country. Examples:

A United States station looking for any Canadian amateur calls: CQ VE CQ VE CQ VE DE W1UE W1UE W1UE K. A western station with traffic for the east coast when looking for an intermediate relay station calls: CQ EAST CQ EAST CQ EAST DE W5CEZ W5CEZ W5CEZ K. A station with messages for points in Massachusetts calls: CQ MASS CQ MASS CQ MASS DE W8KKG W8KKG W8KKG K. In each example indicated it is understood that the combination used is repeated three times.

2. **Answering a call:** Call three times (or less); send DE; sign three times (or less); and after contact is established decrease the use of the call signals of both stations *to once or twice*. Example:

W1GNF DE W1AW GE OM GA K (meaning, "Good evening, old man, go ahead")

3. **Ending signals and sign off:** The proper use of $\overline{\text{AR}}$, K and $\overline{\text{VA}}$ ending signals is as follows: $\overline{\text{AR}}$ (end of transmission) shall be used at the end of messages during communication and also at the end of a call, *indicating when so used that communication is not yet established.* In the case of *CQ calls*, the international regulations recommend that K shall follow. K (invitation to transmit) shall also be used at the end of each transmission *when answering or working* another station, carrying the significance of "go ahead." $\overline{\text{VA}}$ (or $\overline{\text{SK}}$) shall be used by each station only when signing off, this followed by your own call sent once for identification purposes. $\overline{\text{VA}}$ (end of work) sent alone, or for clarification followed by a single (never more) "CQ DE— — — —," indicates to others that you are through with the station which you have been working and will listen for whomever wishes to call. Examples:

($\overline{\text{AR}}$) — G2OD DE W1CTI $\overline{\text{AR}}$ (showing that W1CTI has not yet gotten in touch with G2OD but has called and is now listening for his reply). Used after the signature between messages, it indicates the end of one message. There may be a slight pause before starting the second of the series of messages. The courteous and thoughtful operator allows time for the receiving operator to enter the time on the

World Radio History

message and put another blank in readiness for the traffic to come. If K is added it means that the operator wishes his first message acknowledged before going on with the second message. If no K is heard, preparations should be made to continue copying.

(K) — ZL2AC DE W6AJM R K. (This arrangement is very often used for the acknowledgment of a transmission. When anyone overhears this he at once knows that the two stations are in touch, communicating with each other, that ZL2AC's transmission was all understood by W6AJM, and that W6AJM is telling ZL2AC to go ahead with more of what he has to say.) W9KJY DE W7NH NR 23 R K. (Evidently W9KJY is sending messages to W7NH. The contact is good. The message was all received correctly. W7NH tells W9KJY to "go ahead" with more.)

($\overline{\text{VA}}$) — R NM NW CUL VY 73 $\overline{\text{AR}}$ $\overline{\text{VA}}$ W7WY. (W7WY says "I understand OK, no more now, see you later, very best regards. I am through with you for now and will listen for whomever wishes to call W7WY signing off.")

4. If a station sends **test signals** to adjust the transmitter or at the request of another station to permit the latter to adjust its receiving apparatus, the signals must be composed of a series of V's with the call signal of the transmitting station at frequent intervals.

5. When a station receives a call without being certain that the call is intended for it, it shall not reply until the call has been repeated and is understood. If it receives the call but is uncertain of the call signal of the sending station, it shall answer using the signal . . — — . . (?) instead of the call signal of this latter station. QRZ? (see Appendix) is the appropriate signal to use, followed by your call to ask who is calling and get this station to call again.

6. Several **radiograms** may be transmitted **in series** (QSG. . . . .) with the consent of the station which is to receive them. As a general rule, long radiograms shall be transmitted in sections of approximately fifty words, each ending with . . — — . . (?) meaning, "Have you received the message correctly thus far?"

7. **Receipting** for conversation or traffic: Never send a single acknowledgment until the transmission has been entirely received. "R" means "All right, OK, I understand *completely*." When a poor operator, commonly called a "lid," has only received part of a message, he answers, "R R R R R R R R R R, sorry, missed address and text, pse repeat" and every good operator who hears, raves inwardly. Use R *only* when *all* is received correctly. Example:

When all the message has been received correctly a short call with "NR 155 R K" or simply "155 K" is sufficient.

8. **Repeats:** When most of the message was lost the call should be followed by the correct abbreviations (see Appendix) from the international list, asking for a repetition of the address, text, etc. (RPT ADR AND TXT K.) When but a few words were lost the last word received correctly is given after ?AA, meaning that "all after" this should be repeated. ?AB for "all before" a stated word should be used if most of the first part of the copy is missing. ?BN . . . . . AND . . . . . (two stated words) asks for a fill "between" certain sections. If only a word or two is lost this is the quickest method to get it repeated.

Do not send words twice (QSZ) unless it is requested. Send single. Do not fall into the bad habit of sending double *without a request* from fellows you work.

Do not accept or start incomplete messages.

9. **A file of messages** handled shall be kept, this file subject to call by the Section Manager at any time at his discretion. Only messages which can be produced shall be counted in the monthly reports, and these under the A.R.R.L. provisions for message-counting.

10. The operator will *never make changes or alterations in the texts or other portions of messages passing through his hands.* However slight or however desirable such changes may seem, the changing of a message without proper authority or without the knowledge of the originator of the message may be considered the "unpardonable sin." The proper thing to do of course is to notify the party filing the message or the originating station of your observations, secure permission from the proper source for making the change by sending a "service message" or other means. If the case seems urgent, the traffic should not be delayed but should be delivered or forwarded with appropriate notation or service accompanying it.

Activities — Contests

Operating in the amateur bands offers many thrills. Routine communication is possible, but even the most consistent and reliable communication by amateur radio is not at all limited to routine. The "unexpected" is always around the corner. A pleasant experience may arrive in the form of unusual DX, a renewed friendship over the air, a chance to render message service in some special case, or a sudden communication emergency in which one may play a part.

Special activities are sponsored by the American Radio Relay League, adding to ham interest and fraternalism at the same time opportunity is given for testing station performance over definite periods, making new friendships and QSOs, and developing operating technique. A.R.R.L. also coöperates with foreign amateur societies in many jointly publicized programs for the operating man that have similar beneficial aims.

Contest activities are diversified as greatly as possible to appeal to every classification of amateur interest showing a desire to participate. The most well known of all are the annual Sweepstakes, and the DX contests, and the Field Day, appealing to all groups.

Within the A.R.R.L. field organization the

World Radio History

first Saturday night each month is set aside for *all* A.R.R.L. officials, officers and Directors to get together over the air from their own stations, wherever located. This work is carried out mainly in the 3.5-Mc. band. The night is known to the gang generally as RM NITE because this get-together started as a gathering of Route Managers only. Special activities also are scheduled quarterly for the ORS-OPS appointees, to test stations and develop operating ability and contact organization officials.

It may be interesting to review briefly the general activities of a typical "full" season, to note the program offered to every A.R.R.L. member — this in addition to the first-Saturday-night officials schedule, and the quarterly ORS/OPS doings, of course.

With the start of the radio season in October, we customarily take part in a VK-ZL (Australia-New Zealand) Contest, operating each week-end of that month to make as many two way contacts with VK's and ZL's as possible. The annual Navy Day Receiving Competition is managed by the A.R.R.L. in late October, an opportunity for any receiving ham to check his copying ability and proficiency by getting the telegraphic dispatches sent from NAA and NPG to amateurs on the occasion of Navy Day, October 27th. An "honor roll" in *QST* and letters of commendation follow this event.

One of the very biggest events of the year is the annual Sweepstakes Contest which has potentialities of operating fun and new QSOs for everybody, the operation extending to all bands. Each November the rules for this are announced. A large number of contacts, new stations, new Sections and other operating records are always reported in and after the "SS" and the spirit of fraternalism prevails. The magic key to open the door to QSOs, new and old, during the Sweepstakes is a CQ SS, sent in a snappy manner, by any ham, anywhere in the 71 A.R.R.L. Sections.

In December a Copying Bee has been arranged. The League offers a special award to the most proficient. Unusual word and figure combinations are transmitted at a fairly rapid speed by tape transmitters from three or four of the more powerful amateur stations throughout the country. Note the schedules in December *QST* and report your copy from one of these stations to A.R.R.L. Coöperative announcements of operating arrangements with other societies are often made for December and January, also.

An A.R.R.L. Member QSO Party is scheduled for January. Also, a study is being made of the possibilities for a big Red Cross Relay in February.

Every year, in March, comes the annual A.R.R.L. International DX Competition, an activity in which W/VE amateurs invite all the world to take part with them. Serial numbers are exchanged as proof of QSOs. New countries, new continents, etc., are worked and many new W.A.C. certificates are awarded annually after the 9-day activity (usually provided with a 90-hour-total-time limit) is over. The QSL-bureaus of the world are also taxed by the annual flood of DX confirmations exchanged by hams after their operating in this DX free-for-all is over. The interest in the DX QSO's made possible is evidenced every year by stacks of logs several feet deep, and hundreds of course enjoy the DX made possible, even without submitting logs. Every ham looks forward eagerly to the full DX report in *QST* which shows his report compared with the others submitted.

The VE/W (Canada-United States) Contact Contest is a chance to see which U. S. A. ham can work most of our Canadian brothers, and vice versa. This is sponsored by the C.G.M. and a Canadian Committee and League certificate awards are made to the winners in each A.R.R.L. Section following this April activity.

Of major importance in the League's operating program, is the annual A.R.R.L. Field Day held on a week-end in June, combining the out-of-door opportunities with the Field testing of portables. As in all our operating, the idea of having a good time is combined with the more serious thought of preparing ourselves to shoulder the communication load as emergencies turn up and the occasion requires. A premium is placed on the use of low or medium power, on portability, and on the use of equipment without connection to commercial sources of power supply. Clubs as well as individuals have a major part in this.

Working DX

Hams who do not raise DX stations readily may find that (a) their sending is poor, (b) their calls ill-timed or judgment in error. It is usually *wasted* effort for W/VE stations to send CQ DX. When conditions are right to bring in the DX, and the receiver sensitive enough to bring in several stations from the desired locality, the way to raise DX is to use the appropriate frequency and to *call these stations.* Reasonably *short* calls, with appropriate and brief breaks to listen will raise stations with minimum time and trouble. The reason W/VE CQs do *not* raise DX is that the number of U. S. A. and Canadian hams is so great that it is always possible for a foreign station to find a large number of W/VE's calling, without wasting time on stations not definitely looking for this station.

A sensitive receiver is often more important than the power input in working foreigners.

World Radio History

There is not much difference in results with the different powers used, though 500 watts will probably give 10% better signal strength at the distant point than 100 watts, other factors being the same. It will not do much better than this because the field strength drops so rapidly as we get away from the antenna. In working foreign countries and DX stations you should be able to hear ten or a dozen stations before expecting that one of them will hear you call.

Conditions in the transmission medium make all field strengths from a given region more nearly equal at a distance, irrespective of power used. In general, the higher the frequency band, the less important "power" considerations become.

General Practices

The signal "V" is used for testing. When one station has trouble in receiving, the operator asks the transmitting station to "QSV" while he tries to adjust his receiving set for better reception. A decimal point is often sent by the letter "R." Example: 2:30 PM is sent "2R30PM." A long dash for "zero" and the Morse C (.. .) for "clear" are in common use. Figures are best spelled out in texts, for highest accuracy. An operator who misses directions for a repeat will send "4," meaning, "Please start me, where?" NFT for "no filing time" is common.

The law concerning superfluous signals should be noted carefully by every amateur. Do not hold the key down for long periods of time when testing or thinking of something to send. If you must test, disconnect the antenna system and use an equivalent "dummy" antenna (made of lumped resistance, capacity and inductance). Send your call frequently when operating with the antenna. Pick a time for adjusting the station apparatus when few stations will be bothered.

Long calls after communication has been established are unnecessary and inexcusable. The up-to-date amateur station uses a "break-in" system of operation and just one switch controlling the power supply to the transmitter. The best sending speed is a medium speed with the letters quickly formed and sent evenly with proper spacing. The standard type telegraph key is best for all-round use. Before any freak keys are used a few months should be spent listening-in and practicing with a buzzer. Regular daily practice periods, two or three half hour periods a day, are best to acquire real familiarity and proficiency with code.

No excuse can be made for a "garbled" text. Operators should copy what is sent and refuse to acknowledge messages until every word has been received correctly. *Good operators never guess.* "Swing" in a fist is *not* the mark of a good operator, is undesirable. Unusual words are sent twice, the word repeated following transmission of "?". If not *sure*, good operators systematically ask for fills or repeats.

Don't say, "QRM" or "QRN" when you mean "QRS."

Don't acknowledge any message until you have received it completely.

Don't CQ unless there is definite reason for so doing. When sending CQ, use judgment. Sign your call frequently, interspersed with calls, and at the end of all transmissions.

Abbreviated standard procedure deserves a word in the interest of brevity on the air. Abbreviated practices help to cut down unnecessary transmission. However, make it a rule not to abbreviate unnecessarily when working an operator of unknown experience.

NIL is shorter than *QRU CU NEXT SKED.* Instead of using the completely spelled out preamble *HR MSG NR 287 W1GME CK 18 MIDDLEBURY CONN OCTOBER 28 TO,* etc., transmission can be saved by using *287 W1GME 18 MIDDLEBURY CT OCT 28 TO,* etc. One more thing that conserves operating time is the cultivation of the operating practice of writing down "287 W1UE 615P 11/13/37" with the free hand during the sending of the next message.

"Handling" a message always includes the transmission and receipt of radio acknowledgment (QSL) of same, and entry of date, time and station call *on the traffic,* as handled, for purposes of record. Chapter Twenty will amplify in detail on that most important phase of communication work, message handling.

Procedure for Voice Work

Most broadcasting work is casual and merely one-way communication while amateur radio and point-to-point services such as the airways require the specific attention of the listener, and receipting for all transmissions. The International Radiotelecommunications Convention and the supplementary regulations thereto prescribe method and system for time saving and maximum understandability. The most effective amateur voice operation conforms closely, where *accuracy* is the required objective, and examples of such procedure in accordance with the universal practice will be given. The general practices of radio extend to voice and telegraph alike and may be followed with the special voice procedure mentioned.

At the start of communication the calling formula is spoken twice by both the station called and the calling station. After contact is established it is spoken once only. Examples:

W5QL calls: "Hello W3JZ Philadelphia, hello W3JZ Philadelphia, W5QL Oklahoma City calling, W5QL Oklahoma City calling, message for you, message for you, come in please."

World Radio History

W3JZ replies: "Hello W5QL Oklahoma City, hello W5QL Oklahoma City, W3JZ Philadelphia answering, W3JZ Philadelphia answering, send your message, send your message, come in please."

W5QL replies: "Hello W3JZ Philadelphia, W5QL Oklahoma City answering, the message begins, from Oklahoma City Oklahoma W5QL number .... [usual preamble, address, text, signature, etc.], message ends; I repeat, the message begins, from Oklahoma City Oklahoma W5QL number ...... [repetition of preamble, address, text, signature, etc.], message ends, come in please."

W3JZ replies: "Hello W5QL Oklahoma City, W3JZ Philadelphia answering, your message begins, from Oklahoma City Oklahoma W5QL number ...... [repetition of complete message], end of your message, come in please."

W5QL replies: "Hello W3JZ Philadelphia, W5QL Oklahoma City answering, you have the message correctly, you have the message correctly, W5QL Oklahoma City signing off."

Note that in handling traffic by voice, messages are repeated *twice* for accuracy, using the word list to spell names and prevent misunderstandings. The receiving station must repeat the message back *in addition.* Only when the sender *confirms* the repetition as correct can the message be regarded as handled.

Word List for Accurate Transmission

When sending *messages* containing radio calls or initials likely to be confused and where errors must be avoided, the calls or initials should be thrown into short code words:

A — ABLE	J — JIG	S — SALE
B — BOY	K — KING	T — TARE
C — CAST	L — LOVE	U — UNIT
D — DOG	M — MIKE	V — VICE
E — EASY	N — NAN	W — WATCH
F — FOX	O — OBOE	X — X-RAY
G — GEORGE	P — PUP	Y — YOKE
H — HAVE	Q — QUACK	Z — ZED
I — ITEM	R — ROT	

Example: *W1BCG* is sent as *WATCH ONE BOY CAST GEORGE.*

A somewhat different list can be obtained from the local Western Union telegraph office and posted beside the telephone to use when telephoning messages containing initials and difficult words. Such code words prevent errors due to phonetic similarity. Here is the Western Union word-list:

A — ADAMS	J — JOHN	S — SUGAR
B — BOSTON	K — KING	T — THOMAS
C — CHICAGO	L — LINCOLN	U — UNION
D — DENVER	M — MARY	V — VICTOR
E — EDWARD	N — NEW YORK	W — WILLIAM
F — FRANK	O — OCEAN	X — X-RAY
G — GEORGE	P — PETER	Y — YOUNG
H — HENRY	Q — QUEEN	Z — ZERO
I — IDA	R — ROBERT	

Names of states and countries are often used for identifying letters in amateur radiotelephone work, the possible objection being the confusion of the names of places with the station's location. It is recommended by A.R.R.L. that use of special abbreviations such as Q code be minimized insofar as possible in voice work, and that full expression (with conciseness) be substituted. O.P.S. have adopted the Western Union word list as A.R.R.L. practice for avoiding difficulty with phonetic similarity. All word lists should be used in moderation, as necessary in avoiding misunderstanding, and at the end of calls not more than once.

Using a Break-In System

If you aim to have the best, and every ham does, you will have break-in, whether of the push-to-talk or open the key variety, but if you haven't the ideal installation yet, by all means operate intelligently and take every advantage of the other fellow's facilities when break-in is offered! Break-in avoids unnecessarily long calls, prevents QRM, gives you more communication per hour of operating. Brief calls with frequent short pauses for reply can approach (but not equal) break-in efficiency.

See Chapter XVII of this book for technical details of "break-in" arrangement.

A separate receiving antenna makes it possible to listen to most stations while the transmitting tubes are lighted. It is only necessary with break-in to pause just a moment occasionally when the key is up (or to cut the carrier momentarily and pause in a 'phone conversation) to listen for the other station. The click when the carrier is cut off is as effective as the word "break."

For *'phone* a push button to put the carrier on the air only while talking is a completely practical device, and amateur 'phone operators would do well to emulate the push-to-talk efficiency of the Airways operators to improve conditions in the 'phone bands.

C.w. *telegraph* break-in is usually simple to arrange. With break-in, ideas and messages to be transmitted can be pulled right through the holes in the QRM. Snappy, effective, efficient, enjoyable amateur work really requires but a simple switching arrangement in your station to cut off the power and switch 'phones from monitor to receiver. If trouble occurs the sending station can "stand by" (QRX), or it can take traffic until the reception conditions at the distant point are again good.

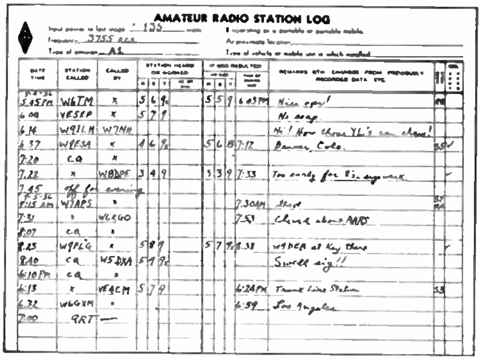
In calling, the transmitting operator sends the letters "BK," "BK IN," or "BK ME" at frequent intervals during his call so that stations hearing the call may know that a break-in is in use and take advantage of the fact. *He pauses at intervals* during his call, to listen for a moment for a reply from the station being called. If the station being called does not answer, the call can be continued. If the station called answers someone else, he will be heard and the calling can be broken off. With *full* break-in, transmitter may be remotely controlled so no receiver switching is necessary. A tap of the key, and the man on the receiving end can interrupt (if a word is missed) since

World Radio History

the receiver is monitoring, awaiting just such directions constantly. But it is not necessary that *you* have such complete perfect facilities to take advantage of break-in when the stations you work are break-in equipped. It is not intelligent handling of a station or coöperation with an operator advertising that he has "bk in" with his calls, to sit idly by minute after minute of a properly sent call. After the first invitation to break is given and at each subsequent pause turn on your transmitter and tap your key — and you will find that conversation or business can start immediately.

Keeping a Log

The F.C.C. requires every amateur to keep a complete station operating record. It may



KEEP AN ACCURATE AND COMPLETE STATION LOG AT ALL TIMES! THE F.C.C. REQUIRES IT

The official A.R.R.L. log is shown above, answering every government requirement in respect to station records. Bound logs made up in accord with the above form can be obtained from Headquarters for a nominal sum or you can prepare your own, in which case we offer this form as a suggestion, hoping that you find it worthy of adoption. Every station must keep some sort of a log. The above log has a special wire binding and lies perfectly flat on the table.

also contain records of experimental tests and adjustment data. A stenographer's notebook can be ruled with vertical lines in any form to suit the user. The Federal Communications Commission requirements are that a log be maintained which shows (1) the date and time of *each* transmission, (2) *all calls* and transmissions made (whether two way contacts resulted or not), (3) the input power to the last stage of the transmitter, (4) the frequency band used, (5) the time of *ending* each QSO, and the operator's identifying signature for responsibility for each session of operating. Messages may be written in the log or separate records kept — but record must be made for one year as required by the F.C.C. For the convenience of amateurs A.R.R.L. stocks both log books and message blanks, and if one uses the official log he is sure to fully comply with the government requirements if the precautions and suggestions included in the log are followed.

Amateur Status

An amateur's most precious possession, by virtue of which he holds his license, is his amateur status. A business house, organized for profit cannot qualify to use amateur frequencies. Amateur radio in its very definition and nature is a non-pecuniary pursuit.

No brief can be held for the amateur who accepts direct or indirect compensation for handling specific messages or any other use of his transmitting station on the air. This violates the terms of the station license and the regulations of F.C.C.

There is a fine distinction here — an amateur can handle messages for any concern or individual as long as he himself does not profit in any way therefrom through the use of his station. An amateur station cannot be hired to be operated for an advertising exhibit in a store, or an operator made to agree as a provision of his employment by a business house to handle messages of the concern while he is accepting pay from the company therefor.

It is the purpose of these paragraphs to warn amateurs to avoid being "used" by commercial interests in unethical ways. A hotel on the Pacific Coast offered an amateur radio club a fine meeting place with free light, power and heat — provided the amateurs would establish an amateur station and relay messages for guests of the hotel. A certain newspaper planned to "organize an amateur radio club" and establish a "net" for the collecting of amateur news for the paper. It offered the amateurs a club room and the facilities of a powerful station that it would install as a "net control station" in return for the things it could gain by making amateurs violate their amateur status!

An amateur who owned and ran a radio business could not conceivably send messages relating to that business over the air through his own amateur station — though any other amateur station might with impunity so engage as long as no compensation existed. A "consideration" of any nature establishes the commercial nature of any traffic or use of station. *Our right to handle worthwhile communications in the U.S.A. is unquestioned.* This is warning about agreements or set ups in which the amateur *accepts* anything for the use of his station which might jeopardize his ability to hold an amateur station license.

The R-S-T System of Signal Reports

The R-S-T system is an abbreviated method of indicating the main characteristics of a re-

World Radio History

ceived signal, the Readability, Signal Strength, and Tone. The letters R-S-T determine the order of sending the report. In asking for this form of report, one transmits RST? or simply QRK?

READABILITY

1 — Unreadable
2 — Barely readable, occasional words distinguishable
3 — Readable with considerable difficulty
4 — Readable with practically no difficulty
5 — Perfectly readable

SIGNAL STRENGTH

1 — Faint — signals barely perceptible
2 — Very weak signals
3 — Weak signals
4 — Fair signals
5 — Fairly good signals
6 — Good signals
7 — Moderately strong signals
8 — Strong signals
9 — Extremely strong signals

TONE

1 — Extremely rough hissing note
2 — Very rough a.c. note, no trace of musicality
3 — Rough, low-pitched a.c. note, slightly musical
4 — Rather rough a.c. note, moderately musical
5 — Musically modulated note
6 — Modulated note, slight trace of whistle
7 — Near d.c. note, smooth ripple
8 — Good d.c. note, just a trace of ripple
9 — Purest d.c. note
(If the note appears to be crystal controlled simply add an X after the appropriate number.)

Such a signal report as "RST 387X" (abbreviated to 387X) will be interpreted as, "Your signals are readable with considerable difficulty; good signals (strength); near d.c. note, smooth ripple; crystal characteristic noticed." Unless it is desired to comment in regard to a crystal characteristic of the signal, *a single three-numeral group will constitute a complete report* on an amateur signal. The R-S-T system is the standard A.R.R.L. method of reporting. Various report combinations are based on the table.

Interference Problems

The subject of public relations is important to us amateurs both individually and as an organization. No amateur can long afford to operate when he knowingly interferes widely with broadcast reception. Even the observance of prescribed quiet hours, while covering the situation legally, does not entirely suffice. Patience in explaining, frankness, tolerance in listening to other viewpoints and other qualities of diplomacy are needed to give the full technical explanations required. Evidence of fair dealing, and coöperation with listeners is always given weight when F.C.C. representatives find it necessary to investigate facts in an interference case.

It is necessary for both parties to an interference problem to understand that *both the transmitter and the receiver* are part of the problem — improved adjustment of the former — improved design of the latter to increase its selectivity, may be necessary. Each individual must accept responsibility for his equipment. Coöperation is the only policy that will help either party.

See Chapter Nine for details on interference filters, wavetraps for receivers, circuits for key thump suppression, etc. A.R.R.L. will be glad to assist all members who write for special interference helps by study of their cases.

Club Interference Work

We recommend and request that each A.R.R.L. affiliated club organization maintain an interference committee, to keep order, make investigations and recommendations locally, coöperate with the press, the public, and listeners who wish to file complaints of amateur interference. These committees can be composed of representative broadcast listeners, amateurs and with one member from a local newspaper to assist in collecting and referring complaints. A few leading questions will disclose the amateur cases and other difficulties can be referred to local power and communications companies.

Emergency Operating Precautions[1]

In emergency operating[1] a fine sense of discrimination is necessary. Desire to help through *transmitting* participation is often a dangerous thing. Careful listening locates stations, places, nets, keeps general calls at minimum and enables handling traffic efficiently responsive to the CQ of an emergency area station. "Talking it over" and general chatter should be *reserved* until emergency conditions no longer exist.

As soon as the F.C.C. has "declared" a condition of general communications emergency, special amateur regulations (Sec. 152.54) govern absolutely, with the following provisions effective until the Commission declares the emergency ended:

1. No transmissions in the 80- or 160-meter bands may be made *except* those relating to the relief or emergency service. Casual conversation, incidental calling or testing, remarks not pertinent to the constructive handling of the emergency communications, shall be prohibited.

2. 25-kc. band-edge segments shall be reserved at all times for (a) emergency calling channels, (b) initial calls from the isolated, (c) first calls initiating dispatch of important priority relief matters. All

stations shall. for general communication, shift to other within-band frequencies for carrying on communication. The channels for calling ONLY, in emergencies, are: 1975–2000* 3500–3525 and 3975–4000 kcs.

3. Hourly observance of mandatory quiet or listening periods, the first five minutes of each hour. (No calls may be answered in this period. Only "utmost priority" traffic may continue.)

4. For promulgating the emergency-declaration, for policing-warning-observing work in 1715–2000 and 3500–4000 kc. bands, F.C.C. may designate certain amateur stations. Announcements from these stations will be identified by their reference to Sec. 152.54 by number, and their specification of the date of the F.C.C.'s declaration, with statement of the area and nature of the emergency.

Where a communications emergency is part of a general emergency accompanied by relief problems and movements of the population it will be found that many refugees are created by the situation and deliveries of ingoing messages to these people are well nigh impossible. There is great good will as a result of handling personal safety messages in each instance where delivery can be effected, but it must be remembered that relief problems of the community at large, official messages from Red Cross, military and civic officials have *absolute priority.* Radio circuits must carry the important messages first, and when personal safety messages are permissible in the judgment of operators in the affected area it is even then much more profitable to have the burden of traffic outgoing messages of safety rather than requests for investigating safety which cannot be acted upon except at a deferred date. Organization must avoid unnecessary duplication of channels, must load telegraph circuits properly to avoid congesting telephone channels where fewer circuits are available. Messages should be routed for point to point delivery by a single channel, and no irritating duplications or repeating of the same messages (broadcast) be permitted where this can be avoided. The function of broadcasting stations is to reach the public, that of amateur stations to handle point to point information efficiently with as little public excitement as possible and maximum secrecy for texts of official messages and any information that might start rumors.

It is important that originating stations *number* their messages and *put them in standard form.* That makes the work systematic and respected and takes it out of the hit or miss classification into which casual exchanges fall in the minds of recipients. Such method in all amateur work instantly nails duplicate messages, makes tracing possible, and makes amateur performance comparable with that of other communication services. See the Chapter on message handling for full details.

Unauthorized broadcasting and modifying of broadcasts [1] addressed to the amateur service has caused difficulty in major emergencies of recent years. Rumors are started by unintelligent expansion or contraction (and subsequent repetitions) of broadcast dispatches. It is improper and deserving of censure and severe penalties to delete essential limiting words that qualify a message, to expand, exaggerate, or alter meanings. Broadcasts should include their source and authority; they should be repeated exactly if at all, or not repeated; League and F.C.C. transmissions through vigilantes appointees in emergencies of the future will as in the past extend no authority, or specified limited authority, to rebroadcast.

The League's Emergency Corps (also covered in Chapter Twenty) has adopted the principles tabulated for "before — in — after emergencies" and in addition is pledged to a man to observe the following:

. . . . to confirm the authenticity of reports, and as a responsible individual avoid publication or transmission of any rumor, except labelled as such. (Vital information should be released only when verified by proper authority. Make your operation in connection with official agencies such as the Red Cross, civil and military authorities so that messages may be signed by *officials* in as many cases as possible.)

. . . . to work closely with any A.R.R.L. (city or regional) Emergency Coördinator that may be appointed. Also to coöperate with Section Communications Manager, Route Manager, or Phone Activities Manager in any definite steps for emergency organization.

. . . . to have proper regard to priority of communications. To keep quiet (QRX) as much as possible to reduce interference. Priority is normally determined within the emergency zone itself.

. . . . to become acquainted with the special frequencies and facilities of organized amateur groups, the A.A.R.S. and U.S.N.R.

. . . . to use QRR *only* if necessary, and then use it correctly. (It may ONLY be used by a station in an emergency zone with an actual distress message.)

Emergency Communication

A communications emergency occurs whenever normal facilities are interrupted or overloaded, and may or may not involve general public participation. A communications emergency need not involve a public relief or welfare emergency, but the latter condition usually is accompanied by a communications emergency.

In scores of emergencies radio amateurs have given a good account of themselves. Radio has proved the only agency to span the gap with power failing and wires down. Since our amateur stations are of the most numerous class licensed, because they are located anywhere and everywhere, many are located strategically to give an account of themselves as need arises. Those amateurs best *prepared* before trouble comes are credited with having played most important parts. It should be a matter of pride with every amateur to fit himself as a superlative *operator,* and equip himself with apparatus with an eye to emergencies when power may evaporate from customary commercial sources with a view to

World Radio History

BEFORE EMERGENCIES

Be ready, with emergency power supply. Six-volt tubes in exciters and receivers make for convertibility and utility in portable work where gas engine generators are not available. Overhaul and test periodically.

Test set/operator ability in A.R.R.L. Field Day and Contests. Give local officials and agencies your address; explain amateur facilities; act via the A.R.R.L. Emergency Coördinator wherever one is appointed.

IN EMERGENCY

REPORT at once to the A.R.R.L. Emergency Coördinator so he will have full data on availability of stations — operators — circuits. Work direct with agencies we serve where no appointed official is in charge, and when so assigned.

CHECK station operating facilities; offer services to all who may use them, via Coördinator or helping official where one is available.

QRR is the official A.R.R.L. "land SOS," a distress call for emergency uses *only* . . . for use *only* by station asking assistance.

RESTRICT all work in accord with F.C.C. regulations, Sec. 152.54, as soon as F.C.C. has "declared" a state of communications emergency.

THE KEY STATION in emergency zone is the first and the supreme authority for priority and traffic routing in the early stages of emergency relief communications.

PRIORITY must be given messages in the general public interest (relief plans, re food, medicine, necessities). Press reports and personal assurance messages can then be handled if practicable.

COÖPERATION is required of all amateurs with those we serve; with other communication agencies. Don't clutter air with CQ's. The *majority* of amateurs must *listen in;* QRX, avoid QRMing. Be ready to help; operate as intelligently as possible; coöperate by staying off the air while vital information and relief measures are handled, if stations able to help as well as yours are on the job. (CQ STORM AREA is nothing but "more QRM.")

AFTER EMERGENCIES

REPORT to A.R.R.L. as soon as possible and as fully as possible so amateur radio can receive full credit. Amateur radio communication in 52 major disasters since 1919 has won glowing public tribute. Maintain this record.

carrying on the vital service of amateur communication if urgent opportunity for a service large or small arrives. An earlier Chapter has covered important equipment provisions relative to making our stations prepared for emergency. It is the purpose of this section to summarize some emergency operating principles that should govern in amateur emergency operations, if greatest effectiveness within the amateur service is to be attained.

We serve *best* by manning a few powerful, best situated stations with amateur operators in 8-hour shifts, rather than inadequately manning too many amateur stations with overworked operators creating band congestion. Coördinators will aim to create an organized operator-reserve in general emergencies. See Chapter Twenty-one which outlines the functions of A.R.R.L. Emergency Coördinators.

Those we serve in widespread emergency are the Red Cross, civil and military authorities, transportation agencies, power-gas-light-water utilities, the Coast Guard, Army engineers and others. In doing this we often work hand in hand with other wire and radio services as well as with each other.

In the event of new cases of serious and widespread communications emergency, it is likely that the F.C.C. will follow precedent (and its new regulations, Sec. 152.54) and again declare a general communications emergency. Then, as in the Ohio valley flood (1937) it is likely that F.C.C. will call on your A.R.R.L. to recommend policing-observing stations for F.C.C. to appoint in the different amateur bands to function for the duration of the emergency. A.R.R.L. stands ready with its experience, its program of preparedness, and its member-station organization in which every live amateur who volunteers has a part.

Monitored Frequencies

A few words on the last two points: In dire disaster where life and property are threatened and a region is isolated except for wireless communication, government aid may be secured when all attempts on normal channels have failed, by "breaking" an existing government circuit. A.A.R.S. use 6990-, 3497½-, etc., kcs. Naval shore stations guard certain frequencies constantly, also. In the east 4040-, 4075, 4235- and 8920- kcs. at night, or 7995 kcs. in daylight hours, and in the west 4010-, 4235-, 4525- and 7995- kcs. are the night, with 8150 kc. a day frequency.

Emergency Calling Frequencies

Regarding QRR, which call is limited to use of isolated stations for first emergency calls, special provision and methods are necessary to assist the stations under handicap of no commercial power in remote sections in getting

World Radio History

contact and help. Their problem is vital, and different from the problem of casual participation by the amateur community at large.

It is recommended by A.R.R.L. that frequencies *at the band edges* be utilized for emergency calls, with no general emergency declared or in effect. This lends point and specification to builders of emergency equipment. This spot on all bands is well covered continuously by receivers. It gives hope to the isolated operator that he be heard. At such frequencies all listeners are instructed to hunt for weak signals in any periods in general emergency established for taking account of the isolated, and establishing new important connections.

The F.C.C. regulations now *require* that in general emergency 2000–1975* kcs., 4000–3975 kcs. and 3500–3525 kcs. shall be reserved as *emergency calling channels* — prohibited to all stations except for first emergency or QRR calls, and initial or important emergency relief traffic or arrangements, *whenever F.C.C. shall have recognized and declared a general communications emergency exists.* All stations using such channels shall as rapidly as practicable shift to normal working and calling frequencies, to leave these emergency channels clear for important calls of this type.

0000–0005 Listening Time in Emergency

The Federal Communications Commission rules also require that in emergency, all amateur stations in the designated areas observe a silent or listening period for the *first five minutes of each hour* (0000–0005), *on all amateur channels* (3500–4000 kcs., 1715–2000 kcs.), tuning through the emergency calling channels *and other channels* for any QRR or initial-important calls from weak stations, previously unheard in interference.

The League requests the fullest collaboration and coöperation of all amateurs to add to our public service record. *Preparedness* of station and operator is the first step. Voluntary enlistment of every amateur is requested (1) in abiding by the precepts above outlined (2) in registering in the A.R.R.L. Emergency Corps (3) in coöperation for local community and regional planning and tests, which will be initiated by appointed coördinators and other League Officials (4) in building self-powered[2] equipment.

After emergency (large or small) full individual reports to the A.R.R.L. Communications Department are requested for the amateur service record. The part that every amateur played must be recorded not only for the *QST* account, but to strengthen and support the running record of amateur achievement.

From analysis of all reports A.R.R.L. Public Service Certificates are awarded for notable "public service" work.

Stations outside an "emergency zone" in communication with relief stations in that zone are requested to inform A.R.R.L. Headquarters at once of this situation by telegram to facilitate traffic movement and for the information of the press.

Bibliography

[1] Plans for Emergency Operating, page 35, April 1938 *QST*.[2] Practical Organization and Equipment for Emergency Operation (Tynes), p. 13, Feb. 1937 *QST*. * With a prospective F.C.C. change in early 1939 from 1715–2000 kcs. to 1750–2050 kcs., it is likely that this "calling" band segment for emergencies will become 2025–2050 kcs. QRR Preparation (Burchfield), p. 59, Jan. 1937 *QST*; A Compact Airplane Type Transmitter with Vibrator Power Supply, p. 46, Sept. 1937 *QST*; A Unit Style Portable Station, p. 20, Aug. 1937 *QST*; Break-in Operation with a Dynamotor, p. 50, Aug. 1937 *QST*; New Vibrator Type Plate Supplies, p. 52, Aug. 1937 *QST*; Rewinding an Auto Generator for 110 v.a.c. p. 26, Nov. 1937 *QST*; A Battery Operated Emergency Rig of Proved Performance, p. 14, June 1937 *QST*; A 28-Mc. Mobile Installation, p. 49, June 1937 *QST*; A Complete Portable Station with Crystal Control, p. 11, June 1937 *QST*; A Four-Band Portable or Mobile Transmitter, p. 23, July 1937 *QST*; A Versatile Emergency Transmitter, p. 36, Oct. 1937 *QST*; DeLuxe Battery-Operated Portable Stations, p. 20, April, 1938 *QST*; 56-Mc. Transceiver, p. 28, April, 1938 *QST*; (June '36 *QST*, page 43, and Aug. '36 *QST*, page 39, give numerous "possible" and then popular tube line ups); A Portable-Mobile Crystal-Controlled U.H.F. Transmitter, p. 37, May 1938 *QST*; 75-Meter 'Phone in the Maine Woods (portable), p. 27, June 1938 *QST*; A Three-Tube Super for Portable or Emergency Work (Grammer), p. 8, Aug. 1938 *QST*; Norfolk Amateurs Prepare for Emergencies (W3EMM-W3BEK), p. 8, Sept. 1938 *QST*.

World Radio History

that, where feasible, words be substituted for figures to reduce the possibility of error in transmission. Detailed examples of word counting are about as difficult in one system of count as another.

Count as words dictionary words taken from English, German, French, Spanish, Latin, Italian, Dutch and Portuguese languages: initial letters, surnames of persons, names of countries, cities and territorial subdivisions. Abbreviations as a rule should be used only in service messages. Complete spelling of words is one way to avoid error. Contractions such as "don't" should be changed to "do not." Examples:

Emergency (English dictionary)	1 word
Nous arriverrons dimanche (French dictionary)	3 words
DeWitt (surname)	1 word
E.L.B.D. (initials)	4 words
United States (country)	1 word
President Hoover (steamship)	1 word
Prince William Sound	3 words
M.S. City of Belgrade (motor ship)	2 words

EXCEPTIONS

A.M., P.M.	1 word
F.O.B. (or fob)	1 word
O.K.	1 word
Per cent (or percent)	1 word

Figures, punctuation marks, bars of division, decimal points, count each separately as one word. The best practise is to spell out all such when it is desired to send them in messages. In groups consisting of letters and figures *each* letter and figure will count as one word. In ordinal numbers, affixes d, nd, rd, st, and th count as one word. Abbreviations of weights and measures in common use count as one word each. Examples:

10 000 000 (figures)	8 words
Ten millions (dictionary words)	2 words
5348 (figures)	4 words
67.98 (figures)	5 words
64A2	4 words
45¼ (figures and bar of division)	5 words
3rd (ordinal number and affix)	2 words

Groups of letters which are not dictionary words of one of the languages enumerated, or combinations of such words will count at the rate of five letters or fraction thereof to a word. In the case of combinations each dictionary word so combined will count as a word. In addition USS USCG etc. written and sent as compact letter-groups count as one word. Examples:

Tyffa (artificial 5 letter group)	1 word
Adecol (artificial 6 letter group)	2 words
allright, alright (improperly combined)	2 words
Dothe (improperly combined)	2 words
ARRL	1 word

At the request of sender the words "report back delivery" asking for a service showing success or failure in delivering at the terminal station, may be inserted after the check or "rush" or "get answer" similarly, such words counting as extras in the group or check designation as just covered by example. "Phone" or "Don't Phone" or other sender's instructions in the address are not counted as extra words. In transmitting street addresses where the words east, west, north or south are part of the address, spell out the words in full. Suffixes "th," "nd," "st," etc., should not be transmitted. Example: Transmit "19 W 9th St" as "19 West 9 St." "F St NE" should be sent, "F St Northeast." When figures and a decimal point are to be transmitted, add the words CNT DOT in the check.

Isolated characters each count as one word. Words joined by a hyphen or apostrophe count as separate words. Such words are sent as two words, without the hyphen. A hyphen or apostrophe each counts as one word. However, they are seldom transmitted. Two quotation marks or parenthesis signs count as one word. Punctuation is *never* sent in radio messages except at the express command of the sender. *Even then it is spelled out.*

Here is an example of a plain language message in correct A.R.R.L. form carrying the land line check:

NR 601 W1AW CK 9 WEST HARTFORD CONN
1R15P OCT 28

ALL RADIO HAMS
9 COMPLETE ADR ST
ANYCITY USA

ALL AMATEURS ARE REQUESTED TO FOLLOW STANDARD ARRL FORM
HANDY ARRL CM

Very important messages should be checked carefully to insure accuracy. Request originators *to spell out all punctuation marks that must appear in delivered copies. Likewise, never abbreviate in texts,* or use ham abbreviations except in conversations.

Message handling is one of the major things that lies in our power as amateurs to do to show our amateur radio in a respected light, rather than from a novelty standpoint. Regardless of experimental, QSL-collecting, friendly ragchews, and DX objectives, we doubt if the amateur exists who does not want to know how to phrase a message, how to put the preamble in order, how to communicate wisely and well when called upon to do so. Scarcely a month passes but what some of us in some section of our A.R.R.L. are called upon to add to the communication service record of the amateur.

It is important that deliveries be made in business-like fashion to give the best impression, and so that in each case a new friend and booster for amateur radio may be won. Messages should be typed or neatly copied, preferably on a standard blank, retaining original for the F.C.C. station file where these

World Radio History

are mailed. The designation and address of the delivering station should be plainly given so a reply can be made by the same route if desired.

For those who would disparage some message texts as unimportant, perhaps a reminder is in order that in the last analysis it is not the importance to the ham that handles it that counts, but the importance to the party that sends and the party that receives a message.

The individual handling of traffic in quantities small as well as large is to a very great extent the material that we amateurs use for developing our operating ability, for organizing our relay lines, for making ourselves such a very valuable asset to the public and our country in every communications emergency that comes along, not to mention the individual utility and service performed by each message passed in normal amateur communications.

For those "breaking-in" may we say that any O.R.S., Trunkliner or experienced A.R.R.L. traffic handler will be only too glad to answer your questions and give additional pointers both in procedure and concerning your station set-up to help you make yours a really effective communications set-up. Since experience is the only real teacher we conclude by suggesting to all and sundry that becoming proficient in any branch of the game is partly just a matter of practice. Start a few messages, to get accustomed to the form. Check some messages to become familiar with the official A.R.R.L. (land line) check. You will find increased enjoyment in this side of amateur radio by adding to your ability to perform; by your familiarity with these things the chance of being able to serve your community or country in emergency will be greater. Credit will be reflected on amateur radio as a whole thereby.

Foreign Traffic Restrictions

Any and all kinds of traffic may be handled between amateur stations in different parts of the United States, Hawaii, Alaska, and Porto Rico. There is no qualification or restriction except that amateur status must be observed and no compensation, direct or indirect, be accepted for station operations or services. Radio amateurs in all U. S. possessions except the Philippines (which has its own radio administration) are licensed by the U. S. Federal Communications Commission. The F.C.C. permits U. S. amateurs to handle with P. I. all types of communication permitted internally in the U. S. as with the other possessions. But the Philippine Island administration, since part of the inter-island communications system is government owned, leans toward the incorporation of certain additional restrictions on its amateurs relating to the handling of messages of "business importance."

There is a binding international communications treaty in full effect between the United States and the following foreign countries: Aden, Australia and territories, Austria, Belgium and Belgian Congo and Ruandi Urundi, Brazil, Bulgaria, Burma, Dominican Republic, China, Colombia, Cuba, Czechoslovakia, Danzig, Denmark, Egypt, Estonia, Ethiopia, Finland, France, Germany, Great Britain, Hungary, Iceland, British India, Italy and its colonies and islands, Japan (and Chosen, Taiwan, Karafuto, Kwantung, and islands under mandate), Luxembourg, Morocco except Spanish zone, the Netherlands plus Netherlands Indies, Norway, Portugal, Rumania, Surinam and Curaçao, New Zealand, Persia, Poland, Spain and its territory of Gulf of Guinea, Southern Rhodesia, Sweden, Switzerland, Syria & Lebanon, Union of South Africa, Tunesia, Uruguay, Vatican City State, Venezuela, Yugoslavia.

Internationally the general regulations attached to the international communications treaty state the limitations to which work between amateur stations in different foreign countries is subject. In practically every country outside our own country and its possessions, the government owns or controls the public communications systems. Since these systems are maintained as a state monopoly, foreign amateurs have been prohibited by their governments from exchanging traffic which might be regarded as "competition" with state owned telegraphs. The international treaty regulations reflect this condition and the domestic traffic restrictions (internal policy) of the majority of foreign countries. Oct. 1935 *QST* (p. 57–58), Sept. 1936 *QST* (p. 41–42) and Sept. 1937 (p. 57) give interesting résumés of the amateur regulations of foreign countries. Any country ratifying the Madrid (1932) or Cairo (1938) Conventions can make its domestic regulations as liberal as it likes; in addition it may conclude special agreements with other governments for amateur communications that are *more liberal* than the quoted terms of the treaty itself. If no specific formal negotiations have been concluded, however, amateurs must observe the following (treaty) regulations in conducting international amateur work:

> **The exchange of communications between amateur stations and between private experimental stations of different countries shall be forbidden if the Administration of one of the interested countries has given notice of its opposition to this exchange.**
>
> **When this exchange is permitted the communications must be conducted in plain language and be limited to remarks of a personal nature, for which, by reason of their lack of importance, recourse to the public telegraph service would not be warranted. It shall be absolutely forbidden to licenses of amateur stations to transmit international communications emanating from third parties. The above provisions may be modified by special arrangements between the interested countries.**

World Radio History

Referring to the first paragraph above, in the years since the Washington Convention (1927) *no* prohibition on amateur communication (international QSOs) has been filed by *any* country with the Berne Bureau. In some countries, principally European, amateurs are restricted by regulation to privileges much *less* than made available by international agreement. The use of some amateur bands is withheld, or the width of certain band severely restricted by proclamation of "buffer bands," power is restricted, absurd time regulations restricting operation to two hours per day, fifteen minutes per hour, etc., enacted, and "third party" messages absolutely forbidden *domestically* as well as internationally. In the U. S. A. it is the policy, and of course necessary to take care of our greater numbers of amateurs, to give amateurs the fullest frequency allocations and rights possible under international treaty provisions, and to permit free exchange of domestic non-commercial traffic in addition. This policy has justified itself, giving the public amateur radio traffic service, and developing highly skilled operators and technicians who have the ability to keep the U. S. A. in the lead in radio matters.

The second paragraph quoted prohibits *international* handling of third party traffic, except where two governments have a special arrangement for such exchange. In any event, traffic relating to experimental work, and personal remarks which would not be sent by commercial communications channels may be sent, when in communication with foreign amateurs.

A considerable number of Central and South American countries are signatory to an inter-American agreement, concluded at Habana (Nov. '37), in which they all signify their willingness to allow amateurs to handle traffic between their respective countries in the western hemisphere. This permissive agreement permitting third party traffic handling was effective in mid-1938, but subject to ratification by the ten or twelve contracting governments. Information on ratifications, naming the countries so favoring amateurs, will appear in *QST*, as rapidly as it becomes available.

Previous special arrangements, extending the basic international telecommunications treaty arrangements have also been effected through A.R.R.L. and U. S. A. representations. The special U. S. A.-Canadian agreement will be explained. Similar arrangements with Chile and Peru permit the handling to those countries of certain types of traffic. With all other countries besides those listed as ratifying the binding international treaty we are free to handle third-party traffic — if we can find a ham on the other end who is not prohibited by his government from handling messages.

The Canadian Agreement

The special reciprocal agreement concluded between our country and the Dominion of Canada at the behest of the A.R.R.L. permits Canadian and U. S. amateurs to exchange messages of importance under certain restrictions. This agreement is an expansion of the international regulations to permit the handling of important traffic.

The authorized traffic is described as follows:

"1. Messages that would not normally be sent by any existing means of electrical communication and on which no tolls must be charged.

"2. Messages from other radio stations in isolated points not connected by any regular means of electrical communications; such messages to be handed to the local office of the telegraph company by the amateur receiving station for transmission to final destination, e.g., messages from expeditions in remote points such as the Arctic, etc.

"3. Messages handled by amateur stations in cases of emergency, e.g., floods, etc., where the regular electrical communication systems become interrupted; such messages to be handed to the nearest point on the established commercial telegraph system remaining in operation."

The arrangement applies to the United States and its territories and possessions including Alaska, the Hawaiian Islands, Porto Rico, the Virgin Islands, the Panama Canal Zone and the Philippine Islands. The agreements with Chile and Peru are similar to the above.

Originating Traffic

Messages to other amateurs are a natural means of exchanging comment and maintaining friendships. The simplest additional way to get messages is to offer to send a few for friends, reminding them that the message service is free and no one can be held responsible for delay or non-delivery. Wide-awake amateurs have distributed message blanks to tourist camps. Lots of good traffic has been collected through a system of message-collection boxes placed in public buildings and hospitals. A neatly typed card should be displayed near-by explaining the workings of our A.R.R.L. traffic organization, and *listing the points to which the best possible service can be given.*

Messages that are not complete in every respect *should not be accepted* for relaying. *Complete address* on every message is important.

To properly represent amateur radio, placards when used should avoid any possible confusion with telegraph and cable services. Any posters should refer to AMATEUR RADIO-

World Radio History

GRAMS, and explain that messages are sent through AMATEUR RADIO STATIONS, as a HOBBY, FREE, without cost (since amateurs can't and will not accept compensation). The exact conditions of the service should be stated or explained as completely as possible, including the fact that there is NO GUARANTEE OF DELIVERY. The individual in charge of the station has full powers to refuse any traffic unsuitable for radio transmission, or addressed to points where deliveries cannot be made. Relaying is subject to radio conditions and favorable opportunity for contacting. Better service can be expected on 15-word texts *of apparent importance* than on extremely long messages. Traffic should *not* be accepted for "all over the world."

Careful planning and organized schedules are necessary if a *real* job of handling traffic is to be done. Advance schedules are essential to assist in the distribution of messages. It may be possible to schedule stations in cities to which you know quantities of messages will be filed. Distribute messages, in the proper directions, widely enough so that a few outside stations do not become seriously overburdened. Operators must route traffic properly — not merely aim to "clear the hook."

It is better to handle a small or moderate volume of traffic *well* than to attempt to break records in a manner that results in delayed messages, non-deliveries, and the like which certainly cannot help in creating any public good-will for amateur radio.

Whatever type of exhibit is planned, write A.R.R.L. in advance, in order to receive sample material to make your amateur booth more complete. A *portable* station can be installed and operated, by an already licensed amateur subject to F.C.C. notification of location, etc., as provided by regulations. No license coverage is needed if no station is operated, of course.

Amateur Stations at Exhibits and Fairs

If the time is short and there is no opportunity for special organization of schedules to insure reliable routing and delivery, quite likely exhibit work, to be most productive of good-will results, had best *not* include message handling plans — at least not from the booth-station itself where subject to noise, electrical interference, and other handicaps. To handle such traffic as offered with *real efficiency*, it should be distributed for origination via existing schedules of the *several most reliable local amateur stations. By dividing the traffic filed with other stations it may be sent more speedily on its way.* Be sure that the operators undertaking to help are qualified and have good schedules for distributing messages.

"Show stations" must avoid origination of "poor traffic" by rigid supervision and elimination of meaningless messages with guessed-at inaccurate and incomplete addresses *at the source.*

General

In successful relaying, *all* factors including "apparent importance" must be taken into account. Incomplete preambles are a common fault. Every station should demand an "office of origin" from stations who have messages, and traffic may be rightly cancelled (QTA) on failure to include it. Thus messages will never get on the air without a starting place.

Originating stations should refuse to accept messages to transmit when it is apparent that the address is too meagre. A simple log book, a good filing system, an accurate frequency meter and an equally accurate clock, are sure signs of a well-operated station. The apparatus on the operating table will tell a story without words.

The well-balanced amateur will not only know how to handle a message, but will have extended the principles of neatness and efficiency to his other station activities. The complete amateur station includes attention to traffic matters as part of its regular routine; it is one essential in building a reputation for "reliability" in amateur work. Communication (general) involves an exchange of thoughts. "Traffic" is merely the exchange of thoughts for ourselves or others using *messages.*

Relay Procedure

Messages shall be relayed to the station nearest the location of the addressee and over the greatest distance permitting reliable communication.

No abbreviations shall be substituted for the words in the text of a message with the exception of "service messages," to be explained. Delivering stations must be careful that no confusing abbreviations are written into delivered messages.

Sending "words twice" is a practice to avoid. Use it only when expressly called for by the receiving operator when receiving conditions are poor.

Messages shall be transmitted as many as three times at the request of the receiving operator. Failing to make a complete copy after three attempts, the receiving operator shall cancel the message (QTA).

Agreement to handle (relay or deliver) a message properly and promptly is always tacitly implied in accepting traffic. When temporarily *not* in a position to so handle, it is a service to amateur radio and your fellow ham to courteously *refuse* a message.

An operator with California traffic does not hear any western stations so he decides to give

World Radio History

a directional "CQ" as per A.R.R.L. practice. He calls, *CQ CALIF CQ CALIF DE W1INF W1INF W1INF*, repeating the combination three times.

He listens and hears W9CXX in Cedar Rapids calling him, *W1INF W1INF W1INF DE W9CXX W9CXX W9CXX AR.*

Then he answers W9CXX indicating that he wishes him to take the message. W1INF says *W9CXX W9CXX DE W1INF R QSP MILL VALLEY CALIF NEAR SF? K.*

After W9CXX has given him the signal to go ahead, the message is transmitted, thus:

HR MSG NR 78 W1INF CK18 WEST HARTFORD CONN NFT (for "no filing time") NOV 18

ALAN D WHITTAKER JR W6SG
79 ELINOR AVE
MILL VALLEY CALIF

SUGGEST YOU USE ARRL TRUNK LINE K THROUGH W5NW TO HANDLE PROPOSED VOLUME TRAFFIC REGARDS

BUBB W1JTD

W9CXX acknowledges the message like this: *W1INF DE W9CXX NR 78 R. K.* Not a single *R* should be sent unless the whole message has been correctly received.

Full handling data is placed on the message for permanent record at W1INF. The operator at W9CXX has now taken full responsibility for doing his best in forwarding the message.

Getting Fills

If the first part of a message is received but substantially all of the latter portions lost, the request for the missing parts is simply *RPT TXT AND SIG*, meaning "Repeat text and signature." *PBL* and *ADR* may be used similarly for the preamble and address of a message. *RPT AL* or *RPT MSG* should not be sent unless nearly all of the message is lost.

Each abbreviation used after a question mark (. . — — . .) asks for a repetition of that particular part of a message.

When a few word-groups in conversation or message handling have been missed, a selection of one or more of the following abbreviations will enable you to ask for a repeat on the parts in doubt. 'Phone stations of course request fills by using the full wording specified, without attempt at abbreviation.

Abbreviation	*Meaning*
?AA	Repeat all after
?AB	Repeat all before
?AL	Repeat all that has been sent
?BN...AND	Repeat all between..and....
?WA	Repeat the word after
?WB	Repeat the word before

The good operator will ask for only what fills are needed, separating different requests for repetition by using the break sign or double dash (— . . . —) between these parts. There is seldom any excuse for repeating a whole message just to get a few lost words.

Another interrogation method is sometimes used, the question signal (. . — — . .) being sent between the last word received correctly and the first word (or first few words) received after the interruption. *RPT FROM . . . . TO . . . .* is a long way of asking for fills which we have heard used by beginners.

The figure four (. . . . —) is a time-saving abbreviation which deserves popularity with traffic men. It is another of those hybrid abbreviations whose original meaning, "Please start me, where?" has come to us from Morse practice. Of course *?AL* or *RPT AL* will serve the same purpose, where a request for a repetition of parts of a message have been missed.

Delivering Messages

Provisions of the Radio Act of 1934 make it a misdemeanor to give out information of any sort to any person except the addressee of a message. It is in no manner unethical to deliver an unofficial copy of a radiogram, if you carefully mark it *duplicate* or *unofficial copy* and do it to improve the speed of handling a message or to insure certain and prompt delivery. Do not forget that there are heavy fines prescribed by Federal laws for divulging the contents of messages to anyone *except* the person addressed in a message.

When it is possible to deliver messages in person, that is usually the most effective way. When the telephone does not prove instrumental in locating the party addressed in the message it is usually quickest to mail the message.

A.R.R.L. delivery rules:

Messages received by stations shall be delivered immediately.

Every domestic message shall be relayed within forty-eight (48) hours after receipt or if it cannot be relayed within this time shall be mailed to the addressee.

Messages for points outside North America must not be held longer than half the length of time required for them to reach their destination by mail.

When a message cannot be delivered, or if it is unduly delayed, a "service" message should be written and started back to the "office of origin."

Each operator who reads these pages is asked to assume *personal responsibility* for accuracy, speed of each message handled and *delivery* that we may approach a 100% delivery figure.

The Service Message

A service message is a message sent by one station to another station relating to the service which we are or are not able to give in message handling. The service message may

World Radio History

refer to non-deliveries, to delayed transmission, errors, or to any phase of message handling activity. It is not proper to abbreviate words in the texts of regular messages, but it is quite desirable and correct to use abbreviations in these station-to-station messages relating to traffic-handling work. Example:

HR SVC NR 291 W3CA CK XX ROANOKE VA NFT AUG 19
L C MAYBEE W7GE
110 SOUTH SEVENTH AVE
PASCO WASHN —···—
UR NR 87 AUG 17 TO CUSHING SIG BOB HELD HR UNDLD PSE GBA —···—
WOHLFORD W3CA

Counting Messages

To compare the number originated and delivered each month to learn some facts about the "efficiency" of our work in handling messages, a method of counting is used. Each time a message is *handled by radio* it counts one in the total.

A message received in person, by telephone, by telegraph, or by mail, *filed at the station and transmitted by radio* in proper form, counts as *one originated.*

A message *received by radio and delivered* in person, by telephone, telegraph, or mail, counts as *one delivered.*

A message *received by radio and sent forward by radio* counts as two messages *relayed* (one when received and again one when sent forward).

All messages counted under one of the three classes mentioned must be handled within a 48-hour (maximum) delay period to count as "messages handled." Messages for continents except North America may be held half the length of time it would take them to reach their destination by mail. A "service" message counts the same as any other type of message.

Extra Delivery Credit

In addition to the basic count of *one* for each time a message is handled by radio, an *extra credit* of one point for each delivery made by mail, telephone, in person, by messenger or other external means *other than use of radio* (which would count as a "relay" of course) will also be allowed. A message received by an operator for himself or his station or party on the immediate premises counts *only* "one delivered." A message for a third party delivered by *additional means or effort* will receive a point under "extra delivery credits."

The message total shall be the *sum* of the messages originated, delivered and relayed and the "extra" delivery credits. Each station's message file and log shall be used to determine the report submitted by that particular station. Messages with identical texts (so-called rubber-stamp messages) shall count once only for *each* time the complete text, preamble and signature are sent by radio.

A.R.R.L. traffic totals may include all traffic handled on amateur frequencies with full data included by any standard form of message. Most messages you receive will be in standard A.R.R.L. form. But traffic in N.C.R. or A.A.R.S. form (when in drills or net operation using an amateur frequency) counts too, the principle being that when all essential data required by those agencies are included a message may be considered complete. In whatever volunteer work it is engaged, a station has an amateur status, and the total is a strictly "amateur" total if handled under ham-band conditions on amateur frequencies.

Classify Your Amateur, A.A.R.S. and N.C.R. Traffic

Traffic handled under a government (non-amateur) call, on a non-amateur-band frequency, should not be counted in "amateur" totals reported to S.C.M.s, but should be classified separately. Both the amateur total, and the "army" and "navy" totals, as the case may be, may be sent to your A.R.R.L. Section Manager, who invites these reports. Such totals must be clearly and separately classified, since in our B.P.L. it is our desire to avoid placing amateur-band work in direct competition with that accomplished on special frequencies.

Message texts should be transmitted *exactly* as received. Do not accept messages unless and until words are spelled out completely. No abbreviations in texts is an excellent rule. It is *not* a violation of good practice to change the *order* of preamble though, when traffic is transferred between services. Standard *amateur* procedure uses the land line check. The preamble goes NR-STN CALL-CK-PLACE OF ORIGIN-TIME-DATE. The NCR uses tactical procedure, and cable count check, which is a check including words (or groups) in address, text, and signature, customary in all maritime work.

Examples of Counting

A monthly report should be sent to the local A.R.R.L. S.C.M. The closing date of the "message month" is the 15th of each month (the last of the month in Hawaii and the Philippines). Reports must go forward the next day. Some examples:

Let us assume that on the 15th of the month one operator of a large amateur station receives several messages from another station. (a) Some of these messages are for relaying by radio. (b) Some of them are for local delivery. (c) There are still other messages the disposal of which cannot be accurately predicted. They

World Radio History

are for the immediate neighborhood but either can be mailed or forwarded to another amateur by radio. A short-haul toll telephone call will deliver them but the chances of landing them nearer the destination by radio are pretty good. This operator's "trick" ends at midnight on the 15th and he must make the report with some messages "on the hook" to be carried over for the next month's report.

(a) The messages on the hook that are to be relayed have been received and are to be sent. They count as "1 relayed" in the report that is made out now, and they will also count as "1 relayed" in the next month's report (the month during which they were forwarded by radio).

(b) By mailing or 'phoning the messages at once, they count as "1 delivered" for the current report. By holding them until next day they will count in the *next* report as "1 delivered." Also they will each have a count of one *extra* delivery credit since they had to be telephoned, mailed, etc.

(c) The messages in this class may be carried forward into the next month. If they *have* to be mailed then they will count in the *next* report as "1 delivered." If they are relayed, we count them as "1 relayed"; "1 received" in the preceding month (already reported) and "1 relayed" for the next month, the month in which it was sent forward by radio. If the operator wishes to count this message *at once* as delivered it must be mailed promptly and counted at once.

Some examples of counting:

The operator of Station A gets a message by radio from Station B addressed to himself. This counts as "1 delivered" by himself and by Station A. There is no extra delivery credit possible for no additional delivery effort was needed.

The operator of Station A takes a verbal message from a friend for relaying. He gives it to Station B over the telephone. Operator A does not handle the message by radio. Station B and operator B count the message as "1 originated." A cannot count the message in *any* manner.

The operator and owner of Station A visits Station B and *while operating* there takes a message for relaying. The operator and owner of B cannot operate for a day or two so the message is carried back to Station A by operator A who relays it along within a few hours. The traffic report of both Station A and Station B shows "1 relayed" for this work.

Please note that "handling" a message always includes the transmission and receipt of radio acknowledgment (QSL) of same, and the entry of date, time, and station call on the traffic, as handled, for purposes of record. Only messages promptly handled and with information so recorded shall be counted in A.R.R.L. totals.

"Rubber-Stamp" Messages

The handling of traffic must be either fun or constructive, interesting work. Because multiple-address (rubber stamp) messages mean much drudgery for little accomplished they cannot be handled effectively in a hobby like amateur radio.

Obviously, a station in handling a rubber-stamp message has to exert only a small amount of effort in receiving the text and signature once. Then by handling the address to different points *en groupe* a large number of messages (?) can be received and transmitted with little time and effort. The League's system for crediting points for messages handled (and except for any *extra* delivery credit) is based on giving one credit each time a *complete* message is handled by amateur radio, i.e., one credit for each originated message, one credit for each delivered message and two credits for each relayed message (one credit for the work in receiving it and one for the work in transmitting it). *Only* every message handled BY RADIO *with a complete preamble, address, text, and signature* shall be counted, except in the case of *deliveries*, each mailed, telephoned or otherwise delivered message shall count "one delivered" *regardless* of handling in "book" form (with text sent once only).

Reporting

Whether the principal accomplishments of the station are in traffic handling or other lines, *what you are doing* is always of interest. One part of *QST* is devoted to Station Activities, this written up by your elected Section Communications Manager. His address is given on an up-front page of each *QST*. Reports from *all active hams*, sent the S.C.M. between the 16th and 20th of the month covering the 30 days just previous are used.

Operating on Schedules

Traffic handling work can be most advantageously carried on by arranging and keeping a few schedules. The message "hook" can be cleared in a few minutes of work on schedule and the station will be free for DX or experimental work.

The Route Manager is very frequently able to help in arranging schedules. Write your S.C.M. (see *QST*) and through him get lined up with your R.M.

The Five-Point System

To make our relaying more systematic the "five-point system" of arranging schedules was proposed and has worked out very nicely in many cases. After getting the station in good operating condition, each station's operator arranges to work four stations, one north, one east, one south, and one west. These directions are not exact but general. The distances are not too great but they must be distances that can be worked with absolute certainty under any conditions. Listen in. Select and invite stations to schedule you. Keep a list of *their* scheduled points and see they get some messages for those points. Report results to the S.C.M. It's fun.

Traffic Handling Develops Skill

The dispatch of messages makes operators keen and alert. The better the individual operator, the better the whole organization. Proper form in handling traffic, getting fills, and in general operating procedure develops operators who excel in "getting results." Station per-

World Radio History

formance depends 90% on operating ability, and 10% on the equipment involved, granting of course that station and operator are always interdependent. Experience in message handling develops a high degree of operating "intelligence."

Message handling leads to organization naturally, through the need for schedules and coöperation between operators. It offers systematic training in "real" operating. It leads to planned, useful, unselfish, constructive work for others at the same time it represents the highest form of operating "skill" and enjoyment to its devotees. Emphasis should be placed on the importance of traffic handling in training operators in the use of procedure — and in general operating reliability. The value of the amateur (as a group), in cases of local or national emergency, depends to a great extent on the *operating ability* of individual operators. This ability is largely developed by message handling.

Practice in handling traffic familiarizes one with detailed time-saving procedure, and develops general skill and accuracy to a higher extent than obtains in "just rag-chewing" or haphazard work. This work provides a definite aim. Message handling is a vital link in guiding the interest of operators to the point where many accept additional responsibilities in the Signal Corps organization (A.A.R.S.), or the Volunteer Naval Communication Reserve (U.S.N.R.). The interest amateurs show in these services is directly reflected by a full measure of appreciation and important backing by Uncle Sam whenever amateur rights are threatened with encroachment of any kind. Message handling work represents an advanced form of amateur operating activity in which all amateurs sooner or later become interested.

SAFETY

In "Message Handling" or any other class of activity in operating a station, safety, as well as convenience, should be a paramount consideration. Some of the following precautions observed at the A.R.R.L. Maxim Memorial station, W1AW, may well be employed at your installation.

Safety Devices

The safety features of W1AW, in brief: (1) Interlock* switches. In series with 110–220-volt power, "kill" the transmitters instantly, if a dust cover door is opened in the rear of any unit. (2) A lattice, in front of antenna condensers and feed-line leads, prevents "burning curiosity" from burning fingers. (3) Grounding antennas, accomplished by plug jacks, protects from lightning — fire hazard — and grounding metal frames of the sets — putting meters in B minus (no metal cased meters) completes the job. (4) An illuminated danger sign, within *each* unit automatically warns the operator to be ever watchful — as well as showing if fuses have been removed on either side of the power circuit. These signs are turned *on* by an interlock at the same time the *power* is turned off.

* Arrow-Hart & Hegeman Electric Co.'s No. 80630 switch

World Radio History

CHAPTER TWENTY

LEAGUE OPERATING ORGANIZATION

Your A.R.R.L. arranges amateur operating activities, promotes preparation and organization for communications emergencies, establishes procedure to aid efficient operation, encourages good operating and maintains a strong field organization. The Communications Department of the League is concerned with the practical operation of stations in all branches of amateur activity. Appointments and awards are available for rag chewer, 'phone operator, traffic enthusiast and DX man. It is the League's policy to benefit each group concerned along lines of natural interest. All activities have specific objectives with widest participation invited. This insures maximum fun and benefit to the whole fraternity.

The organization of the amateur fraternity into a strong unified body, capable of maintaining its rights, and able to render practical assistance to the public and the government in local and national emergencies, in traffic relaying and in training operators in systematic procedure for effective station operation are important objectives. Definite policies tend toward the avoidance of off-frequency operation, and the local solution of interference with other services, especially local listeners. The general attitude, what one says over his station, is important. Operation must have point and constructive purpose to win public respect. Each individual amateur is the ambassador to the entire fraternity in his public relations and attitude toward his hobby! A.R.R.L. field organization adds point and purpose to amateur operating.

Organization of the League is by Divisions and by Sections. Members in the fourteen United States Divisions and five Canadian Divisions elect fifteen Directors. With the President and Vice-President chosen by this group they constitute the governing and policy-making body of the League. Seventy-one A.R.R.L. Sections, the territory of the several Sections within each Division determined jointly by the Director and the Communications Manager, form convenient units for field organization and operating administration. Operating affairs in each Section are supervised by a Section Communications Manager elected by members in that Section for a two year term of office. Organization appointments are made by the Section Managers. The election of officials is covered in detail in the League's Constitution and By-Laws. Section Communications Managers addresses for all Sections are given in full in each issue of *QST*. They welcome monthly activity reports from all amateur stations in their jurisdiction each mid-month and write up these reports for *QST*. Full information on appointments may be obtained from S.C.M.s and is also contained in a League booklet, Operating an Amateur Radio Station, which will be sent from Headquarters on request. (10¢ to non-members.)

Organization Appointments

Whether your activity is directed toward 'phone or telegraph, there is a place for you in League organization.

We live in an age of specialization, and A.R.R.L. appointees specialize in particular branches of amateur operation for which they have special interest, aptitude or equipment. The voluntary acceptance of organization appointment carries prestige. It is a symbol of the mature, serious, accomplished amateur. Appointment also entitles the individual to certain bulletins that carry the first facts on new items of legislation and regulation as well as reports on activity and operating announcements. Every amateur should aim to become and remain a *member* of the League, and take an active part in his society and field organization work. There is fun and profit in doing this.

Complete information on appointments is included in the booklet, Operating an Amateur Radio Station. Without detailing all the qualifications of each, the field covered by each will be briefly explained.

Section Communications Manager

The Section Manager is the section executive or administrator in operating matters. He is the only elected official for the Section alone, and the office is open to election each two years, or oftener if a vacancy occurs. Requirements for nominations and the system of mail balloting are covered in the operating booklet. Section Managers report on all forms of amateur activity (for *QST*) monthly. The "station activities" are summarized including information from each amateur report, whether from League members or others. Reports are mailed to Hq. by S.C.M.s on or before the 20th of each month for the reporting month (16th to 15th

World Radio History

inclusive) in the mainland U.S.A. and Canada.

The Section Manager makes appointments for specific work in accordance with the qualifications and rules for such appointments. He makes cancellations, likewise, for inactivity, ineptitude or failure to perform the actions contemplated in appointment adequately. The object is to keep field organization standards high, and insure a live functioning organization in each amateur group at all times. The Section Manager desires representative appointees in each city and town and radio club. He studies geographical distribution and coverage for official observer, broadcasting station, emergency coördinator, etc., appointments, and gives careful consideration to the initiative, experience, tact, ability and other recognized qualifications in building the best Section organization possible on every front.

Appointees shall have authority within their territory over the activities indicated by their titles. A competent League member may be designated to investigate or act for a Section Manager in a particular capacity or matter in any part of his territory. The Section Manager's appointments will include the following designated assistants to take charge of particular branches of activity in which operating organization is required.

A.R.R.L. Emergency Coördinator

In *every community* in our country insofar as possible, Emergency Coördinators, shall be appointed after consultation and recommendations from prominent amateurs, active clubs and other informed sources. (Coördinators may also be appointed for *regions*, such as a watershed, or part of any system to be served, when such agency designates a control desired within a particular League Section for a special purpose.)

The Coördinator will arrange and head a committee of representative men from each amateur frequency-band-mode group to plan the most effective disposition of amateur facilities, foster tests, preparedness of all, and full registrations of equipment and ability in each local group. Plans shall be based on assumed local and regional contingencies. Registrations shall include normal operating frequency, power, nature of emergency equipment if any, telegraph operating speeds, normal availability, occupation, address, working hours, address and telephone number, membership in AARS, NCR, ORS-OPS, AEC, etc., groups. Liaison with agencies served and other radio services is part of a coördinator's work. Coördinators are to act as advisers, in controlling the activities of volunteers within the structure of the amateur service in accord with prearranged plans.

The idea in emergency is to limit the number of channels set up to the minimum number advisable and necessary, to select the most suitable stations and frequencies for work in view, to create reserves of skilled amateur operators so these will be available to man selected stations fully, for 24-hour shifts if needed, rather than to have a large number of simultaneously operated stations causing interference in congested bands, with overloaded operators whose efficiency becomes rapidly impaired by lack of proper rest. Planning, preparedness, and coördination, are the essence of the emergency communication problem for amateurs.

The special *emergency regulations* for the amateur service are explained in Chapter XVIII, the plans including, for the amateur service:

(1) F.C.C. declaration of general communications emergencies.

(2) Restriction in 3500–4000 kc. and 1715–2000 kc. bands to handling relief or emergency traffic *only*. No remarks not relating to such situation permitted.

(3) Mandatory *silence* during a listening period the first five minutes of each hour, for the duration of such emergency.

(4) Mandatory use of 1975–2000 kc., 3500–3525 kc., and 3975-4000 kc. for *emergency calling* frequencies. For calling, *only*.

(5) Designation of stations for policing, warning, and observing work by the F.C.C., their announcements in accordance with Sec. 152.54 of the Commission's regulations.

Official Broadcasting Stations

O.B.S. are appointed by Section Managers, and regularly transmit information specifically addressed to A.R.R.L. member-amateurs by code and voice, in all frequency bands. Official and special transmissions, daily except holidays, are made from the Headquarters station, W1AW. O.B.S. appointees receive

MEMBERSHIP CARD, A.R.R.L. EMERGENCY CORPS

Every **licencee is requested to register in the E. C.**

their information direct from this source and by mail, upwards of 200 stations covering all A.R.R.L. Sections with amateur information of national and local interest with new information at least once a week. Member-stations must agree to render a good service on regular schedule to receive appointment, and power and signal quality are carefully considered. Many of the stations are so well operated that beginners use their transmissions for code practice. Hours between six P.M. and midnight have been chosen for most O.B.S. schedules, for that is the time when most amateurs are listening. Code transmissions are preceded by the call "QST" for four or five minutes to inform amateurs this official addressed information is to be sent.

Official Observers

To help all amateurs keep on assigned frequencies, and assist brother amateurs in keeping clear of F.C.C. discrepancy reports and the penalties for infraction of regulations, A.R.R.L. Observers have been appointed. S.C.M.s require such appointees to have an accurate frequency meter, or oscilloscope, or other equipment for accurate work of the type in which a specific observer engages. Special postal warning forms are provided for different classes of trouble. Reports direct to the amateurs concerned by radio or mail cover improper broadness, a.c. notes, overmodulation, poor speech quality, off-frequency operation, harmonic radiation or other operating and technical violations of good practice. If you need a frequency check (or other test) ask the S.C.M. for the address of the O.O. Observers not only help amateurs individually, they also protect the privileges of all amateurs and avert official government restriction invited by the careless. Valuable occupancy and station-distribution surveys have been made several times in the history of the observing system.

Route Managers

The Route Manager is the authority on schedules and routes and his station must be active in traffic and organization work. Section Managers generally appoint one Route Manager to every twenty or twenty-five Official Relay Stations. The Route Manager's duties include coöperation with all radio amateurs in his territory in organizing and maintaining traffic routes, nets, and schedules. His authority extends to station inspection and/or radio operating tests of candidates for O.R.S. appointment as directed by the S.C.M. Special R.M.s are appointed also for liaison and work with A.A.R.S. and N.C.R. groups, and reports are welcome from all members of the services. Advice to amateurs wanting schedules or traffic routings via Trunk Lines, Section Nets, etc., will be given by R.M.'s on request.

'Phone Activities Manager

The 'Phone Activities Manager has authority to sponsor 'phone operating activities in his territory, in the name of the League. The P.A.M. appointment, while paralleling that of R.M. in some respects, has to do with the upbuilding of A.R.R.L. Section and National 'phone organization. The 'Phone Activities Manager conducts station inspections and/or radio operating tests of candidates for O.P.S. when referred by the S.C.M. 'Phone nets may develop ability to handle traffic by point-to-point procedure or follow objectives entirely divorced from traffic at the vote of net-members or as directed by the P.A.M.

Emblem Colors

Members of the League only may obtain the official League emblem and member stationery. Members wear the emblem with gold border and lettering and black enamel background. A red background for an emblem will indicate that the wearer is S.C.M. or ex-S.C.M. All Official Relay Station and Official 'Phone Station appointees are entitled to wear emblems with blue background.

The Official Relay Station Appointment

Every radio telegraphing amateur interested in traffic work and worthwhile operating organization activities who can meet the qualifications is eligible for appointment of his station as A.R.R.L. Official Relay Station. Brasspounders handle traffic because they enjoy such work. There is fun in efficient operation; pride in accomplishing something; opportunity to demonstrate operating proficiency at the same time this is maintained and increased. The potential value of the operator who handles traffic to his community and country is enhanced by his ability, and the readiness of his station and schedules to function in the community interest in case of emergency.


The American Radio Relay League, Inc.
Hartford, Conn., U. S. A.
OFFICIAL RELAY STATION APPOINTMENT
This certifies that

The appointment, like O.P.S. appointment for the 'phone operators, identifies the holder with high standards of amateur operating, and indicates personal keenness, responsibility and qualifications certified by the Section officials. The holder voluntarily agrees to report each month, and with absolute reliability to forward and deliver a number of messages regularly through his station or accept cancellation of appointment as a routine expectation necessary in keeping a live organization that is widely respected and useful in existence. The Official Relay Station appointment is a much sought after appointment. The earnest and qualified ham will find it readily attainable. Secure application forms from your local S.C.M. See full details on requirements in the Operating an Amateur Station booklet.

The Official 'Phone Station Appointment

This appointment is for every qualified ham who normally uses his "mike" more than his key in his amateur station, and who takes a pride in the manner of signal he puts on the air, and aims to have his station really accomplish worthwhile communication work. Official 'Phone Station appointees must endeavor to live up to the Amateur's Code of good fraternalism and operating equality. The appointment gives 'phone operators the advantages of organization for systematic coöperation in emergencies, quarterly bulletin news, and operating tests. O.P.S. appointment aids 'phone operating enjoyment by helping to formulate good voice operating practices, not overlooking the emergency organization aspect.

Message handling as an activity is not the main objective, though cultivation of operating ability that is essential to assure accuracy, conciseness and speed for point to point work, in which the desirable technique is altogether different than in broadcasting, is encouraged. O.P.S. technique and operating is designed to encourage fraternalism, facilitate tests between stations of the group, and cultivate by example, a precept for excellence looked up to by others operating voice stations. Official 'Phone Station appointees, like O.R.S., agree voluntarily in accepting appointment that they will keep active stations and report on activities to the S.C.M. monthly. Application forms are available from your S.C.M., detailed requirements which include one year of experience as an amateur, but no code test such as O.R.S. have, are given in full in Operating an Amateur Radio Station.


The American Radio Relay League, Inc.
West Hartford, Conn., U. S. A.
OFFICIAL PHONE STATION APPOINTMENT
This certifies that

Benefits Exchanged in Appointment

Because O.R.S. and O.P.S. appointment is founded on the working together of groups of the best stations and keenest operators, these men by exchange of individual ideas and comment in addition to radio contacts can *each* benefit from *all* such information. All appointees receive an appointment certificate to be displayed in the station, stickers identifying their status for use on QSLs and letters, reporting card forms to facilitate monthly reports via the S.C.M., and a quarterly and special field organization bulletins. These bulletins include the latest detailed news on regulation and legislation, operating announcements, reports on special activities within the O.R.S. or O.P.S. groups, a picture supplement sheet of general amateur significance and interest, and personal comments and article contributions.

O.R.S. or O.P.S. certificates must be returned to S.C.M.s annually for endorsement to keep them in effect — no trouble to this if there is continuing activity. Applicants who for any reason do not meet the tests or qualifications may apply again after three months have elapsed. By arrangement with S.C.M.s concerned appointments may be kept in effect when an amateur moves from one Section to another. Cancellations are based on three missing reports, and reinstated following activity reports for three consecutive months, new application being waived or required at the discretion of the S.C.M.

It is the duty of Official Relay Station and Official 'Phone Station appointees (a) to report activities monthly to the S.C.M. whether or not a special reporting form is available; (b) to keep stations always on the air, i.e., in readiness for operation and in actual service; (c) to follow A.R.R.L. operating practices; (d) to take part in the activities of the League whenever possible; (e) to hold message files three months ready for any call by the S.C.M. or licensing authority. *Reports are due on the 16th* of each month for mainland United States stations.

In many instances experience as O.R.S. or O.P.S. has preceded the appointment of experienced men to carry out the work of Route

World Radio History

Manager or 'Phone Activities Manager, and similarly those who have been outstanding in organization work in either of those posts, or who have experience in club work, have been chosen by members to administer the affairs of Sections as S.C.M. To get full value from amateur organization you must take part in it. The different appointments have been explained. If your station is active you are invited to qualify and take part fully in A.R.R.L. work. Write your S.C.M.!

Trunk Lines

Official Relay Stations at key points are organized in Trunk Line formation, covering fourteen East-West and North-South routes, connecting with numerous Section and local networks and feeder systems for the purpose of efficient dispatch of traffic. Speedy and reliable work is carried on, the operation entirely on separate spot frequencies in the 3.5-Mc. amateur band. A station must hold O.R.S. appointment to be considered for a Trunk Line post.

Radio Clubs and Affiliation

To add to the strength and unity of amateur radio, to improve understanding and coöperation, to promote technical discussions, to solve interference problems locally and quell bootleg or illegal operation in each community, there is nothing like a local radio club which is on the job. The American Radio Relay League believes in radio clubs and offers to any individual organizers of new amateur associations in different localities a wealth of information gleaned from contacts and experience and compiled to assist in club organization work. Papers on club work, suggestions for organizing, for constitutions, for radio courses of study, etc., are available in mimeographed form free on request.

In addition it is the policy of the League to grant affiliation to any amateur society having 51 percent of its licensed amateurs also members of the A.R.R.L. Where a society has common aims, wishes to add its strength to that of other club groups to strengthen amateur radio by affiliation with the national amateur organization, a request addressed to the Communications Manager will bring the necessary forms and information to initiate the application for affiliation. Affiliated club news appears in *QST* and such clubs receive field organization bulletins and special information at intervals for posting on club bulletin boards or relay to their memberships. The clubs also receive special price schedules on A.R.R.L. supplies ordered in quantity. A travel plan providing communications, technical and secretarial contact from the Headquarters is worked out seasonally to give maximum benefits to as many as possible of the more than four hundred affiliated radio clubs. Affiliation besides having the benefits cited gives national identification and recognition for local societies.

W1AW-W1MK

Besides the hamming of individual A.R.R.L. staff members from their personal stations, the Maxim Memorial Station,[1] W1AW, is on the air daily, except for holidays.* The new W1AW operated by the League headquarters is located about four miles south of the Headquarters offices on a seven acre site. The operating room is shown in the frontispiece to this book to give an idea of the facilities available. Telegraph and 'phone transmitters are provided for *all principal amateur bands.* Operating-visiting hours are 3 P.M. to 3 A.M. daily except week ends. On Saturdays the hours are 8:30 P.M. to 2:30 A.M. E.S.T. and on Sundays, 7:00 P.M. to 1:00 A.M. E.S.T.

W1AW is dedicated to fraternity and service. The available time is divided between different bands and modes of QSO's with Rag Chewer, DXer, Traffic Man, etc. The station takes part in all A.R.R.L. operating activities. With its new facilities[1] it does not compete with individual members, though results are recounted for the information of Members.

All amateurs, members of the League particularly, are invited to visit W1AW, as well as to work the station from their own shacks. The station was made possible by the Board of Directors, and established to be a living memorial to Hiram Percy Maxim,[1] and to carry on the work and traditions of the fraternity. W1AW replaces on the air, the presence of W1MK, the first station[2] of your headquarters to be established by order of the Board, which station was flooded out in the 1936 New England flood.

Maps of the U. S. A. and the world are conveniently located in the operating room. O.R.S., O.P.S., and O.B.S. certificates indicate the service, work and high standards of the operating program. The transmitters are all rack-and-panel built. Separate 72″ high racks, from left to right, in the front of the operating room contain: The 28-Mc. transmitter, the 14-Mc. transmitter, the 7-Mc. transmitter, the 500-watt modulator (switchable to any set), the 3.5-Mc. transmitter, and the 1.8-Mc. transmitter. All the transmitters are kilowatt jobs. There is room for a 56-Mc. transmitter which will be added. A table near the control

* The station will not be operated Jan. 1st, Feb. 22nd, May 30th, July 4th, Labor Day (1st Mon. in Sept.), Thanksgiving (last Thurs. in Nov.) and Christmas Eve and Day.

World Radio History

position carries a perforator for punching out tapes for the constant-speed transmissions of the "automatic." Tube line-ups are as follows:

1.7 Mc.: 47-RK28-204A's, P.P.
3.5 Mc.: 89/6L6-RK48-HK 354's P.P.
7 Mc.: 6L6-RK20-HF200's P.P.
14 Mc.: 89–807-35T's P.P.–Eimac 250THs, P.P.
28–30 Mc.: 89–807-814's P.P.–806 P.P.
Speech Amplifier, Signal-Limiting Volume-Compressor and Modulator: 6J7, 6C5-6J7 6L7-6H6 — 6C5's P.P., 6L6's P.P., Taylor 822's P.P.

Operators

While different members of the A.R.R.L. staff may work you from W1AW on occasion, or by special schedule, the most regular operation is by the men who take care of the building and show us its facilities. Mr. Harold Bubb (Hal) is the first operator, and Mr. George Hart (Geo) his able "relief." Both operators are well known to A.R.R.L. field organization members, having participated in seasonal and official activities for some years.

General Operation

Daily, except Saturday and Sunday, W1AW sets aside the following hours to work on particular bands, independent of other schedules and station programs. This is to enable anyone anxious to QSO to know the best time to look for us. This general contact schedule is subject to possible modification by later announcement in *QST*, if conditions make changes necessary: (1808–1800.5 kcs. 'phone/c.w.) 3:00–3:30 P.M. and 11:00–11:30 P.M. E.S.T.; (3800-kc. c.w.) 3:30–4:00 P.M. and 8:00–8:30 P.M. E.S.T.; (3950-kc. 'phone) 4:00–5:00 P.M. E.S.T.; (7150-kc. c.w.) 1:00–2:00 A.M. (except Sun. & Mon.); (14254-kc. c.w.) 6:00–7:00 P.M. E.S.T.; (14240-kc. 'phone) 10:00–11:00 P.M. E.S.T.

The O.B.S. Program

The station observes the following regular schedules for sending addressed information to all Member Radio Amateurs:

Frequencies	*Starting Times (P.M.)*				*Speeds (W.P.M.) of "automatic"*						
C.W.: 1800.5–3800–7150–14254 kcs.											
	EST	*CST*	*MST*	*PST*	*M*	*T*	*W*	*Th*	*Fri*	*Sat*	*Sun*
	8:30	7:30	6:30	5:30	20	15	25	15	20	..	20
	Midnight	11:00	10:00	9:00	15	25	15	20	15	15	..

'Phone: The simultaneous code transmissions, will be followed by voice transmissions, in turn, on 1808, 3950, and then 14240 kcs.

W1AW also carries authorization from the Signal Corps as WLMK, permitting utilization of 3497.5 and 6990 kcs. if required in emergencies. The transmitters are a model of *safety* engineering — any of the several safety precautions being worthy of adoption in individual shacks, to improve on some of the situations we have seen.

A.R.R.L.'s Emergency Corps for Every Licensee

All amateurs, for real preparedness, should be registered as to equipment, telephone number, and availability, in the Emergency Corps. Registrations should be deposited with the Coördinator for the amateur service in each community having such an appointee, but may be made via A.R.R.L. Headquarters or suitable registration forms sent to *any licensed amateur* in the United States or Canada, on request.

The "emergency" identification cards, provided by Headquarters for all amateurs who register in the A.E.C. classify the Corp into two groups by the wording thereon, in recognizing those having portable equipment and other equipment in the existing station, capable of immediate operation from a self-powered electrical source — batteries, gas engine generators, etc. The two groups are — (1) Emergency Powered Stations, (2) the Supporting Division — those *not* yet possessing a self-powered source but who pledge themselves to assist and give fullest coöperation with their regular stations in the event of any emergency due to communication overload or failure of wire lines. Registrations in the A.E.C. are not even limited to League members since the desire is to create a great body of amateurs dedicated to public emergency service without limitation. Members without auxiliary power, but registered in the Supporting Division may turn in their identifying pocket cards for new as they achieve the objective of supplying equipment with emergency power sources such as Vibra packs, genemotors, or batteries.

Chapter Nineteen lists the special operating policies of A.E.C. members, recommending them to all amateurs as vital to success in rendering emergency communication service. To register in the A.E.C. simply send a postal to Communications Department, A.R.R.L., West Hartford, Conn., asking for the application form. Help yourself and amateur radio by getting your enrollment data in the Emergency Corps in at Hq. at once.

Special Awards or Mention

The League sponsors a variety of operating activities, mentioned in Chapter Nineteen. These have useful objectives and add much enjoyment for members of the fraternity. Point is also added to achievement through recognition in the following:

W.A.S. (Worked All States) Club.[3]
W.A.C. (Worked All Continents) Club.
DX Century Club.
Brass Pounders' League.
The A-1 Operator Club.
Rag Chewers' Club.[4]

World Radio History

Those amateurs who "work all forty-eight of the United States" from one location, get the cards or written confirmation of this accomplishment, and have the entry certified by sending these to A.R.R.L. for examination will receive a handsome W.A.S. certificate. This "not so easy" attainment of communicating with all parts of the country makes the certificate highly prized. Any amateur in the world is welcome to qualify and need only submit postage for the return of his confirmations. See the detailed rules and announcement for all these awards in Operating an Amateur Radio Station. Endorsement for c.w.t. or telephony or for a particular band will be given on request, accompanied by proof. It is an honor to have **Worked All States.**

In collaboration with the I.A.R.U., the League issues W.A.C. certificates to all member-amateurs who submit proof of communication with at least one station on each continent. Foreign amateurs submit their proof to member societies in the I.A.R.U. A c.w.t. and a telephony certificate are available. Also special 28 Mc. endorsement will be placed on certificates by request, accompanied by proof of this way of having **Worked All Continents.**

Higher honors, for the DX-minded ham include admittance to the DX Century Club which includes all those amateurs having confirmed and certified communication with 100 or more different countries (according to A.R.R.L. list of countries). While the certificates are given only at the time proof of the "100 mark" is passed, amateurs are invited to start submitting proof when they have confirmations from 75 countries to be sent A.R.R.L. for examination. A monthly honor-roll in *QST* lists the number of countries worked *and certified*, from the 75-country mark *upwards*, revising the figure as new countries confirm and the proof is used in moving the *QST*-listing upward. See December 1938 *QST* for detailed rules. Return postage must be sent with cards expected to be returned. The list will be the only official confirmed list in existence. Start adding your countries (and send that card to help your brother amateurs) to make the **DX Century Club.**

The value to amateurs in operator training, and the utility of amateur message handling to the members of the fraternity itself as well as to the general public, make message handling work of prime importance to the fraternity. Fun, enjoyment, and the feeling of having done something really worthwhile for one's fellows (in traffic handling) is accentuated by the pride of actual message files and records, and letters from those served will give the individual who is making himself a superlative amateur operator through handling traffic. Every individual reporting more than a specified minimum in official monthly traffic totals is given an honor listing in the *QST* department known as the **Brass Pounders' League.** New men are invited to aim to make themselves good operators by trying for it.

The A-1 Operator Club should include in its ranks every good operator. To become a member, one must be nominated by at least two operators who already belong. General keying or voice technique, procedure, copying ability, judgment and courtesy all count in rating candidates under the club rules detailed in the operating booklet at length. Aim to make yourself a fine operator, and one of these days you will be pleasantly surprised by an invitation to belong to the **A-1 Operator Club,** which carries a worthwhile certificate in its own right.

A "club" to encourage friendly contacts, discourage hello-goodbye QSOs, and bond together honest-to-goodness rag chewing operators was organized in 1925. To get in one chews the rag *with a club member* for at least a solid half hour, reporting the performance to A.R.R.L. at West Hartford. When this club member sends his nomination in and it is checked with applicant's request, membership certificate is forwarded. Four attributes of R.C.C. members: (1) They are real conversationalists, not mere automatons using "QRU," "cuagn," nil, etc., in perfunctory talk. (2) Stations are operated in accord with F.C.C. and A.R.R.L. practice. (3) Rules of courtesy are observed. (4) "RCC" is indicated after a call. Aim to qualify for the **Rag Chewers' Club.**

Invitation

Amateur radio is capable of giving enjoyment and training and continued profit in proportion to what the individual amateur puts into his hobby. All amateurs are invited to become A.R.R.L. Members, to work toward awards, and to accept the challenge and invitation offered in field organization appointments. Drop a line for the booklet, Operating an Amateur Radio Station, which has detailed information on the field organization appointments and awards covered briefly in this chapter. Accept today the invitation to take full part in all the A.R.R.L. activities and organization work going forward.

Bibliography

[1] A Visit to W1AW, p. 10, Oct. 1938 *QST*. [2] The Story of W1MK, p. 31, Dec. 1930 *QST*. [3] The Worked All States Award, p. 33, Jan. 1936 *QST*. [4] Rag Chewers' Club, p. 52, Dec. 1936 *QST*.

World Radio History

APPENDIX

The "Q" Code

IN THE REGULATIONS accompanying the existing International Radiotelegraph Convention there is a very useful internationally-agreed code designed to meet major needs in international radio communication. This code follows. The abbreviations themselves have the meanings shown in the "answer" column. When an abbreviation is followed by an interrogation mark (?) it assumes the meaning shown in the "question" column.

Abbreviation	*Question*	*Answer*
QRA	What is the name of your station?	The name of my station is ....
QRB	How far approximately are you from my station?	The approximate distance between our stations is .... nautical miles (or .... kilometers).
QRC	What company (or Government Administration) settles the accounts for your station?	The accounts for my station are settled by the ....company (or by the Government Administration of ....).
QRD	Where are you bound and where are you from?	I am bound for .... from ....
QRG	Will you tell me my exact frequency (wave-length) in kc/s (or m)?	Your exact frequency (wave-length) is ....kc/s (or .... m).
QRH	Does my frequency (wave-length) vary?	Your frequency (wave-length) varies.
QRI	Is my note good?	Your note varies.
QRJ	Do you receive me badly? Are my signals weak?	I cannot receive you. Your signals are too weak.
QRK	What is the readability of my signals (1 to 5)?	The readability of your signals is .... (1 to 5).
QRL	Are you busy?	I am busy (or I am busy with ....). Please do not interfere.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are you troubled by atmospherics?	I am troubled by atmospherics.
QRO	Shall I increase power?	Increase power.
QRP	Shall I decrease power?	Decrease power.
QRQ	Shall I send faster?	Send faster (........ words per minute).
QRS	Shall I send more slowly?	Send more slowly (........ words per minute).
QRT	Shall I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.
QRV	Are you ready?	I am ready.
QRW	Shall I tell .... that you are calling him on .... kc/s (or .... m)?	Please tell .... that I am calling him on .... kc/s (or .... m).
QRX	Shall I wait? When will you call me again?	Wait (or wait until I have finished communicating with ....) I will call you at .... o'clock (or immediately).
QRY	What is my turn?	Your turn is No. .... (or according to any other method of arranging it).
QRZ	Who is calling me?	You are being called by ....
QSA	What is the strength of my signals (1 to 5)?	The strength of your signals is .... (1 to 5).
QSB	Does the strength of my signals vary?	The strength of your signals varies.
QSD	Is my keying correct; are my signals distinct?	Your keying is incorrect; your signals are bad.
QSG	Shall I send .... telegrams (or one telegram) at a time?	Send .... telegrams (or one telegram) at a time.
QSJ	What is the charge per word for .... including your internal telegraph charge?	The charge per word for .... is .... francs, including my internal telegraph charge.
QSK	Shall I continue with the transmission of all my traffic, I can hear you through my signals?	Continue with the transmission of all your traffic, I will interrupt you if necessary.
QSL	Can you give me acknowledgment of receipt?	I give you acknowledgment of receipt.
QSM	Shall I repeat the last telegram I sent you?	Repeat the last telegram you have sent me.
QSO	Can you communicate with .... direct (or through the medium of ....)?	I can communicate with .... direct (or through the medium of ....).
QSP	Will you retransmit to .... free of charge?	I will retransmit to .... free of charge.
QSR	Has the distress call received from .... been cleared?	The distress call received from .... has been cleared by ....
QSU	Shall I send (or reply) on .... kc/s (or m) and/or on waves of Type A1, A2, A3, or B?	Send (or reply) on .... kc/s (or ....m) and/or on waves of Type A1, A2, A3, or B.
QSV	Shall I send a series of VVV ....?	Send a series of VVV ....

World Radio History

Abbreviation	*Question*	*Answer*
QSW	Will you send on .... kc/s (or .... m) and/or on waves of Type A1, A2, A3 or B?	I am going to send (or I will send) on .... kc/s (or .... m) and/or on waves of Type A1, A2 A3 or B.
QSX	Will you listen for .... (call sign) on .... kc/s (or .... m)?	I am listening for .... (call sign) on .... kc/s (or .... m).
QSY	Shall I change to transmission on .... kc/s (or ...... m) without changing the type of wave? or Shall I change to transmission on another wave?	Change to transmission on .... kc/s (or .... m) without changing the type of wave or Change to transmission on another wave.
QSZ	Shall I send each word or group twice?	Send each word or group twice.
QTA	Shall I cancel telegram No. .... as if it had not been sent?	Cancel telegram No. .... as if it had not been sent.
QTB	Do you agree with my number of words?	I do not agree with your number of words; I will repeat the first letter of each word and the first figure of each number.
QTC	How many telegrams have you to send?	I have .... telegrams for you (or for ....).
QTE	What is my true bearing in relation to you? or What is my true bearing in relation to .... (call sign)? or What is the true bearing of .... (call sign) in relation to .... (call sign)?	Your true bearing in relation to me is ....degrees or Your true bearing in relation to .... (call sign) is .... degrees at .... (time) or The true bearing of .... (call sign) in relation to ...... (call sign) is ...... degrees at .... (time).
QTF	Will you give me the position of my station according to the bearings taken by the direction-finding stations which you control?	The position of your station according to the bearings taken by the direction-finding stations which I control is .... latitude .... longitude.
QTG	Will you send your call sign for fifty seconds followed by a dash of ten seconds on .... kc/s (or .... m) in order that I may take your bearing?	I will send my call sign for fifty seconds followed by a dash of ten seconds on .... kc/s (or .... m) in order that you may take my bearing.
QTH	What is your position in latitude and longitude (or by any other way of showing it)?	My position is .... latitude .... longitude (or by any other way of showing it).
QTI	What is your true course?	My true course is .... degrees.
QTJ	What is your speed?	My speed is .... knots (or .... kilometers) per hour.
QTM	Send radioelectric signals and submarine sound signals to enable me to fix my bearing and my distance.	I will send radioelectric signals and submarine sound signals to enable you to fix your bearing and your distance.
QTO	Have you left dock (or port)?	I have just left dock (or port).
QTP	Are you going to enter dock (or port)?	I am going to enter dock (or port).
QTQ	Can you communicate with my station by means of the International Code of Signals?	I am going to communicate with your station by means of the International Code of Signals.
QTR	What is the exact time?	The exact time is ....
QTU	What are the hours during which your station is open?	My station is open from .... to ....
QUA	Have you news of .... (call sign of the mobile station)?	Here is news of .... (call sign of the mobile station).
QUB	Can you give me in this order, information concerning: visibility, height of clouds, ground wind for .... (place of observation)?	Here is the information requested ....
QUC	What is the last message received by you from .... (call sign of the mobile station)?	The last message received by me from .... (call sign of the mobile station) is ....
QUD	Have you received the urgency signal sent by .... (call sign of the mobile station)?	I have received the urgency signal sent by .... (call sign of the mobile station) at ......(time).
QUF	Have you received the distress signal sent by .... (call sign of the mobile station)?	I have received the distress signal sent by .... (call sign of the mobile station) at .... (time).
QUG	Are you being forced to alight in the sea (or to land)?	I am forced to alight (or land) at .... (place).
QUH	Will you indicate the present barometric pressure at sea level?	The present barometric pressure at sea level is .... (units).
QUJ	Will you indicate the true course for me to follow, with no wind, to make for you?	The true course for you to follow, with no wind, to make for me is .... degrees at .... (time).
QUK	Can you tell me the condition of the sea observed at .... (place or coördinates)?	The sea at .... (place or coördinates) is ....
QUL	Can you tell me the swell observed at .... (place or coördinates)?	The swell at .... (place or coördinates) is ......
QUM	Is the distress traffic ended?	The distress traffic is ended.

Special abbreviations adopted by the A.R.R.L.

QRS General call preceding a message addressed to all amateurs and A.R.R.L. Members. This is in effect "CQ ARRL."

QRR Official A.R.R.L. "land SOS." A distress call for use by stations in emergency zones only.

World Radio History

MISCELLANEOUS ABBREVIATIONS

Abbreviation	*Meaning*	*Abbreviation*	*Meaning*
C	Yes	**JM**	If I may transmit, send a series of dashes. To stop my transmission, send a series of dots [not to be used on 500 kc/s (600 m)].
N	No.	**MN**	Minute or minutes (to be used to indicate the duration of a wait).
P	Indicator of private telegram in the mobile service (to be used as a prefix).	**NW**	I resume transmission (to be used more especially in the fixed service).
W	Word or words.	**OK**	Agreed.
AA	All after .... (to be used after a note of interrogation to ask for a repetition).	**RQ**	Designation of a request.
AB	All before .... (to be used after a note of interrogation to ask for a repetition).	**SA**	Indicator preceding the name of an aircraft station (to be used in the sending of particulars of flight).
AL	All that has just been sent (to be used after a note of interrogation to ask for a repetition).	**SF**	Indicator preceding the name of an aeronautical station.
BN	All between .... (to be used after a note of interrogation to ask for a repetition).	**SN**	Indicator preceding the name of a coast station.
BQ	A reply to an RQ.	**SS**	Indicator preceding the name of a ship station (to be used in sending particulars of voyage).
CL	I am closing my station.	**TR**	Indicator used in sending particulars concerning a mobile station.
CS	Call sign (to be used to ask for a call sign or to have one repeated).	**TU**	Thank you for your coöperation.
DB	I cannot give you a bearing, you are not in the calibrated sector of this station.	**UA**	Are we agreed?
DC	The minimum of your signal is suitable for the bearing.	**WA**	Word after .... (to be used after a note of interrogation to request a repetition).
DF	Your bearing at .... (time) was .... degrees, in the doubtful sector of this station, with a possible error of two degrees.	**WB**	Word before .... (to be used after a note of interrogation to request a repetition).
DG	Please advise me if you note an error in the bearing given.	**XS**	Atmospherics.
DI	Bearing doubtful in consequence of the bad quality of your signal.	**YS**	Your service message.
DJ	Bearing doubtful because of interference.	**ABV**	Repeat (or I repeat) the figures in abbreviated form.
DL	Your bearing at .... (time) was .... degrees, in the doubtful sector of this station.	**ADR**	Address (to be used after a note of interrogation to request a repetition).
DO	Bearing doubtful. Ask for another bearing later, or at .... (time).	**CFM**	Confirm (or I confirm).
DP	Beyond 50 miles, the possible error of bearing may amount to two degrees.	**COL**	Collate (or I collate).
DS	Adjust your transmitter, the minimum of your signal is too broad.	**ITP**	The punctuation counts.
DT	I cannot furnish you with a bearing; the minimum of your signal is too broad.	**MSG**	Telegram concerning the service of the ship (to be used as a prefix).
DY	This station is two-way, what is your approximate direction in degrees in relation to this station?	**NIL**	I have nothing for you (to be used after an abbreviation of the Q code to mean that the answer to the question put is negative).
DZ	Your bearing is reciprocal (to be used only by the control station of a group of direction-finding stations when it is addressing other stations of the same group).	**PBL**	Preamble (to be used after a note of interrogation to request a repetition).
ER	Here .... (to be used before the name of the mobile station in the sending of route indications).	**REF**	Referring to .... (or Refer to ....).
GA	Resume sending (to be used more specially in the fixed service).	**RPT**	Repeat (or I repeat) (to be used to ask for or to give repetition of all or part of the traffic, the relative particulars being sent after the abbreviation).
		SIG	Signature (to be used after a note of interrogation to request a repetition).
		SVC	Indicator of service telegram concerning private traffic (to be used as a prefix).
		TFC	Traffic.
		TXT	Text (to be used after a note of interrogation to request a repetition).

Scales Used in Expressing Signal Strength and Readability

(See QRK and QSA in the Q Code)

Strength		*Readability*	
QSA1	Barely perceptible	**QRK1**	Unreadable
QSA2	Weak	**QRK2**	Readable now and then
QSA3	Fairly good	**QRK3**	Readable with difficulty
QSA4	Good	**QRK4**	Readable
QSA5	Very good	**QRK5**	Perfectly readable

World Radio History

INTERNATIONAL PREFIXES

The nationality of a radio station is shown by the initial letter or letters of its call signal. The International Telecommunications Convention, supplemented by provisional action of the Berne Bureau, allocates the alphabet amongst the nations of the world for that purpose. Every station call of a nation must be taken from the block of letters thus assigned it. The amateur station call commonly consists of one or two initial letters thus chosen (to indicate nationality), a digit (assigned by the local government to indicate the subdivision of the nation in which the station is located), and two or three additional letters (to identify the individual station).

In the list which follows the first column shows the international allocation of blocks of call signals. This list is useful in identifying the nationality of any call heard, whether amateur or not. In the second column appears the area to which the calls are assigned. In the third column the amateur prefixes, the beginning letters of amateur calls, are listed. Where a prefix is shown in brackets, it indicates that that government has more than one assignment of initial letters and that the indicated letter will be found assigned, in another part of the list, to that country. The list:

Block	*Assigned to*	*Amateur Prefix*
CAA-CEZ	Chile	CE
CFA-CKZ	Canada	[VE]
CLA-CMZ	Cuba	CM [CO][1]
CNA-CNZ	Morocco	CN
COA-COZ	Cuba	CO [CM]
CPA-CPZ	Bolivia	CP
CQA-CRZ	Portuguese Colonies:	
	Cape Verde Islands	CR4
	Portuguese Guinea	CR5
	Angola	CR6
	Mozambique	CR7
	Portuguese India	CR8
	Macao	CR9
	Timor	CR10
CSA-CUZ	Portugal:	
	Portugal proper	CT1
	Azores Islands	CT2
	Madeira Islands	CT3
CVA-CXZ	Uruguay	CX
CYA-CZZ	Canada	[VE]
D	Germany	D
EAA-EHZ	Spain:	
	Spain proper	EA1-2-3-4-5-7
	Balearic Islands	EA6
	Canary Islands	EA8
	Spanish Morocco and North Africa	EA9
EIA-EJZ	Irish Free State	EI
EKA-EKZ	Japan	[J]
ELA-ELZ	Liberia	EL
EMA-EOZ	Japan	[J]
EPA-EQZ	Iran (Persia)	EP
ERA-ERZ	Japan	[J]
ESA-ESZ	Estonia	ES
ETA-ETZ	Ethiopia (Abyssinia)	ET
EUA-EYZ	Japan	[J]
EZA-EZZ	Germany	[D]
F	France:	
	France proper	F3, F8
	Algeria	FA
	Madagascar	FB8
	French Togoland	FD8
	French Cameroons	FE8
	French West Africa	FF8
	Guadeloupe	FG8
	French Indo-China	FI8
	New Caledonia	FK8
	French Somaliland	FL8
	Martinique	FM8
	French India	FN8
	French Oceania	FO8
	Miquelon & St. Pierre Islands	FP8
	French Equatorial Africa	FQ8
	Reunion	FR8
	Tunisia	FT4
	New Hebrides (French)	FU8
	French Guiana and Inini	FY8
G	United Kingdom:	
	England	G
	Northern Ireland	GI
	Scotland	GM
	Wales	GW
HAA-HAZ	Hungary	HA
HBA-HBZ	Swiss Confederation	HB
HCA-HDZ	Ecuador	HC
HEA-HEZ	Switzerland	[HB]
HFA-HFZ	Poland	[SP]
HGA-HGZ	Japan	[J]
HHA-HHZ	Republic of Haiti	HH
HIA-HIZ	Dominican Republic	HI
HJA-HKZ	Republic of Colombia	HJ-HK
HLA-HMZ	Japan	[J]
HNA-HNZ	Iraq	[YI]
HOA-HPZ	Republic of Panama	HP
HQA-HRZ	Republic of Honduras	HR
HSA-HSZ	Siam	HS
HTA-HTZ	Nicaragua	[YN]
HUA-HUZ	Salvador	[YS]
HVA-HVZ	Vatican City	
HWA-HYZ	France and Colonies	[F]
HZA-HZZ	Hedjaz	HZ
I	Italy and Colonies	I
J	Japanese Empire:	
	Japan	J1-J7
	Chosen (Korea)	J8
	Taiwan (Formosa)	J9
K	United States of America:	
	Continental United States	[W] (N)[2]
	Puerto Rico, Virgin Islands	K4, KB4
	Canal Zone	K5
	Territory of Hawaii, Guam, U. S. Samoa, Midway & Wake Islands (See Country List pp. 430)	
	Alaska	K7
	Philippine Islands	KA
LAA-LNZ	Norway	LA
LOA-LWZ	Argentine Republic	LU
LXA-LXZ	Luxemburg	LX
LYA-LYZ	Lithuania	LY
LZA-LZZ	Bulgaria	LZ
M	Great Britain	[G]
N	United States of America	[K-W] (N)[2]
OAA-OCZ	Peru	OA
ODA-ODZ	Syria and Lebanon	
OEA-OEZ	Austria	OE
OFA-OJZ	Finland	OH
OKA-OMZ	Czechoslovakia	OK
ONA-OTZ	Belgium and Colonies	ON
	Belgian Congo	OQ
OUA-OZZ	Denmark:	
	Denmark	OZ
	The Faeroes	OY
	Greenland	OX
PAA-PIZ	Netherlands	PA
PJA-PJZ	Curacao	PJ
PKA-POZ	Netherlands Indies:	
	Java	PK1-2-3
	Sumatra	PK4

	Dutch Borneo	PK5
	Celebes, Moluccas and New Guinea	PK6
PPA-PYZ	Brazil	PY
PZA-PZZ	Netherlands Guiana (Surinam)	PZ
R	Union of Socialist Soviet Republics	[U]
SAA-SMZ	Sweden	SM
SNA-SRZ	Poland	SP
SSA-SUZ	Egypt:	
	Sudan	ST
	Egypt	SU
SVA-SZZ	Greece	SV-SX
TAA-TCZ	Turkey	TA
TDA-TDZ	Guatemala	[TG]
TEA-TEZ	Costa Rica	[TI]
TFA-TFZ	Iceland	TF
TGA-TGZ	Guatemala	TG
THA-THZ	France and Colonies	[F]
TIA-TIZ	Costa Rica	TI
TJA-TZZ	France and Colonies and Protectorates	[F]
U	Union of Socialist Soviet Republics:	
	European Russian S.F.S.R.	U1-3-4-7
	White Russian S.S.R.	U2
	Ukrainian S.S.R.	U5
	Transcaucasian S.F.S.R.	U6
	Uzbek S.S.R. and Turkoman S.S.R.	U8
	Asiatic Russian S.F.S.R.	U9-0
VAA-VGZ	Canada	VE
VHA-VNZ	Commonwealth of Australia:	
	Australia	VK2-3-4-5-6-8
	Papua Territory	VK4
	Tasmania	VK7
	New Guinea Territory	VK9
VOA-VOZ	Newfoundland	VO
VPA-VSZ	British Colonies and Protectorates:	
	British Honduras and Zanzibar	VP1
	Leeward and Windward Ids.	VP2
	British Guiana	VP3
	Trinidad and Tobago	VP4
	Jamaica and Cayman Islands	VP5
	Barbados	VP6
	Bahamas	VP7
	Falkland Ids	VP8
	Bermuda	VP9
	Fanning Island	VQ1
	Northern Rhodesia	VQ2
	Tanganyika	VQ3
	Kenya	VQ4
	Uganda	VQ5
	British Somaliland	VQ6
	Mauritius and St. Helena	VQ8
	Seychelles	VQ9
	Gilbert & Ellice Islands and Ocean Id.	VR1
	Fiji Islands	VR2
	Fanning Island	VR3
	Solomon Islands	VR4
	Tonga (Friendly) Islands	VR5
	Pitcairn Island	VR6
	Straits Settlements	VS1
	Malaya	VS2-VS3
	North Borneo	VS4
	Sarawak	VS5
	Hongkong	VS6
	Ceylon	VS7
	Bahrein Id.	VS8
	Maldive Ids.	VS9
VTA-VWZ	British India	VU
VXA-VYZ	Canada	[VE]
VZA-VZZ	Australia	[VK]
W	United States of America	[K] (N)[2] W
XAA-XFZ	Mexico	XE
XGA-XUZ	China	XU
XVA-XWZ	France and Colonies	[F]
XXA-XXZ	Portuguese Colonies	[CT]
XYA-XZZ	British India	[VU]
	Burma	XZ
YAA-YAZ	Afghanistan	YA
YBA-YHZ	Netherlands Indies	[PK]
YIA-YIZ	Iraq	YI
YJA-YJZ	New Hebrides	YJ
YKA-YKZ	U.S.S.R.	[U]
YLA-YLZ	Latvia	YL
YMA-YMZ	Free City of Danzig	YM
YNA-YNZ	Nicaragua	YN
YOA-YRZ	Roumania	YR
YSA-YSZ	Republic of El Salvador	YS
YTA-YUZ	Yugo-Slavia	YT-YU
YVA-YWZ	Venezuela	YV
YXA-YZZ	U.S.S.R.	[U]
ZAA-ZAZ	Albania	ZA
ZBA-ZJZ	British Colonies and Protectorates:	
	Malta	ZB1
	Gibraltar	ZB2
	Transjordania	ZC1
	Cocos Islands	ZC2
	Christmas Island	ZC3
	Cyprus	ZC4
	Palestine	ZC6
	Sierra Leone	ZD1
	Nigeria and British Cameroons	ZD2
	Gambia	ZD3
	Gold Coast	ZD4
	Nyassaland	ZD6
	Ascencion Island	ZD8
	Southern Rhodesia	ZE
ZKA-ZMZ	New Zealand:	
	Cook Islands	ZK1
	Niue	ZK2
	New Zealand	ZL
	British Samoa	ZM
ZNA-ZOZ	British Colonies	
ZPA-ZPZ	Paraguay	ZP
ZQA-ZQZ	British Colonies	
ZRA-ZUZ	Union of South Africa:	ZS-ZT-ZU
ZVA-ZZZ	Brazil	[PY]

[1] CM is used by c.w. stations; CO by 'phones.

There are, in addition, certain prefixes not officially assigned which are at present used by amateurs of several countries. Some of these are:

AC4	Tibet
AR	Syria
NY	Canal Zone
PX	Andorra

[2] Certain amateur stations licensed to members of the U. S. Naval Communications Reserve are authorized to use the prefix N.

COUNTRIES

Although not to be regarded as an "official" list of countries, the following tabulation is now regarded as a reasonable standard and has been prepared after extensive collaboration with various groups including several geographical authorities and representative DX men. It is the list used in connection with the awarding of the DX Century Club certificate, issued to all members of the A.R.R.L. submitting proof of two-way contact by amateur radio with 100 countries.

Country	*Prefix*
Aden	
Aegean Islands	
Afghanistan	YA
Alaska (including Pribilof Islands)	K7
Albania	ZA
Aldabra Islands	
Algeria	FA
Andaman Islands	
Andorra	
Anglo-Egyptian Sudan	ST
Angola	CR6
Argentina	LU
Ascension Island	ZD8
Australia	VK

Country	*Prefix*
Azores Islands	CT2
Bahama Islands	VP7
Bahrein Islands	VS8
Baker Island, Howland Island Am. Phœnix Ids	KF6
Balearic Islands	EA6
Baluchistan	
Barbados	VP6
Bechuanaland	
Belgian Congo	OQ
Belgium	ON
Bermuda Islands	VP9
Bhutan	
Bolivia	CP
Borneo, Netherlands	PK5
Brasil	PY
British Honduras	VP1
British North Borneo	VS4
Brunei	
Bulgaria	LZ
Burma	XZ
Cameroons, French	FE8
Canada	VE
Canal Zone	(K5)
Canary Islands	EA8
Cape Verde Islands	CR4
Caroline Islands	
Cayman Islands	VP5
Celebes and Molucca Islands	PK6
Ceylon	VS7
Chagos Islands	VQ8
Channel Islands	G
Chile	CE
China	XU
Chosen (Korea)	J8
Christmas Island	ZC3
Cocos Island	TI
Cocos Islands	ZC2
Colombia	HJ
Cook Islands	ZK1
Corsica	
Costa Rica	TI
Crete	
Cuba	CM-CO
Cyprus	ZC4
Czechoslovakia	OK
Danzig	YM
Denmark	OZ
Dominican Republic	HI
Easter Island	
Ecuador	HC
Egypt	SU
England	G
Eritrea	
Estonia	ES
Ethiopa	ET
Faeroes, The	OY
Falkland Islands	VP8
Fanning Island	VR3
Federated Malay States	VS2
Fiji Islands	VR2
Finland	OH
France	F
French Equatorial Africa	FQ8
French India	FN
French Indochina	FI8
French Oceania	FO8
French West Africa	FF8
Fridtjof Nansen Land (Franz Josef Land)	
Galapagos Islands	
Gambia	ZD3
Germany	D
Gibraltar	ZB2
Gilbert & Ellice Islands and Ocean Island	VR1
Goa (Portuguese India)	CR8
Gold Coast (and British Togoland)	ZD4
Gough Island	
Greece	SV
Greenland	OX
Guadeloupe	FG8
Guam	KB6
Guatemala	TG
Guiana, British	VP3
Guiana, Netherlands (Surinam)	PZ
Guiana, French. and Inini	FY8
Guinea, Portuguese	CR5
Guinea, Spanish	
Haiti	HH
Hawaiian Islands	K6
Hejaz	HZ
Honduras	HR
Hong Kong	VS6
Hungary	HA
Iceland	TF
Ifni	
India	VU
Iran (Persia)	EP
Iraq (Mesopotamia)	YI
Ireland, Northern	GI
Irish Free State	EI
Isle of Man	G
Italy	I
Jamaica	VP5
Jan Mayen Island	OY
Japan	J
Jarvis Island, Palmyra group	KG6
Java	PK
Johnston Island	KE6
Kenya	VQ4
Kerguelen Islands	
Kuweit	
Laccadive Islands	
Latvia	YL
Leeward Islands	VP2
Liberia	EL
Libya	
Liechtenstein	
Lithuania	LY
Luxembourg	LX
Macau	CR9
Madagascar	FB8
Madeira Islands	CT3
Maldive Islands	VS9
Malta	ZB1
Manchukuo	(MX)
Marianas Islands	
Marshall Islands	
Martinique	FM8
Mauritius	VQ8
Mexico	XE
Midway Islands	KD6
Miquelon and St. Pierre Islands	FP8
Monaco	
Mongolia	
Morocco, French	CN
Morocco, Spanish	EA9
Mozambique	CR7
Nepal	
Netherlands	PA
Netherlands West Indies (Curacao)	PJ
New Caledonia	FK8
Newfoundland and Labrador	VO
New Guinea. Netherlands	PK6
New Guinea. Territory of	VK9
New Hebrides	FUB, YJ
New Zealand	ZL
Nicaragua	YN
Nicobar Islands	
Nigeria (British Cameroons)	ZD2
Niue	ZK2
Non-Federated Malay States	VS3
Norway	LA
Nyasaland	ZD6
Oman	
Palau (Pelew) Islands	
Palestine	ZC6
Panama	HP
Papua Territory	VK4
Paraguay	ZP
Peru	OA
Philippine Islands	KA
Phoenix Islands	
Pitcairn Island	VR6
Poland	SP
Portugal	CT
Principe and Sao Thome Islands	
Puerto Rico	K4
Reunion Island	FR8
Rhodesia, Northern	VQ2
Rhodesia, Southern	ZE
Rio de Oro	
Roumania	YR
St. Helena	ZD7
Salvador	YS
Sardinia	
Samoa, U. S.	KH6
Samoa, Western	ZM
Sarawak	VS5
Saudi Arabia	
Scotland	GM
Seychelles	VQ9
Siam	HS
Sierra Leone	ZD1

World Radio History

Country	Prefix
Socotra	
Solomon Islands	VR4
Somaliland, British	VQ6
Somaliland, French	FL8
Somaliland, Italian	
South Georgia	VP8
South Orkney Islands	VP8
South Shetland Islands	VP8
Southwest Africa	ZS3
Soviet Union:	
European Russian Socialist Federated Soviet Republic	U1–3–4–7
White Russian Soviet Socialist Republic	U2
Ukranian Soviet Socialist Republic	U5
Transcaucasian Socialist Federal Soviet Republic	U6
Uzbek Soviet Socialist Republic (Uzbekistan)	U8
Turkoman Soviet Socialist Republic	U8
Asiatic Russian S.F.S.R.	U9–0
Spain	EA
Straits Settlements	VS1
Sumatra	PK4
Svalbard (Spitzbergen)	
Sweden	SM
Switzerland	HB
Syria	
Taiwan (Formosa)	J9
Tanganyika Territory	VQ3
Tangier Zone	
Tannu Tuva	
Tasmania	VK7
Tibet	
Timor, Portugese	CR10
Togoland, French	FD8
Tokelau (Union) Islands	
Tonga (Friendly) Islands	VR5
Transjordan	ZC1
Trinidad and Tobago	VP4
Tristan da Cunha	ZU9
Tunisia	FT4
Turkey	TA
Turks and Caicos Islands	VP5
Uganda	VQ5
Union of South Africa	ZS
United States	W [N]
Uruguay	CX
Venezuela	YV
Virgin Islands	KB4
Wake group	KC6
Wales	GW
Windward Islands	VP2
Wrangel Island	
Yemen	
Yugoslavia	YT-YU
Zanzibar	

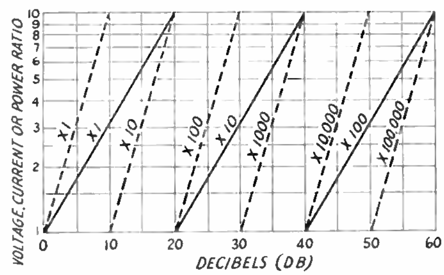
THE DECIBEL

The decibel (abbreviated *db*) is a convenient unit for the measurement of electrical or acoustic power ratios on a logarithmic scale. The number of decibels equivalent to the ratio between two amounts of power is

$$db = 10 \log_{10} \frac{P_1}{P_2}$$

Since the decibel is a logarithmic unit, successive gains and losses expressed in db can be added algebraically. If the ratio of the two power values is greater than 1 there is a power gain; if the ratio is less than 1 there is a loss of power. A gain is expressed in "plus db"; a loss in "minus db."

The decibel also can be used to express ratios between voltages and currents provided the circuit conditions are the same for the two quantities whose magnitudes are being compared; i.e., if the impedances and power factors of the circuits are the same.



DECIBEL CHART FOR POWER, VOLTAGE OR CURRENT CALCULATIONS

Solid lines, voltage or current ratios; dotted lines, power ratios. To find db gain, divide output power by corresponding input power and read db value for this ratio, using the appropriate curve (i.e., "X1" for ratios from 1 to 10, "X10" for ratios from 10 to 100, "X100" for ratios from 1 to 1000, and so on). To find db loss, as where output is less than input, divide input value by output value. Current and voltage ratios in db can be found similarly, provided the input and output impedances are the same. Power, voltage and current values must be in the same units (watts, millivolts, microamperes, etc.). The chart also can be used for voltage and current ratios greater than 1000; for ratios between 1000 and 10,000, divide given ratio by 10 and add 20 db to value read from the chart. For example, to find db gain for a voltage ratio of 8000, read db value for voltage ratio of 800 (58 db) and add 20 db., the answer being 78 db. Power ratios greater than 1,000,000 may be handled similarly, but adding only 10 db each time the actual ratio is divided by 10.

The decibel is primarily a unit which specifies gains or losses with reference to the power value at some point in a system regardless of the actual value of the reference power. In telephone and radio work, however, it is convenient to assume a reference power level and express the power at a point in a circuit in terms of "plus db" or "minus db" above or below this reference level. A standard reference level in radio work is 0.006 watts, or 6 milliwatts.

SYMBOLS FOR ELECTRICAL QUANTITIES

Admittance	Y, y
Angular velocity (πf)	ω
Capacitance	C
Conductance	G, g
Current	I, i
Difference of potential	E, e
Dielectric constant	K or ϵ
Energy	W
Frequency	f
Impedance	Z, z
Inductance	L
Magnetic intensity	H
Magnetic flux	Φ
Magnetic flux density	B
Mutual inductance	M
Number of conductors or turns	N
Permeability	μ

World Radio History

Phase displacement	θ or Φ
Power	P, p
Quantity of electricity	Q, q
Reactance	X, x
Resistance	R, r
Susceptance	b
Speed of rotation	n
Voltage	E, e
Work	W

LETTER SYMBOLS FOR VACUUM TUBE NOTATION

Grid potential	E_g, e_c
Grid current	I_g, i_g
Grid conductance	g_g
Grid resistance	r_g
Grid bias voltage	E_c
Plate potential	E_p, e_p
Plate current	I_b, I_p, i_p
Plate conductance	g_p
Plate resistance	r_p
Plate supply voltage	E_b
Emission current	I_s
Mutual conductance	g_m
Amplification factor	μ
Filament terminal voltage	E_f
Filament current	I_f
Grid-plate capacity	C_{gp}
Grid-cathode capacity	C_{gk}
Plate-cathode capacity	C_{pk}
Grid capacity (input)	C_g
Plate capacity (output)	C_p

NOTE. — Small letters refer to instantaneous values.

METRIC PREFIXES

μ	$\frac{1}{1,000,000}$	One-millionth	micro-
m	$\frac{1}{1,000}$	One-thousandth	milli-
c	$\frac{1}{100}$	One-hundredth	centi-
d	$\frac{1}{10}$	One-tenth	deci-
	1	One	uni-
dk	10	Ten	deka-
h	100	One hundred	hekto-
k	1,000	One thousand	kilo-
	10,000	Ten thousand	myria-
	1,000,000	One million	mega-

A.R.R.L. QSL BUREAU

FOR the convenience of its members, the League maintains a QSL-card forwarding system which operates through volunteer "District QSL Managers" in each of the nine United States and five Canadian districts, the principal U. S. territories and possessions, and the Philippine Islands. In order to secure such foreign cards as may be received for you, send your district manager a standard No. 10 *stamped* envelope. If you have reason to expect a considerable number of cards, put on extra postage. Your own name and address go in the customary place on the face, and *your station call should be printed prominently in the upper left-hand corner.*

W1 — J. T. Steiger, W1BGY, 35 Call Street, Willimansett, Mass.

W2 — H. W. Yahnel, W2SN, Lake Ave., Helmetta, N. J.

W3 — Barron P. Freeburger, W3DK, 435 5th St., N. E., Washington, D. C.

W4 — G. W. Hoke, W4DYB, 328 Mell Ave., N. E., Atlanta, Ga.

W5 — E. H. Treadaway, W5DKR, 2749 Myrtle St., New Orleans, La.

W6 — Horace Greer, W6TI, 414 Fairmount Ave., Oakland, Calif.

W7 — Frank E. Pratt, W7DXZ, 5023 So. Ferry St., Tacoma, Wash.

W8 — F. W. Allen, W8GER, 324 Richmond Ave., Dayton, Ohio.

W9 — Roy W. McCarty, W9KA, 11 South Michigan Ave., Villa Park, Ill.

VE1 — J. E. Roue, VE1FB, 84 Spring Garden Rd., Halifax, N. S.

VE2 — C. W. Skarstedt, VE2DR, 236 Elm Ave., Westmount, P. Q.

VE3 — Bert Knowles, VE3QB, Lanark, Ont.

VE4 — George Behrends, VE4RO, 186 Oakdean Blvd., St. James, Winnipeg, Manitoba.

VE5 — H. R. Hough, VE5HR, 1785 First St., Victoria, B. C.

K4 — F. McCown, K4RJ, Family Court 7, Santurce, Puerto Rico.

K5 — Norman F. Miller, K5AF, 15th Air Base Squadron, Albrook Field, Canal Zone.

K6 — James F. Pa, K6LBH, 1416D Lunalilo St., Honolulu, T. H.

K7 — Dean Williams, K7ELM, Box 2373, Juneau, Alaska.

KA — George L. Rickard, KA1GR, P. O. Box 849, Manila, P. I.

COLOR CODE FOR RESISTORS AND CONDENSERS

A STANDARD color code is used for identification of resistance and capacitance values of small carbon-type resistors and midget mica condensers. In this code, numbers are represented by the following colors:

0 — Black	5 — Green
1 — Brown	6 — Blue
2 — Red	7 — Violet
3 — Orange	8 — Gray
4 — Yellow	9 — White

Three colors are used on each resistor to identify its value. The body color represents

World Radio History

DESIGN DATA FOR INDUCTANCE COILS WITH IRON CORES *Weight of Steel taken as 480 $\frac{lbs}{cu. ft.}$ = 0.28 $\frac{pounds}{cubic\ inches}$*

	CORE SIZE Cross Section	INDUCTANCE HENRYS	EQUIV GAP (G)	*ACTUAL GAP Decimals	GAP Nearest Fraction	NO TURNS (N)	✣FLUX DENS. (B) Lines to inch	WINDING FORM b	WINDING FORM c	MEAN TURN inches	FEET OF WIRE	RESISTANCE (D C)	WEIGHT OF COPPER	CORE DIMENTIONS Long Piece	CORE DIMENTIONS Short Piece	POUNDS STEEL
All wound with No. 33 enamelled wire 206.6 ohms per 1000 ft. 6591 ft. per lb Carrying Capacity 0.05 amperes.	½x½	0.5	.040"	.017*	1/64"	1600	6500	0.42"	0.28"	3.0	400	82.5	1.0oz	½x1.6"	½x.50	0.30
		1.0	.041	.019		2300	9000	0.50	0.33	3.2	615	127.0	1.5 "	½x1.7	½x.55	0.31
		5.0	.043	.023		5200	20000	0.75	0.50	3.8	1670	345.0	4.0 "	½x1.92	½x.75	0.37
		10.0	.046	.030	1/32"	7600	27000	0.90	0.60	4.2	2640	545.0	6.5 "	½x2.1	½x.85	0.41
		15.0	.048	.035		9500	32000	1.00	0.68	4.5	3510	725.0	8.5 "	½x2.2	½x.85	0.43
	¾x¾	5.0	.043"	.023		3500	13000	0.62"	0.42"	4.5	1310	271	3.25oz	¾x2.4	¾x.75	1.0
		10.0	.046	.030		5000	18000	0.73	0.49	4.75	2000	411	5.0 "	¾x2.5	¾x.75	1.0
		15.0	.048	.035		6300	21000	0.82	0.55	5.0	2630	544	6.5 "	¾x2.6	¾x.75	1.05
		20.0	.052	.044	3/64"	7600	24000	0.91	0.60	5.2	3280	678	8.0 "	¾x2.7	¾x.85	1.1
		50.0	.070	.100	7/64"	14000	33000	1.25	0.83	6.0	7000	1445	1LB 1 "	¾x3.0	¾x1.0	1.25
	1x1	10.0	.046"	.030	1/32"	3800	14000	0.64"	0.43"	5.6	1760	364	4.25oz	1x3.0	1x.75	2.1
		15.0	.048	.035		4800	16000	0.69	0.49	5.8	2310	478	5.5 "	1x3.0	1x.75	2.1
		20.0	.052	.044	3/64"	5700	18000	0.78	0.52	5.9	2800	580	6.75 "	1x3.1	1x.75	2.2
		50.0	.070	.100	7/64"	11000	25000	1.10	0.75	6.7	6130	1270	15.0 "	1x3.5	1x1.0	2.5
		100.0	.100	.250	1/4"	18000	29000	1.40	0.93	7.4	11000	2280	1LB 10 "	1x3.8	1x1.1	2.75
	2x2	100.0	.100"	.250	1/4"	8900	14000	0.97"	0.65"	10.4	7700	1590	1LB 3oz	2x5.5	2x1.0	14.5
All wound with No. 30 enamelled wire, 103 ohms per 1000 ft. 3287 ft. per lb Carrying Capacity 0.10 amps.	½x½	0.5	.040"	.017	1/64"	1600	13000	0.55"	0.38"	3.4	450	46	2.2oz	½x1.6	½x0.63	0.31
		1.0	.041	.019		2300	18000	0.66	0.45	3.6	700	72	3.5 "	½x1.75	½x0.70	0.35
		5.0	.043	.023		5200	39000	1.00	0.68	4.5	1950	200	9.5 "	½x2.10	½x0.95	0.43
	¾x¾	1.0	.041"	.019		1500	12000	0.53"	0.37"	4.3	540	56	2.7oz	¾x2.10	¾x0.63	0.87
		5.0	.043	.023		3500	26000	0.83	0.56	5.0	1470	151	7.2 "	¾x2.5	¾x0.80	1.05
		10.0	.046	.030	1/32"	5000	35000	1.00	0.67	5.4	2250	230	11.0 "	¾x2.6	¾x0.95	1.12
	1x1	5.0	.043"	.023		2600	20000	0.71"	0.49"	5.8	1250	130	6.1oz	1x2.8	1x0.75	2.0
		10.0	.046	.030	1/32"	3800	27000	0.86	0.58	6.1	1940	200	9.5 "	1x3.0	1x0.85	2.2
		15.0	.048	.035		4800	32000	0.96	0.65	6.4	2550	260	12.5 "	1x3.1	1x0.90	2.25
	2x2	10.0	.046"	.030	1/32"	1900	13000	0.60"	0.42"	9.5	1500	160	7.5oz	2x4.66	2x0.60	11.5
		15.0	.048	.035		2400	16000	0.68	0.46	9.7	1900	200	9.5 "	2x4.75	2x0.66	12.3
		20.0	.052	.044	3/64"	2900	18000	0.75	0.51	9.8	2400	250	11.5 "	2x4.85	2x0.75	12.5
		50.0	.070	.100	7/64"	5300	24000	1.00	0.70	10.5	4600	480	1LB 6.5 "	2x5.50	2x0.95	14.0
		100.0	.100	.250	1/4"	8900	28000	1.33	0.90	11.2	8300	860	2LB 8 "	2x5.90	2x1.15	16.0
All wound with No. 26 enamelled wire 40.75 ohms per 1000 ft. 1300 ft. per lb Carrying Capacity 0.25 amps	½x½	0.5	.040"	.017	1/64"	1600	32000	0.90"	0.60"	4.2	550	22.5	7oz	½x2	½x.85	0.40
		1.0	.082	.120	1/8"	3200	32000	1.30	0.85	5.1	1350	55	1LB 1 "	½x2.5	½x1.10	0.50
	¾x¾	0.5	.040"	.017	1/64"	1000	21000	0.72"	0.46"	4.7	390	16	5oz	¾x2.3	¾x0.71	0.96
		1.0	.041	.019		1500	30000	0.90	0.58	5.1	640	26	8 "	¾x2.5	¾x0.83	1.05
	1x1	1.0	.041"	.019		1100	22000	0.75"	0.50"	5.8	530	22	6.5oz	1x2.9	1x0.75	2.10
		5.0	.086	.170	11/64"	3700	35000	1.40	0.92	7.3	2260	92	1LB 12 "	1x3.6	1x1.20	2.7
	2x2	5.0	.043"	.023	1/4"	1300	23000	0.82"	0.53"	9.7	1050	43	13oz	2x4.9	2x0.80	12.7
		10.0	.050	.040	1/64"	2000	32000	1.05	0.68	10.5	1750	71	1LB 6 "	2x5.2	2x1.0	13.8
		15.0	.096	.200	13/64"	3300	28000	1.35	0.86	11.1	3060	125	2 " 6 "	2x5.5	2x1.1	14.7
		20.0	.104	.280	9/32"	4000	32000	1.43	0.95	11.5	3820	156	2 " 15 "	2x5.6	2x1.2	15.2
	3x3	10.0	.046"	.030		1300	22000	0.81"	0.53"	14.0	1510	62	1LB 3oz	3x6.9	3x0.8	39
		15.0	.048	.035		1600	26000	0.90	0.60	14.2	1900	77	1 " 7 "	3x7.0	3x0.85	40
		20.0	.052	.044	3/64"	1900	30000	1.00	0.65	14.4	2300	93	1 " 12 "	3x7.1	3x0.9	41
		50.0	.140	.330	1/3"	5000	28000	1.60	1.10	15.9	6600	270	5 " 2 "	3x7.8	3x1.35	46
		100.0	.200	.600	19/32"	8400	34000	2.10	1.40	17.0	12000	485	9 " 3 "	3x8.3	3x1.65	50
All wound with No. 23 enamelled wire 20.32 ohms per 1000 ft. 648.4 ft. per lb. Carrying Capacity 0.50 Amps.	½x½	0.5	0.16"	.35	11/32"	3200	32000	1.80"	1.20"	6.4	1700	35	2LB 10oz	½x3	½x1.45	0.62
	¾x¾	0.5	0.08"	.170	11/64"	1480	30000	1.25"	.83"	6.0	735	15	1LB 2oz	¾x2.9	¾x1.1	1.26
		1.0	0.16	.35	11/32"	3000	30000	1.75	1.20	7.2	1800	37	2 " 13 "	¾x3.5	¾x1.5	1.6
	1x1	0.5	0.04"	.02	1/64"	800	32000	0.90"	0.60"	6.2	410	8.5	0LB 10oz	1x3.0	1x0.85	2.2
		1.0	0.082	.17	11/64"	1600	31000	1.30	0.85	7.1	945	19	1 " 8 "	1x3.5	1x1.0	2.5
		5.0	0.387	.75	3/4"	7800	32000	2.90	1.90	11.0	7000	143	10 " 14 "	1x5.2	1x2.2	4.2
	2x2	1.0	0.041	.019		560	22000	0.75"	0.50"	9.8	460	9.4	0LB 12oz	2x4.9	2x0.75	12.7
		5.0	0.086	.17	11/64"	1800	32000	1.35	0.90	11.3	1700	35	2 " 10 "	2x5.5	2x1.15	15.0
		10.0	0.184	.40	13/32"	3800	33000	2.00	1.30	12.8	4100	83	6 " 6 "	2x6.2	2x1.5	17.3
	3x3	5.0	0.043"	.023		860	30000	1.00"	0.60"	14.2	1000	21	1LB 10oz	3x7.1	3x0.85	40.0
		10.0	0.092	.20	13/64"	1840	31500	1.40	0.92	15.3	2350	48	3 " 10 "	3x7.5	3x1.15	43.5
		15.0	0.130	.30	19/64"	2620	32000	1.65	1.10	16.0	3500	71	5 " 7 "	3x7.8	3x1.4	46.0
		20.0	0.175	.38	3/8"	3500	32000	1.90	1.25	16.6	4850	99	7 " 8 "	3x8.1	3x1.5	48.0
		50.0	0.432	.80	13/16"	8700	32000	3.00	2.00	19.2	14000	282	21 " 8 "	3x9.3	3x2.3	58.0
		100.0	0.900	1.50	1½"	16700	31500	4.10	2.80	22.0	31000	620	47 " 5 "	3x10.5	3x3.1	68.0

* The Actual Gap can only be an approximation owing to the many factors which may effect Fringing of flux, permeability of core, etc. It must be adjusted by trial until the proper value of inductance is obtained or better yet, until the set up operates at the best point.

✣ The values of (B), the flux density, are those obtained with all D.C. & no A.C., or the effective B if all A.C. The maximum value in the latter case will be 1.41 x B as given. In the case of rectified A.C. applied to coil with no previous smoothing the maximum B may be 1.57 times the values given.

World Radio History

COPPER WIRE TABLE

Gauge No. B. & S.	Diam. in Mils [1]	Circular Mil Area	Turns per Linear Inch [2]				Turns per Square Inch [2]			Feet per Lb.		Ohms per 1000 ft. 25° C.	Current Carrying Capacity at 1500 C.M. per Amp. [3]	Diam. in mm.	Nearest British S.W.G. No.
			Enamel	S.C.C.	D.S.C. or S.C.C.	D.C.C.	S.C.C.	Enamel S.C.C.	D.C.C.	Bare	D.C.C.				
1	289.3	82690	—	—	—	—	—	—	—	3.947	—	.1264	55.7	7.348	1
2	257.6	66370	—	—	—	—	—	—	—	4.977	—	.1593	44.1	6.544	3
3	229.4	52640	—	—	—	—	—	—	—	6.276	—	.2009	35.0	5.827	4
4	204.3	41740	—	—	—	—	—	—	—	7.914	—	.2533	27.7	5.189	5
5	181.9	33100	—	—	—	—	—	—	—	9.980	—	.3195	22.0	4.621	7
6	162.0	26250	—	—	—	—	—	—	—	12.58	—	.4028	17.5	4.115	8
7	144.3	20820	—	—	—	—	—	—	—	15.87	—	.5080	13.8	3.665	9
8	128.5	16510	7.6	—	7.4	7.1	—	—	—	20.01	19.6	.6405	11.0	3.264	10
9	114.4	13090	8.6	—	8.2	7.8	—	—	—	25.23	24.6	.8077	8.7	2.906	11
10	101.9	10380	9.6	—	9.3	8.9	87.5	84.8	80.0	31.82	30.9	1.018	6.9	2.588	12
11	90.74	8234	10.7	—	10.3	9.8	110	105	97.5	40.12	38.8	1.284	5.5	2.305	13
12	80.81	6530	12.0	—	11.5	10.9	136	131	121	50.59	48.9	1.619	4.4	2.053	14
13	71.96	5178	13.5	—	12.8	12.0	170	162	150	63.80	61.5	2.042	3.5	1.828	15
14	64.08	4107	15.0	—	14.2	13.8	211	198	183	80.44	77.3	2.575	2.7	1.628	16
15	57.07	3257	16.8	—	15.8	14.7	262	250	223	101.4	97.3	3.247	2.2	1.450	17
16	50.82	2583	18.9	18.9	17.9	16.4	321	306	271	127.9	119	4.094	1.7	1.291	18
17	45.26	2048	21.2	21.2	19.9	18.1	397	372	329	161.3	150	5.163	1.3	1.150	18
18	40.30	1624	23.6	23.6	22.0	19.8	493	454	399	203.4	188	6.510	1.1	1.024	19
19	35.89	1288	26.4	26.4	24.4	21.8	592	553	479	256.5	237	8.210	.86	.9116	20
20	31.96	1022	29.4	29.4	27.0	23.8	775	725	625	323.4	298	10.35	.68	.8118	21
21	28.46	810.1	33.1	32.7	29.8	26.0	940	895	754	407.8	370	13.05	.54	.7230	22
22	25.35	642.4	37.0	36.5	34.1	30.0	1150	1070	910	514.2	461	16.46	.43	.6438	23
23	22.57	509.5	41.3	40.6	37.6	31.6	1400	1300	1080	648.4	584	20.76	.34	.5733	24
24	20.10	404.0	46.3	35.3	41.5	35.6	1700	1570	1260	817.7	745	26.17	.27	.5106	25
25	17.90	320.4	51.7	50.4	45.6	38.6	2060	1910	1510	1031	903	33.00	.21	.4547	26
26	15.94	254.1	58.0	55.6	50.2	41.8	2500	2300	1750	1300	1118	41.62	.17	.4049	27
27	14.20	201.5	64.9	61.5	55.0	45.0	3030	2780	2020	1639	1422	52.48	.13	.3606	29
28	12.64	159.8	72.7	68.6	60.2	48.5	3670	3350	2310	2067	1759	66.17	.11	.3211	30
29	11.26	126.7	81.6	74.8	65.4	51.8	4300	3900	2700	2607	2207	83.44	.084	.2859	31
30	10.03	100.5	90.5	83.3	71.5	55.5	5040	4660	3020	3287	2534	105.2	.067	.2546	33
31	8.928	79.70	101.	92.0	77.5	59.2	5920	5280	—	4145	2768	132.7	.053	.2268	34
32	7.950	63.21	113.	101.	83.6	62.6	7060	6250		5227	3137	167.3	.042	.2019	36
33	7.080	50.13	127.	110.	90.3	66.3	8120	7360	—	6591	4697	211.0	.033	.1798	37
34	6.305	39.75	143.	120.	97.0	70.0	9600	8310	—	8310	6168	266.0	.026	.1601	38
35	5.615	31.52	158.	132.	104.	73.5	10900	8700	—	10480	6737	335.0	.021	.1426	38–39
36	5.000	25.00	175.	143.	111.	77.0	12200	10700	—	13210	7877	423.0	.017	.1270	39–40
37	4.453	19.83	198.	154.	118.	80.3	—	—	—	16660	9309	533.4	.013	.1131	41
38	3.965	15.72	224.	166.	126.	83.6	—	—	—	21010	10666	672.6	.010	.1007	42
39	3.531	12.47	248.	181.	133.	86.6	—	—	—	26500	11907	848.1	.008	.0897	43
40	3.145	9.88	282.	194.	140.	89.7	—	—	—	33410	14222	1069	.006	.0799	44

[1] A mil is 1/1000 (one thousandth) of an inch.
[2] The figures given are approximate only, since the thickness of the insulation varies with different manufacturers.
[3] The current-carrying capacity at 1000 C.M. per ampere is equal to the circular-mil area (Column 3) divided by 1000.

World Radio History

the first figure of the resistance value; one end or tip is colored to represent the second figure; a colored band or dot near the center of the resistor gives the number of zeros following the first two figures. A 25,000-ohm resistor, for example, would be marked as follows: body, red (2); tip, green (5); dot, orange (3 zeros).

Small mica condensers usually are marked with three colored dots, with an arrow or other symbol indicating the sequence of colors. Readings are in micromicrofarads ($\mu\mu$fd.), with the color code same as above. For example, a 0.00025-μfd. (250-$\mu\mu$fd.) condenser would be marked as follows: red (2), green (5), brown (1 zero).

GREEK ALPHABET

SINCE Greek letters are used to stand for many electrical and radio quantities, the names and symbols of the Greek alphabet with the equivalent English characters are given.

Greek Letter	*Greek Name*	*English Equivalent*
Α α	Alpha	a
Β β	Beta	b
Γ γ	Gamma	g
Δ δ	Delta	d
Ε ε	Epsilon	e
Ζ ζ	Zeta	z
Η η	Eta	è
Θ θ	Theta	th
Ι ι	Iota	i
Κ κ	Kappa	k
Λ λ	Lambda	l
Μ μ	Mu	m
Ν ν	Nu	n
Ξ ξ	Xi	x
Ο ο	Omicron	ŏ
Π π	Pi	p
Ρ ρ	Rho	r
Σ σ	Sigma	s
Τ τ	Tau	t
Υ υ	Upsilon	u
Φ φ	Phi	ph
Χ χ	Chi	ch
Ψ ψ	Psi	ps
Ω ω	Omega	ō

HAM ABBREVIATIONS

IN amateur work many of the most commonly used radio and ordinary English words are frequently abbreviated, either by certain generally recognized methods or, as often occurs, on the spur of the moment according to the ideas of the individual operator. Beginning amateurs are likely to be confused by these "ham abbreviations" at first, but will probably pick them up quickly enough in the case of the more or less standard ones, and get the general idea governing the construction of the unusual ones occasionally encountered.

A method much used in short words is to give the first and last letters only, eliminating all intermediate letters. Examples: Now, nw; check, ck; would, wd.

Another method often used in short words employs phonetic spelling. Examples: Some, sum; good, gud; says, sez; night, nite.

A third method uses consonants only, eliminating all vowels. Examples: Letter, ltr; received, rcd; message, msg.

Replacing parts of a word with the letter "x" is a system occasionally used in abbreviating certain words. Examples: Transmitter, xmtr; weather, wx; distance, dx; press, px.

In listing below a short list of some of the more frequently encountered amateur abbreviations, we want to caution the beginner against making too great an effort to abbreviate or to scatter abbreviations wholesale throughout his radio conversation. A judicious use of certain of the short-cut words is permissible and saves time — the only legitimate object of abbreviations, of course. To abbreviate everything one sends, and to do so in many cases to extremes, is merely ridiculous.

ABT	About
ACCT	Account
AGN	Again
AHD	Ahead
AMP	Ampere
AMT	Amount
ANI	Any
AUSSIE	Australian amateur
BCL	Broadcast listener
BD	Bad
BI	By
BKG	Breaking
BLV	Believe
BN	Been, all between
BPL	Brass Pounders' League
BUG	Vibroplex key
CANS	Phones
CK	Check
CKT	Circuit
CL-CLD	Closing station; call; called
CM	Communications Manager
CONGRATS	Congratulations
CRD	Card
CUD	Could
CUL	See you later
CW	Continuous wave
DH	Dead head
DLD-DLVD	Delivered
DLY	Delivery
DX	Distance
ES	And
FB	Fine business, excellent
FIL	Filament
FM	From
FONES	Telephones
FR	For
FREQ	Frequency
GA	Go ahead (resume sending)
GB	Good-bye
GBA	Give better address

World Radio History

GE	Good evening
GG	Going
GM	Good morning
GN	Gone, good night
GND	Ground
GSA	Give some address
HAM	Amateur, brass-pounder
HI	Laughter, high
HR	Here, hear
HRD	Heard
HV	Have
ICW	Interrupted continuous wave
LID	"Lid," a poor operator
LTR	Later, letter
MA	Milliampere
MG	Motor-generator
MILS	Milliamperes
MO	Master oscillator
ND	Nothing doing
NIL	Nothing
NM	No more
NR	Number, near
NSA	No such address
NW	Now
OB	Old Boy, Official Broadcast
OM	Old man
OO	Official Observer
OPN	Operation
OP-OPR	Operator
ORS	Official Relay Station
OT	Old timer, old top
OW	Old woman
PSE	Please
PUNK	Poor operator
R	Are, all right, O.K.
RAC	Rectified alternating current
RCD	Received
RCVR	Receiver
RI	Radio Inspector
RM	Route Manager
SA	Say
SCM	Section Communications Manager
SED	Said
SEZ	Says
SIG-SG	Signature
SIGS	Signals
SINE	Sign, personal initials, signature
SKED	Schedule
TC	Thermocouple
TKS-TNX	Thanks
TNG	Thing
TMW	Tomorrow
TT	That
U	You
UR	Your, you're
URS	Yours
VT	Vacuum tube
VY	Very
WD	Would, word
WCS	Words
WKD	Worked
WKG	Working
WL	Will
WT	What, wait, watt
WUD	Would
WV-WL	Wave, wavelength
WX	Weather
XMTR	Transmitter
YL	Young lady
YR	Your
ZEDDER	New Zealander
73	Best regards
88	Love and kisses

GOOD BOOKS

Every amateur should maintain a carefully selected bookshelf; a few good books, consistently read and consulted, will add immeasurably to the interest and knowledge of the owner. We suggest a selection from the Amateur's Bookshelf at the rear of the *Handbook*. All of these have been gone over carefully and are recommended in their various fields.

EXTRACTS FROM THE COMMUNICATIONS LAW

The complete text of the Communications Act of 1934, would occupy many pages. Only those parts most applicable to amateur radio station licensing and regulation in this country (with which every amateur should be familiar) are given. Note particularly Secs. 324, 325, 326, 605 and 606 and the penalties provided in Secs. 501 and 502.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

Section 1. For the purpose of regulating interstate and foreign commerce in communication by wire and radio so as to make available, so far as possible, to all the people of the United States a rapid, efficient, nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges, for the purpose of the national defense, for the purpose of promoting safety of life and property through the use of wire and radio communication, and for the purpose of securing a more effective execution of this policy by centralizing authority heretofore granted by law to several agencies and by granting additional authority with respect to interstate and foreign commerce in wire and radio communication, there is hereby created a commission to be known as the "Federal Communications Commission," which shall be constituted as hereinafter provided, and which shall execute and enforce the provisions of this Act.

Sec. 2. (a) The provisions of this Act shall apply to all interstate and foreign communication by wire or radio and all interstate and foreign transmission of energy by radio, which originates and/or is received within the United States, and to all persons engaged within the United States in such communication or such transmission of energy by radio, and to the licensing and regulating of all radio stations as hereinafter provided; but it shall not apply to persons engaged in wire or radio communication or transmission in the Philippine Islands or the Canal Zone, or to wire or radio communication or transmission wholly within the Philippine Islands or the Canal Zone. . . .

Sec. 4. (a) The Federal Communications Commission (in this Act referred to as the "Commission") shall be composed of seven commissioners appointed by the President, by and with the advice and consent of the Senate, one of whom the President shall designate as chairman. . . .

Section 301. It is the purpose of this Act, among other things, to maintain the control of the United States over all the channels of interstate and foreign radio transmission; and to provide for the use of such channels, but not the ownership thereof, by persons for limited periods of time, under licenses granted by Federal authority, and no such license shall be construed to create any right, beyond the terms, conditions, and periods of the license. No person shall use or operate any apparatus for the transmission of energy or communications or signals by radio (a) from one place in any Territory or possession of the United States or in the District of Columbia to another place in the same Territory, possession, or District; or (b) from any State, Territory, or possession of the United States, or from the District of Columbia to any other State, Territory, or possession of the United States; or (c) from any place in any State, Territory, or possession of the United States, or in the District of Columbia, to any place in any foreign country or to any vessel; or (d) within any State when the effects of such use extend beyond the borders of said State, or when interference is caused by such use or operation with the transmission of such energy, communications, or signals from within said State to any place beyond its borders, or from any place beyond its borders to any place within said State, or with the transmission or reception of such energy, communications, or signals from and/or to places beyond the borders of said State; or (e) upon any vessel or aircraft of the United States; or (f) upon any other mobile stations within the jurisdiction of the United States, except under and in accordance with this Act and with a license in that behalf granted under the provisions of this Act.

World Radio History

SEC. 303. Except as otherwise provided in this Act, the Commission from time to time, as public convenience, interest, or necessity requires, shall —

(a) Classify radio stations;

(b) Prescribe the nature of the service to be rendered by each class of licensed stations and each station within any class;

(c) Assign bands of frequencies to the various classes of stations, and assign frequencies for each individual station and determine the power which each station shall use and the time during which it may operate;

(d) Determine the location of classes of stations or individual stations;

(e) Regulate the kind of apparatus to be used with respect to its external effects and the purity and sharpness of the emissions from each station and from the apparatus therein;

(f) Make such regulations not inconsistent with law as it may deem necessary to prevent interference between stations and to carry out the provisions of this Act: *Provided, however*, That changes in the frequencies, authorized power, or in the times of operation of any station, shall not be made without the consent of the station licensee unless, after a public hearing, the Commission shall determine that such changes will promote public convenience or interest or will serve public necessity, or the provisions of this Act will be more fully complied with;

(g) Study new uses for radio, provide for experimental uses of frequencies, and generally encourage the larger and more effective use of radio in the public interest; . . .

(j) Have authority to make general rules and regulations requiring stations to keep such records of programs, transmissions of energy, communications, or signals as it may deem desirable; . . .

(l) Have authority to prescribe the qualifications of station operators, to classify them according to the duties to be performed, to fix the forms of such licenses, and to issue them to such citizens of the United States as the Commission finds qualified;

(m) (1) Have authority to suspend the license of any operator upon proof sufficient to satisfy the Commission that the licensee — (A) has violated any provision of any Act, treaty, or convention binding on the United States, which the Commission is authorized to administer, or any regulation made by the Commission under any such Act, treaty, or convention; or (B) has failed to carry out a lawful order of the master or person lawfully in charge of the ship or aircraft on which he is employed; or (C) has willfully damaged or permitted radio apparatus or installations to be damaged; or (D) has transmitted superfluous radio communications or signals or communications containing profane or obscene words, language, or meaning, or has knowingly transmitted —

(1) false or deceptive signals or communications; or

(2) a call signal or letter which has not been assigned by proper authority to the station he is operating; or (E) has willfully or maliciously interfered with any other radio communications or signals; or (F) has obtained or attempted to obtain, or has assisted another to obtain or attempt to obtain, an operator's license by fraudulent means.

(2) No order of suspension of any operator's license shall take effect until fifteen days' notice in writing thereof, stating the cause for the proposed suspension, has been given to the operator licensee who may make written application to the Commission at any time within said fifteen days for a hearing upon such order. The notice to the operator licensee shall not be effective until actually received by him, and from that time he shall have fifteen days in which to mail the said application. In the event that physical conditions prevent mailing of the application at the expiration of the fifteen-day period, the application shall then be mailed as soon as possible thereafter, accompanied by a satisfactory explanation of the delay. Upon receipt by the Commission of such application for hearing, said order of suspension shall be held in abeyance until the conclusion of the hearing which shall be conducted under such rules as the Commission may prescribe. Upon the conclusion of said hearing the Commission may affirm, modify, or revoke said order of suspension.

(n) Have authority to inspect all radio installations associated with stations required to be licensed by any Act or which are subject to the provisions of any Act, treaty, or convention binding on the United States, to ascertain whether in construction, installation, and operation they conform to the requirements of the rules and regulations of the Commission, the provisions of any Act, the terms of any treaty or convention binding on the United States, and the conditions of the license or other instrument of authorization under which they are constructed, installed, or operated.

(o) Have authority to designate call letters of all stations;

(p) Have authority to cause to be published such call letters and such other announcements and data as in the judgment of the Commission may be required for the efficient operation of radio stations subject to the jurisdiction of the United States and for the proper enforcement of this Act; . . .

(q) Have authority to require the painting and/or illumination of radio towers if and when in its judgment such towers constitute, or there is a reasonable possibility that they may constitute, a menace to air navigation.

(r) Make such rules and regulations and prescribe such restrictions and conditions, not inconsistent with law, as may be necessary to carry out the provisions of this Act, or any international radio or wire communications treaty or convention, or regulations annexed thereto, including any treaty or convention insofar as it relates to the use of radio, to which the United States is or may hereafter become a party.

SEC. 309. (a) If upon examination of any application for a station license or for the renewal or modification of a station license the Commission shall determine that public interest, convenience, or necessity would be served by the granting thereof, it shall authorize the issuance, renewal, or modification thereof in accordance with said finding. In the event the Commission upon examination of any such application does not reach such decision with respect thereto, it shall notify the applicant thereof, shall fix and give notice of a time and place for hearing thereon, and shall afford such applicant an opportunity to be heard under such rules and regulations as it may prescribe.

SEC. 318. The actual operation of all transmitting apparatus in any radio station for which a station license is required by this Act shall be carried on only by a person holding an operator's license issued hereunder. No person shall operate any such apparatus in such station except under and in accordance with an operator's license issued to him by the Commission.

SEC. 321. . . . (b) All radio stations, including Government stations and stations on board foreign vessels when within the territorial waters of the United States, shall give absolute priority to radio communications or signals relating to ships in distress; shall cease all sending on frequencies which will interfere with hearing a radio communication or signal of distress, and, except when engaged in answering or aiding the ship in distress, shall refrain from sending any radio communications or signals until there is assurance that no interference will be caused with the radio communications or signals relating thereto, and shall assist the vessel in distress, so far as possible, by complying with its instructions.

SEC. 324. In all circumstances, except in case of radio communications or signals relating to vessels in distress, all radio stations, including those owned and operated by the United States, shall use the minimum amount of power necessary to carry out the communication desired.

SEC. 325. (a) No person within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto, nor shall any broadcasting station rebroadcast the program or any part thereof of another broadcasting station without the express authority of the originating station. . . .

SEC. 326. Nothing in this Act shall be understood or construed to give the Commission the power of censorship over the radio communications or signals transmitted by any radio station, and no regulation or condition shall be promulgated or fixed by the Commission which shall interfere with the right of free speech by means of radio communication. No person within the jurisdiction of the United States shall utter any obscene, indecent, or profane language by means of radio communication.

SEC. 501. Any person who willfully and knowingly does or causes or suffers to be done any act, matter, or thing, in this Act prohibited or declared to be unlawful, or who willfully and knowingly omits or fails to do any act, matter, or thing in this Act required to be done, or willfully and knowingly causes or suffers such omission or failure, shall, upon conviction thereof, be punished for such offense, for which no penalty (other than a forfeiture) is provided herein, by a fine of not more than $10,000 or by imprisonment for a term of not more than two years, or both.

SEC. 502. Any person who willfully and knowingly violates any rule, regulation, restriction, or condition made or imposed by the Commission under authority of this Act, or any rule, regulation, restriction, or condition made or imposed by any international radio or wire communications treaty or convention, or regulations annexed thereto, to which the United States is or may hereafter become a party, shall, in addition to any other penalties provided by law, be punished, upon conviction thereof, by a fine of not more than $500 for each and every day during which such offense occurs.

SEC. 605. No person receiving or assisting in receiving, or transmitting, or assisting in transmitting, any interstate or foreign communication by wire or radio shall divulge or

World Radio History

publish the existence, contents, substance, purport, effect, or meaning thereof, except through authorized channels of transmission or reception, to any person other than the addressee, his agent, or attorney, or to a person employed or authorized to forward such communication to its destination, or to proper accounting or distributing officers of the various communicating centers over which the communication may be passed, or to the master of a ship under whom he is serving, or in response to a subpoena issued by a court of competent jurisdiction, or on demand of other lawful authority; and no person not being authorized by the sender shall intercept any communication and divulge or publish the existence, contents, substance, purport, effect, or meaning of such intercepted communication to any person; and no person not being entitled thereto shall receive or assist in receiving any interstate or foreign communication by wire or radio and use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; and no person having received such intercepted communication or having become acquainted with the contents, substance, purport, effect, or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the existence, contents, substance, purport, effect, or meaning of the same or any part thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto: *Provided*, That this section shall not apply to the receiving, divulging, publishing, or utilizing the contents of any radio communicaton broadcast, or transmitted by amateurs or others for the use of the general public, or relating to ships in distress.

Sec. 606. . . . (c) Upon proclamation by the President that there exists war or a threat of war or a state of public peril or disaster or other national emergency, or in order to preserve the neutrality of the United States, the President may suspend or amend, for such time as he may see fit, the rules and regulations applicable to any or all stations within the jurisdiction of the United States as prescribed by the Commission, and may cause the closing of any station for radio communication and the removal therefrom of its apparatus and equipment, or he may authorize the use or control of any such station and/or its apparatus and equipment by any department of the Government under such regulations as he may prescribe, upon just compensation to the owners.

UNITED STATES AMATEUR REGULATIONS

Pursuant to the basic communications law, general regulations for amateurs have been drafted by the Federal Communications Commission. The number before each regulation is its official number in the complete book of regulations for all classes of radio stations as issued by the Commission; the number of each regulation is of no consequence to the amateur, except as a means of reference.

These regulations are correct as of December 1, 1938. As the regulations are subject to change from time to time, it is recommended that *The Radio Amateur's License Manual* (25¢ postpaid, from the A.R.R.L.) be consulted for latest official regulations, since it is always kept up-to-date either by frequent revisions or by the inclusion of a "change-sheet" giving necessary corrections. It is not expected that any changes of importance will be made during 1939 but if studying for a license it is best to take no chances, and the *License Manual* should always be consulted for the text of regulations in such cases.

RULES AND REGULATIONS GOVERNING AMATEUR RADIO STATIONS

Sec. 150.01. *Amateur service.* The term "amateur service" means a radio service carried on by amateur stations.

Sec. 150.02. *Amateur station.* The term "amateur station" means a station used by an "amateur", that is, a duly authorized person interested in radio technique solely with a personal aim and without pecuniary interest. It embraces all radio transmitting apparatus at a particular location used for amateur service and operated under a single instrument of authorization.

Sec. 150.03. *Amateur portable station.* The term "amateur portable station" means an amateur station that is portable in fact, that is so constructed that it may conveniently be moved about from place to place for communication, and that is in fact so moved from time to time, but which is not operated while in motion.

Sec. 150.04. *Amateur portable-mobile station.* The term "amateur portable-mobile station" means an amateur station that is portable in fact, that is so constructed that it may conveniently be transferred to or from a mobile unit or from one such unit to another, and that is in fact so transferred from time to time and is ordinarily used while such mobile unit is in motion.

Sec. 150.05. *Amateur radio communication.* The term "amateur radio communication" means radio communication between amateur stations solely with a personal aim and without pecuniary interest.

Sec. 150.06. *Amateur operator.* The term "amateur operator" means a person holding a valid license issued by the Federal Communications Commission authorizing him to operate licensed amateur stations.

OPERATOR LICENSES; PRIVILEGES

Sec. 151.01 *Eligibility for license.* The following are eligible to apply for amateur operator license and privileges:

Class A—A United States citizen who has within five years of receipt of application held license as an amateur operator for a year or who in lieu thereof qualified under Section 151.20.

Class B—Any United States citizen.

Class C—A United States citizen whose actual residence, address, and station, are more than 125 miles airline from the nearest point where examination is given at least quarterly for Class B; or is shown by physician's certificate to be unable to appear for examination due to protracted disability; or is shown by certificate of the commanding officer to be in a camp of the Civilian Conservation Corps or in the regular military or naval service of the United States at a military post or naval station and unable to appear for Class B examination.

Sec. 151.02. *Classification of operating privileges.* Amateur operating privileges are as follows:

Class A—All amateur privileges.

Class B—Same as Class A except specially limited as in Section 152.28.

Class C—Same as Class B.

Sec. 151.03. *Scope of operator authority.* Amateur operators' licenses are valid only for the operation of licensed amateur stations; *provided, however*, any person holding a valid radio operator's license of any class may operate stations in the experimental service licensed for, and operating on, frequencies above 300,000 kilocycles.

Sec. 151.04. *Posting of license.* The original operator's license shall be posted in a conspicuous place in the room occupied by such operator while on duty or kept in his personal possession and available for inspection at all times while the operator is on duty, except when such license has been filed with application for modification or renewal, or has been mutilated, lost, or destroyed, and application has been made for a duplicate.

Sec. 151.05. *Duplicate license.* Any licensee applying for a duplicate license to replace an original which has been lost, mutilated, or destroyed, shall submit to the Commission such mutilated license or affidavit attesting to the facts regarding the manner in which the original was lost or destroyed. If the original is later found, it or the duplicate shall be returned to the Commission.

Sec. 151.06. *Renewal of amateur operator license.* An amateur operator license may be renewed upon proper application and a showing that within three months of receipt of the application by the Commission the licensee has lawfully operated an amateur station licensed by the Commission, and that he has communicated by radio with at least three other such amateur stations. Failure to meet the requirments of this section will make it necessary for the applicant to again qualify by examination.

Sec. 151.07. *Who may operate an amateur station.* An amateur station may be operated only by a person holding a valid amateur operator's license, and then only to the extent provided for by the class of privileges for which the operator's license is endorsed. When an amateur station uses radiotelephony (type A-3 emission) the licensee may permit any person to transmit by voice, provided a duly licensed amateur operator maintains control over the emissions by turning the carrier on and off when required and signs the station off after the transmission has been completed.

World Radio History

EXAMINATIONS

SEC. 151.15. *When required.* Examination is required for new license as an amateur operator or for change of class of privileges.

SEC. 151.16. *Elements of examination.* The examination for amateur operator privileges will comprise the following elements:

1. Code test—ability to send and receive, in plain language, messages in the International Morse Code at a speed of not less than thirteen words per minute, counting five characters to the word, each numeral or punctuation mark counting as two characters.
2. Amateur radio operation and apparatus, both telephone and telegraph.
3. Provisions of treaty, statute and regulations affecting amateurs.
4. Advanced amateur radiotelephony.

SEC. 151.17. *Elements required for various privileges.* Examinations for Class A privileges will include all four examination elements as specified in Section 151.16.

Examinations for Classes B and C privileges will include elements 1, 2, and 3 as set forth in Section 151.16.

SEC. 151.18. *Manner of conducting examination.* Examinations for Class A and Class B privileges will be conducted by an authorized Commission employee or representative at points specified by the Commission.

Examinations for Class C privileges will be given by volunteer examiner(s), whom the Commission may designate or permit the applicant to select; in the latter event the examiner giving the code test shall be a holder of an amateur license with Class A or B privileges, or have held within five years a license as a professional radiotelegraph operator or have within that time been employed as a radiotelegraph operator in the service of the United States; and the examiner for the written test, if not the same individual, shall be a person of legal age.

SEC. 151.19. *Additional examination for holders of Class C privileges.* The Commission may require a licensee holding Class C privileges to appear at an examining point for a Class B examination. If such licensee fails to appear for examination when directed to do so, or fails to pass the supervisory examination, the license held will be canceled and the holder thereof will not be issued another license for the Class C privileges.

Whenever the holder of Class C amateur operator privileges changes his actual residence or station location to a point where he would not be eligible to apply for Class C privileges in the first instance, or whenever a new examining point is established in a region from which applicants were previously eligible for Class C privileges, such holders of Class C privileges shall within four months thereafter appear at an examining point and be examined for Class B privileges. The license will be canceled if such licensee fails to appear, or fails to pass the examination.

SEC. 151.20. *Examination abridgment.* An applicant for Class A privileges, who holds a license with Class B privileges, will be required to pass only the added examination element No. 4. (See Section 151.16.)

A holder of Class C privileges will not be accorded an abridged examination for either Class B or Class A privileges.

An applicant who has held a license for the class of privileges specified below, within five years prior to receipt of application, will be credited with examination elements as **follows:**

Class of license or privileges	*Credits*
Commercial extra first	Elements 1, 2 & 4
Radiotelegraph 1st, 2nd, or 3rd	Elements 1 & 2
Radiotelephone 1st or 2nd	Elements 2 & 4
Class A	Elements 2 & 4

No examination credit is given on account of license of Radiotelephone 3rd Class, nor for other class of license or privileges not above listed.

SEC. 151.21. *Examination procedure.* Applicants shall write examinations in longhand,—code tests and diagrams in ink or pencil, written tests in ink—except that applicants unable to do so because of physical disability may typewrite or dictate their examinations and, if unable to draw required diagrams, may make instead a detailed description essentially equivalent. The examiner shall certify the nature of the applicant's disability and, if the examination is dictated, the name and address of the person(s) taking and transcribing the applicant's dictation.

SEC. 151.22. *Grading.* Code tests are graded as passed or failed, separately for sending and receiving tests. A code test is failed unless free of omission or other error for a continuous period of at least one minute at required speed. Failure to pass the required code test will terminate the examination. (See Sec. 151.23.)

A passing grade of 75 per cent is required separately for Class B and Class A written examinations.

SEC. 151.23. *Eligibility for reexamination.* An applicant who fails examination for amateur privileges may not take another examination for such privileges within two months, except that this rule shall not apply to an examination for Class B following one for Class C.

LICENSES

SEC. 152.01. *Eligiblity for amateur station license.* License for an amateur station will be issued only to a licensed amateur operator who has made a satisfactory showing of control of proper transmitting apparatus and control of the premises upon which such apparatus is to be located; provided, however, that in the case of an amateur station of the military or Naval Reserve of the United States located in approved public quarters and established for training purposes, but not operated by the United States Government, a station license may be issued to a person in charge of such a station although not a licensed amateur operator.

SEC. 152.02. *Eligiblity of corporations or organizations to hold license.* An amateur station license will not be issued to a school, company, corporation, association, or other organization; nor for their use; *provided, however*, that in the case of a bona fide amateur radio society a station license may be issued in accordance with Section 152.01 to a licensed amateur operator as trustee for such society.

SEC. 152.03. *Location of station.* An amateur radio station, and the control point thereof when remote control is authorized, shall not be located on premises controlled by an alien.

SEC. 152.04. *License period.* License for an amateur station will normally be for a period of three years from the date of issuance of a new, renewed, or modified license.

SEC. 152.05. *Authorized operation.* An amateur station license authorizes the operation of all transmitting apparatus used by the licensee at the location specified in the station license and in addition the operation of portable and portable-mobile stations at other locations under the same instrument of authorization.

SEC. 152.06. *Renewal of amateur station license.* An amateur station license may be renewed upon proper application and a showing that, within three months of receipt of the application by the Commission, the licensee thereof has lawfully operated such station in communication by radio with at least three other amateur stations licensed by the Commission, except that in the case of an application for renewal of station license issued for an amateur society or reserve group, the required operation may be by any licensed amateur operator. Upon failure to comply with the above requirements, a successor license will not be granted until two months after expiration of the old license.

SEC. 152.07. *Posting of station license.* The original of each station license or a facsimile thereof shall be posted by the licensee in a conspicuous place in the room in which the transmitter is located or kept in the personal possession of the operator on duty, except when such license has been filed with application for modification or renewal, or has been mutilated, lost, or destroyed, and application has been made for a duplicate.

CALL SIGNALS

SEC. 152.08. *Assignment of call letters.* Amateur station calls will be assigned in regular order and special requests will not be considered except that a call may be reassigned to the latest holder, or if not under license during the past five years to any previous holder, or to an amateur organization in memoriam to a deceased member and former holder, and particular calls may be temporarily assigned to stations connected with events of general public interest.

SEC. 152.09. *Call signals for member of U.S.N.R.* In the case of an amateur licensee whose station is licensed to a regularly commissioned or enlisted member of the United States Naval Reserve, the Commandant of the naval district in which such station is located may authorize in his discretion the use of the call-letter prefix N in lieu of the prefix W or K, assigned in the license issued by the Commission, provided that such N prefix shall be used only when operating in the frequency bands 1715–2000 [1] kilocycles, 3500–4000 kilocycles, 56,000–60,000 kilocycles, and 400,000–401,000 kilocycles in accordance with instructions to be issued by the Navy Department.

SEC. 152.10. *Transmission of call signals.* An operator of an amateur station shall transmit its assigned call at the end

[1] Subject to change to "1,750 to 2,050" kilocycles in accordance with the "Inter-American Arrangement Covering Radiocommunication," Havana, 1937.

World Radio History

of each transmission and at least once every ten minutes during transmission of more than ten minutes' duration: *provided, however*, that transmission of less than one minute duration from stations employing break-in operation need be identified only once every ten minutes of operation and at the termination of the correspondence. In addition, an operator of an amateur portable or portable-mobile radiotelegraph station shall transmit immediately after the call of the station the fraction-bar character ($\overline{DN}$) followed by the number of the amateur call area in which the portable or portable-mobile amateur station is then operating, as for example:

Example 1. Portable or portable-mobile amateur station operating in the third amateur call area calls a fixed amateur station: W1ABC W1ABC W1ABC DE W2DEF $\overline{DN}$3 W2DEF $\overline{DN}$3 W2DEF $\overline{DN}$3 $\overline{AR}$.

Example 2. Fixed amateur station answers the portable or portable-mobile amateur station: W2DEF W2DEF W2DEF DE W1ABC W1ABC W1ABC K.

Example 3. Portable or portable-mobile amateur station calls a portable or portable-mobile amateur station: W3GHI W3GHI W3GHI DE W4JKL $\overline{DN}$4 W4JKL $\overline{DN}$4 W4JKL $\overline{DN}$4 $\overline{AR}$.

If telephony is used, the call sign of the station shall be followed by an announcement of the amateur call area in which the portable or portable-mobile station is operating.

SEC. 152.11. *Requirements for portable and portable-mobile operation.* A licensee of an amateur station may operate portable amateur stations (Section 150.03) in accordance with the provisions of Sections 152.09, 152.10, 152.12 and 152.45. Such licensee may operate portable and portable-mobile amateur stations without regard to Section 152.12, but in compliance with Sections 152.09, 152.10, and 152.45, when such operation takes place on authorized amateur frequencies above 28,000 kilocycles.

SEC. 152.12. *Special provisions for portable stations.* Advance notice in writing shall be given by the licensee to the inspector in charge of the district in which such portable station is to be operated. Such notices shall be given prior to any operation contemplated, and shall state the station call, name of licensee, the date of proposed operation, and the locations as specifically as possible. An amateur station operating under this Section shall not be operated during any period exceeding one month without giving further notice to the inspector in charge of the radio-inspection district in which the station will be operated, nor more than four consecutive periods of one month at the same location. This Section does not apply to the operation of portable or portable-mobile amateur stations on frequencies above 28,000 kilocycles. (See Section 152.11.)

SEC. 152.13. *Special provisions for non-portable stations.* The provisions for portable stations shall not be applied to any non-portable station except that:

a. An amateur station that has been moved from one permanent location to another permanent location may be operated at the latter location in accordance with the provisions governing portable stations for a period not exceeding sixty days, but in no event beyond the expiration date of the license, provided an application for modification of license to change the permanent location has been made to the Commission.

b. The licensee of an amateur station who is temporarily residing at a location other than the licensed location for a period not exceeding four months may for such period operate his amateur station at his temporary address in accordance with the provisions governing portable stations.

USE OF AMATEUR STATIONS

SEC. 152.14. *Points of communication.* An amateur station shall communicate only with other amateur stations, except that in emergencies or for testing purposes it may be used also for communication with commercial or Government radio stations. In addition, amateur stations may communicate with any mobile radio station which is licensed by the Commission to communicate with amateur stations, and with stations of expeditions which may also be authorized to communicate with amateur stations. They may also make transmissions to points equipped only with receiving apparatus for the measurement of emissions, observation of transmission phenomena, radio control of remote objects, and similar purely experimental purposes.

SEC. 152.15. *No remuneration for use of station.* An amateur station shall not be used to transmit or receive messages for hire, nor for communication for material compensation, direct or indirect, paid or promised.

SEC. 152.16. *Broadcasting prohibited.* An amateur station shall not be used for broadcasting any form of entertainment, nor for the simultaneous retransmission by automatic means of programs or signals emanating from any class of station other than amateur.

SEC. 152.17. *Radiotelephone tests.* The transmission of music by an amateur station is forbidden. However, single audio-frequency tones may be transmitted by radiotelephony for test purposes of short duration in connection with the development of experimental radiotelephone equipment.

ALLOCATION OF FREQUENCIES

SEC. 152.25. *Frequencies for exclusive use of amateur stations.* The following bands of frequencies are allocated exclusively for use by amateur stations:

1,715 to 2,000 kc.[1]	28,000 to 30,000 kc.
3,500 to 4,000 kc.	56,000 to 60,000 kc.
7,000 to 7,300 kc.	112,000 to 118,000 kc.[2]
14,000 to 14,400 kc.	224,000 to 230,000 kc.[2]
	400,000 to 401,000 kc.

SEC. 152.26. *Use of frequencies above 300,000 kilocycles.* The licensee of an amateur station may, subject to change upon further order, operate amateur stations, with any type of emission authorized for amateur stations, on any frequency above 300,000 kilocycles without separate licenses therefor.

SEC. 152.27. *Frequency bands for telephony.* The following bands of frequencies are allocated for use by amateur stations using radiotelephony, type A-3 emission:

1,800 to 2,000 kc.	112,000 to 118,000 kc.[2]
28,500 to 30,000 kc.	224,000 to 230,000 kc.[2]
56,000 to 60,000 kc.	400,000 to 401,000 kc.

SEC. 152.28. *Additional bands for telephony.* An amateur station may use radiotelephony, type A-3 emission, in the following additional bands of frequencies; *provided* the station is licensed to a person who holds an amateur operator's license endorsed for Class A privileges, and actually is operated by an amateur operator holding Class A privileges:

3,900 to 4,000 kilocycles	14,150 to 14,250 kilocycles

SEC. 152.29. *Television and frequency-modulation transmission.* The following bands of frequencies are allocated for use by amateur stations for television and radiotelephone frequency-modulation transmission:

112,000 to 118,000 kilocycles[2]
224,000 to 230,000 kilocycles[2]
400,000 to 401,000 kilocycles

SEC. 152.30. *Facsimile transmission.* The following bands of frequencies are allocated for use by amateur stations for facsimile transmission:

1,715 to 2,000 kc.[1]	112,000 to 118,000 kc.[2]
56,000 to 60,000 kc.	224,000 to 230,000 kc.[2]
	400,000 to 401,000 kc.

SEC. 152.31. *Individual frequency not specified.* Transmissions by an amateur station may be on any frequency within the bands above assigned. Sideband frequencies resulting from keying or modulating a transmitter shall be confined within the frequency band used.

SEC. 152.32. *Types of emission.* All bands of frequencies allocated to the amateur service may be used for radiotelegraphy, type A-1 emission. Type A-2 emission may be used in the following bands of frequencies only:

56,000 to 60,000 kc.	224,000 to 230,000 kc.[2]
112,000 to 118,000 kc.[2]	400,000 to 401,000 kc.

EQUIPMENT AND OPERATION

SEC. 152.40. *Maximum power input.* The licensee of an amateur station is authorized to use a maximum power input of 1 kilowatt to the plate circuit of the final amplifier stage of an oscillator-amplifier transmitter or to the plate circuit of an oscillator transmitter. An amateur transmitter operating with a power input exceeding nine-hundred watts to the plate circuit shall provide means for accurately measuring the plate power input to the vacuum tube, or tubes, supplying power to the antenna.

SEC. 152.41. *Power supply to transmitter.* The licensee of an amateur station using frequencies below 60,000 kilocycles shall use adequately filtered direct-current plate power

[1] Subject to change to "1,750 to 2,050" kilocycles in accordance with the "Inter-American Arrangement Covering Radiocommunication," Havana, 1937.

[2] The Commission reserves the right to change or cancel these frequencies without advance notice or hearing.

World Radio History

supply for the transmitting equipment to minimize frequency modulation and to prevent the emission of broad signals.

SEC. 152.42. *Requirements for prevention of interference.* Spurious radiations from an amateur transmitter operating on a frequency below 60,000 kilocycles shall be reduced or eliminated in accordance with good engineering practice and shall not be of sufficient intensity to cause interference on receiving sets of modern design which are tuned outside the frequency band of emission normally required for the type of emission employed. In the case of A-3 emission, the transmitter shall not be modulated in excess of its modulation capability to the extent that interfering spurious radiations occur, and in no case shall the emitted carrier be amplitude-modulated in excess of 100 per cent. Means shall be employed to insure that the transmitter is not modulated in excess of its modulation capability. A spurious radiation is any radiation from a transmitter which is outside the frequency band of emission normal for the type of transmission employed, including any component whose frequency is an integral multiple or submultiple of the carrier frequency (harmonics and subharmonics), spurious modulation products, key clicks, and other transient effects, and parasitic oscillations. The frequency of emission shall be as constant as the state of the art permits.

SEC. 152.43. *Modulation of carrier wave.* Except for brief tests or adjustments, an amateur radiotelephone station shall not emit a carrier wave unless modulated for the purpose of communication.

SEC. 152.44. *Frequency measurement and regular check.* The licensee of an amateur station shall provide for measurement of the transmitter frequency and establish procedure for checking it regularly. The measurement of the transmitter frequency shall be made by means independent of the frequency control of the transmitter and shall be of sufficient accuracy to assure operation within the frequency band used.

SEC. 152.45. *Logs.* Each licensee of an amateur station shall keep an accurate log of station operation, including the following data:

(a) The date and time of each transmission. (The date need only be entered once for each day's operation. The expression "time of each transmission" means the time of making a call and need not be repeated during the sequence of communication which immediately follows; however, an entry shall be made in the log when "signing off" so as to show the period during which communication was carried on.)

(b) The signature of the person manipulating the transmitting key of a radiotelegraph transmitter or the signature of the person operating a transmitter of any other type (type A-3 or A-4 emission) with statement as to type of emission, and the signature of any other person who transmits by voice over a radiotelephone transmitter (type A-3 emission). (The signature need only be entered once in the log provided the log contains a statement to the effect that all transmissions were made by the person named except where otherwise stated. The signature of any other person who operates the station shall be entered in the proper space for his transmissions.)

(c) Call letters of the station called. (This entry need not be repeated for calls made to the same station during any sequence of communication, provided the time of "signing off" is given.)

(d) The input power to the oscillator, or to the final amplifier stage where an oscillator-amplifier transmitter is employed. (This need be entered only once, provided the input power is not changed.)

(e) The frequency band used. (This information need be entered only once in the log for all transmissions until there is a change in frequency to another amateur band.)

(f) The location of a portable or portable-mobile station at the time of each transmission. (This need be entered only once provided the location of the station is not changed. However, suitable entry shall be made in the log upon changing location, showing the type of vehicle or mobile unit in which the station is operated and the approximate geographical location of the station at the time of operation.)

(g) The message traffic handled. (If record communications are handled in regular message form, a copy of each message sent and received shall be entered in the log or retained on file for at least one year.)

The log shall be preserved for a period of at least one year following the last date of entry. The copies of record communications and station log, as required under this section, shall be available for inspection upon request by an authorized Government representative.

SPECIAL CONDITIONS

SEC. 152.50. *Additional conditions to be observed by licensee.* An amateur station license is granted subject to the conditions imposed in Sections 152.51 to 152.54 inclusive, in addition to any others that may be imposed during the term of the license. Any licensee receiving due notice requiring the station licensee to observe such conditions shall immediately act in conformity therewith.

SEC. 152.51. *Quiet hours.* In the event that the operation of an amateur station causes general interference to the reception of broadcast programs with receivers of modern design, such amateur station shall not operate during the hours from 8 o'clock P.M. to 10:30 P.M., local time, and on Sunday for the additional period from 10:30 A.M. until 1 P.M., local time, upon such frequency or frequencies as cause such interference.

SEC. 152.52. *Second notice of same violation.* In every case where an amateur station licensee is cited a second time within a year for the same violation under Section 152.25, 152.27, 152.28, 152.30, 152.31, 152.41, or 152.42, the Commission will direct that the station remain silent from 6 P.M. to 10:30 P.M., local time, until written notice has been received authorizing full-time operation. The licensee shall arrange for tests at other hours with at least two amateur stations within fifteen days of the date of notice, such tests to be made for the specific purpose of aiding the licensee in determining whether the emissions of his station are in accordance with the Commission's Regulations. The licensee shall report under oath to the Commission at the conclusion of the tests as to the observations reported by amateur licensees in relation to the reported violation. Such reports shall include a statement as to the corrective measures taken to insure compliance with the Regulations.

SEC. 152.53. *Third notice of same violation.* In every case where an amateur station licensee is cited the third time within a year for the same violation as indicated in Section 152.52, the Commission will direct that the station remain silent from 8 A.M. to 12 midnight, local time, except for the purpose of transmitting a prearranged test to be observed by a monitoring station of the Commission to be designated in each particular case. Upon completion of the test the station shall again remain silent during these hours until authorized by the Commission to resume full-time operation. The Commission will consider the results of the tests and the licensee's past record in determining the advisability of suspending the operator license and/or revoking the station license.

SEC. 152.54. *Operation in emergencies.* In the event of widespread emergency conditions affecting domestic communication facilities, the Commission may confer with representatives of the amateur service and others and, if deemed advisable, will declare that a state of general communications emergency exists, designating the licensing area or areas concerned (in general not exceeding 1,000 miles from center of the affected area), whereupon it shall be incumbent upon each amateur station in such area or areas to observe the following restrictions for the duration of such emergency.

(a) No transmissions except those relating to relief work or other emergency service such as amateur nets can afford, shall be made within the 1715–2000[1] kilocycle or 3500–4000 kilocycle amateur bands. Incidental calling, testing, or working, including casual conversation or remarks not pertinent or necessary to constructive handling of the general situation shall be prohibited.

(b) The frequencies 1975–2000, 3500–3525, and 3975–4000 kilocycles shall be reserved for emergency calling channels, for initial calls from isolated stations or first calls concerning very important emergency relief matters or arrangements. All stations having occasion to use such channels shall, as quickly as possible, shift to other frequencies for carrying on their communications.

(c) A five-minute listening period for the first five minutes of each hour shall be observed for initial calls of major importance, both in the designated emergency calling channels and throughout the 1715–2000[1] and 3500–4000 kilocycle bands. Only stations isolated or engaged in handling official traffic of the highest priority may continue with transmissions in these listening periods, which must be accurately observed. No replies to calls or resumption of routine traffic shall be made in the five-minute listening period.

(d) The Commission may designate certain amateur stations to assist in promulgation of its emergency announcement, and for policing the 1715–2000[1] and 3500–4000 kilocycle bands and warning non-complying stations noted operating therein. The operators of these observing stations shall report fully the identity of any stations failing, after due notice, to comply with any section of this regulation. Such designated stations will act in an advisory capacity when able to provide information on emergency circuits. Their policing authority is limited to the transmission of information from responsible official sources, and full reports of

[1] Subject to change to "1750 to 2050" kilocycles in accordance with the "Inter-American Arrangement Covering Radiocommunication," Havana, 1937.

World Radio History

non-compliance which may serve as a basis for investigation and action under Section 502 of the Communications Act. Policing authority extends only to 1715–2000[1] and 3500–4000 kilocycle bands. Individual policing transmissions shall refer to this Section by number, shall specify the date of the Commission's declaration, the area and nature of the emergency, all briefly and concisely. Policing-observer stations shall not enter into discussions beyond essentials with the stations notified, or other stations.

(e) These special conditions imposed under this Section will cease to apply only after the Commission shall have declared such emergency to be terminated.

103.6. Each application for an instrument of authorization shall be made in writing, under oath of the applicant, on a form prescribed and furnished by the Commission. . . . Separate application shall be filed for each instrument of authorization requested. . . . The required forms may be obtained from the Commission or from any of its field offices. (For a list of such offices and related geographical districts, see rule 30.)

103.7. Each application for . . . station license, with respect to the number of copies and place of filing, shall be submitted as follows: . . . g. Amateur . . . 1 copy to be sent as follows: (a) To proper district office if it requires personal appearance for operator examination under direct supervision from that office; (b) Direct to Washington, D. C., in all other cases, including examinations for class C privileges.

103.14. An application for modification of license may be filed for . . . change in location. . . . Except when filed to cover construction permit, each application for modification of license shall be filed at least 60 days prior to the contemplated modification of license; *Provided, however*, That in emergencies and for good cause shown, the Commission may waive the requirements hereof insofar as time for filing is concerned.

103.15. Unless otherwise directed by the Commission, each application for renewal of license shall be filed at least 60 days prior to the expiration date of the license sought to be renewed.

105.23. Any licensee receiving official notice of a violation of the terms of the Communications Act of 1934, any legislative act, Executive order, treaty to which the United States is a party or the rules and regulations of the Federal Communications Commission, which are binding upon licensee or the terms and conditions of a license, shall, within 3 days from such receipt, send a written reply direct to the Federal Communications Commission at Washington, D. C., and a copy thereof to the office of the Commission originating the official notice, when the originating office is other than the office of the Commission in Washington, D. C. The answer to each notice shall be complete in itself and shall not be abbreviated by reference to other communications or answer to other notices. If the notice relates to some violation that may be due to the physical or electrical characteristics of the transmitting apparatus, the answer shall state fully what steps, if any, are taken to prevent future violations, and if any new type apparatus is to be installed, the date such apparatus was ordered, the name of the manufacturer, and promised date of delivery. . . .

If the notice of violation relates to some lack of attention or improper operation of the transmitter, the name and license number of the operator in charge shall be given.

105.29. Whenever the Commission shall institute a revocation proceeding against the holder of any radio station construction permit or license under section 312(a), it shall initiate said proceeding by serving upon said licensee an order of revocation effective not less than 15 days after written notice thereof is given the licensee. The order of revocation shall contain a statement of the grounds and reasons for such proposed revocation and a notice of the licensee's right to be heard by filing with the Commission a written request for hearing within 15 days after receipt of said order. Upon the filing of such written request for hearing by said licensee the order of revocation shall stand suspended and the Commission will set a time and place for hearing and shall give the licensee and other interested parties notice thereof. If no request for hearing on any order of revocation is made by the licensee against whom such an order is directed within the time hereinabove set forth, the order of revocation shall become final and effective, without further action of the Commission. . . .

105.31. Proceedings for the suspension of an operator license shall in all cases be initiated by the entry of an order of suspension, a copy of which shall be served upon or mailed to the holder of the license involved, to become effective on a day certain, in no event less than 40 days after date of serving or mailing such order. The order shall set forth the name of the operator, class and grade of license, the effective date of the order, the period of suspension, and a statement of the reasons for suspension, and shall contain a notice to the holder of such license of his right to be heard and contest the order, by filing with the Commission within 35 days from the receipt of said order, a written request for hearing with a statement executed by him under oath, denying or explaining specifically and in detail the charges set forth in the order of suspension. Upon receipt of such request and statement, the effective date of the suspension of such license will be extended; and the Commission, upon consideration of the licensee's statement, as herein provided, will either revoke its order of suspension, or fix a time and place for hearing, and notify the licensee thereof.

If no request for hearing on any order of suspension is made by the licensee against whom such order is directed within 35 days of receipt of such order of suspension, the same shall become final and effective.

Where any order of suspension has become final, the person whose license has been suspended shall forthwith send the operator's license in question to the office of the Commission in Washington, D. C.

27. All station licenses will be issued so as to expire at the hour of 3 a.m., eastern standard time. The normal license periods and expiration dates are as follows:

(e) The licenses for amateur stations will be issued for a normal license period of three years from the date of expiration of old license or the date of granting a new license or modification of a license.

30. The following list of the radio districts gives the address of each field office of the Federal Communications Commission and the territory embraced in each district. [This list is reproduced on the last page of this booklet. — Ed.]

(a) Examining cities — Examinations for all classes of radio operator licenses will be given frequently at Washington, D. C., and the District offices of the Commission in accordance with announced schedules.

(1) Such examinations will be held quarterly at:

Cincinnati, O.	Pittsburgh, Pa.
Cleveland, O.	St. Louis, Mo.
Columbus, O.	San Antonio, Tex.
Des Moines, Ia.	Schenectady, N. Y.
Nashville, Tenn.	Winston-Salem, N. C.
Oklahoma City, Okla.	

(2) Examinations will be held not more than twice annually at:

Albuquerque, N. Mex.	Jacksonville, Fla.
Billings, Mont.	Little Rock, Ark.
Bismarck, N. Dak.	Phoenix, Ariz.
Boise, Idaho.	Salt Lake City, Utah.
Butte, Mont.	Spokane, Wash.

210. Radio communcations or signals relating to ships or aircraft in distress shall be given absolute priority. Upon notice from any station, Government or commercial, all other transmission shall cease on such frequencies and for such time as may, in any way, interfere with the reception of distress signals or related traffic.

212a. The licensee of any radiotelegraph or radiotelephone station, other than broadcast, may, if proper notice from authorized government representatives is filed with and approved by the Commission, utilize such stations for military or naval test communications (messages not necessary for the conduct of ordinary governmental business) in preparation for national defense during the period or periods stated in said notice subject to the sole condition that no interference to any service of another country will result therefrom. Nothing herein or in any other regulation of the Commission shall be construed to require any such station to participate in any such test.

213. One or more licensed operators, of grade specified by these regulations, shall be on duty at the place where the transmitting apparatus of each station is located and whenever it is being operated; provided, however, that for a station licensed for service other than broadcast, and remote control is used, the Commission may modify the foregoing requirement upon proper application and showing being made, so that such operator or operators may be on duty at the control station in lieu of the place where the transmitting apparatus is located. Such modification shall be subject to the following conditions:

(a) The transmitter shall be capable of operation and shall be operated in accordance with the terms of the station license.

(b) The transmitter shall be monitored from the control station with apparatus that will permit placing the transmitter in an inoperative condition in the event there is a deviation from the terms of the license, in which case the radiation of the transmitter shall be suspended immediately until corrective measures are effectively applied to place the transmitter in proper condition for operation in accordance with the terms of the station license.

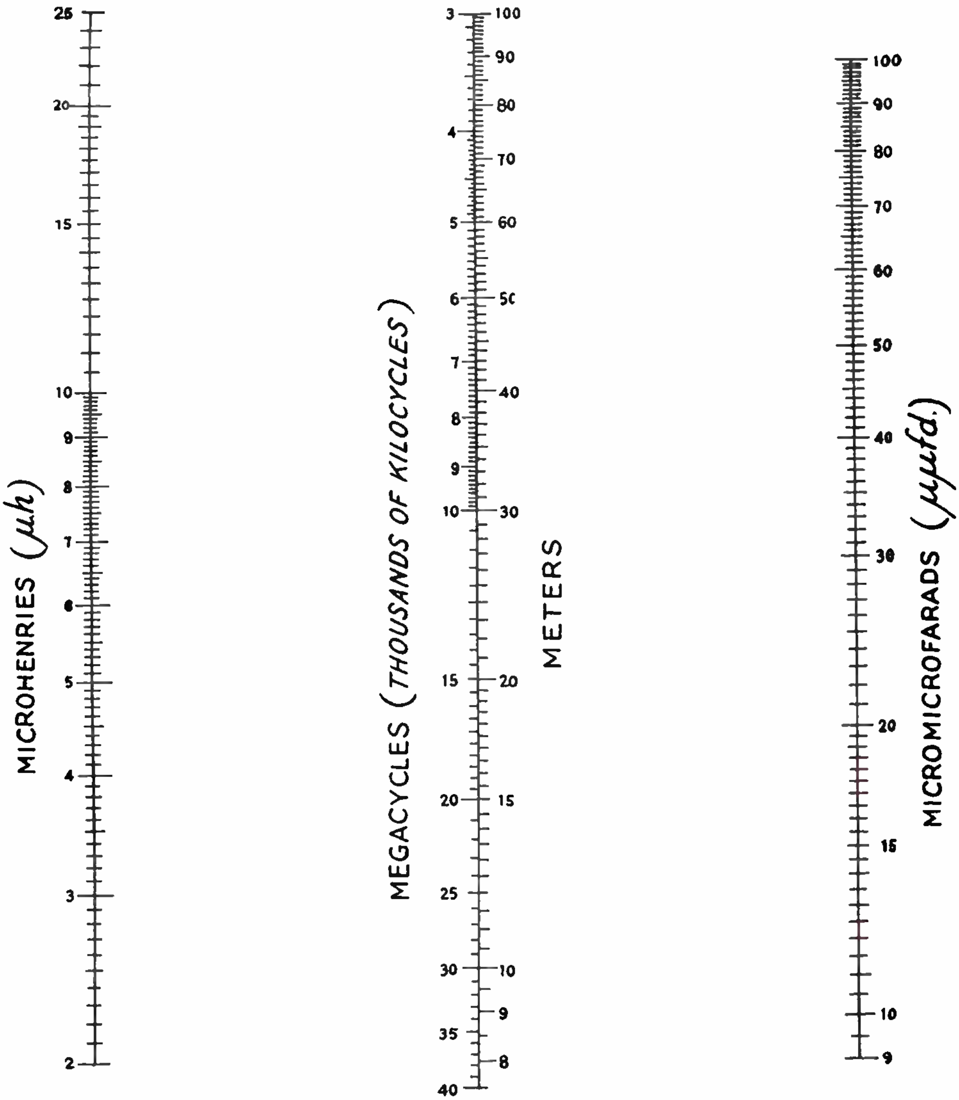
(c) The transmitter shall be so located or housed that it is not accessible to other than duly authorized persons.

World Radio History

U. S. RADIO DISTRICTS

District	*Territory*	*Address, Radio Inspector-in-Charge*
No. 1	The States of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont.	Customhouse, Boston, Mass.
No. 2	The counties of Albany, Bronx, Columbia, Delaware, Dutchess, Greene, Kings, Nassau, New York, Orange, Putnam, Queens, Rensselaer, Richmond, Rockland, Schenectady, Suffolk, Sullivan, Ulster and Westchester of the State of New York; and the counties of Bergen, Essex, Hudson, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Passaic, Somerset, Sussex, Union and Warren of the State of New Jersey.	Federal Building, 641 Washington St., New York, N. Y.
No. 3	The counties of Adams, Berks, Bucks, Carbon, Chester, Cumberland, Dauphin, Delaware, Lancaster, Lebanon, Lehigh, Monroe, Montgomery, Northampton, Perry, Philadelphia, Schuylkill and York of the State of Pennsylvania; and the counties of Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Ocean and Salem of the State of New Jersey; and the county of Newcastle of the State of Delaware.	Room 1200, U. S. Customhouse, Second and Chestnut Sts., Philadelphia, Pa.
No. 4	The State of Maryland; the District of Columbia; the counties of Arlington, Clark, Fairfax, Fauquier, Frederick, Loudoun, Page, Prince William, Rappahannock, Shenandoah and Warren of the State of Virginia; and the counties of Kent and Sussex of the State of Delaware.	Fort McHenry, Baltimore, Md.
No. 5	The State of Virginia except that part lying in District 4, and the State of North Carolina except that part lying in District 6.	402 New Post Office Bldg., Norfolk, Va.
No. 6	The States of Alabama, Georgia, South Carolina, and Tennessee; and the counties of Ashe, Avery, Buncombe, Burke, Caldwell, Cherokee, Clay, Cleveland, Graham, Haywood, Henderson, Jackson, McDowell, Macon, Madison, Mitchell, Polk, Rutherford, Swain, Transylvania, Watauga and Yancey of the State of North Carolina.	411 Federal Annex, Atlanta, Ga.
No. 7	The State of Florida.	312 Federal Bldg., Miami, Fla.
No. 8	The States of Arkansas, Louisiana and Mississippi; and the city of Texarkana in the State of Texas.	326 Customhouse, New Orleans, La.
No. 9	The counties of Arkansas, Brazoria, Brooks, Calhoun, Cameron, Chambers, Fort Bend, Galveston, Goliad, Harris, Hidalgo, Jackson, Jefferson, Jim Wells, Kenedy, Kleberg, Matagorda, Nueces, Refugio, San Patricio, Victoria, Wharton and Willacy of the State of Texas.	404–406 Federal Bldg., Galveston, Tex.
No. 10	The State of Texas except that part lying in District 9 and in the city of Texarkana; and the States of Oklahoma and New Mexico.	302 U. S. Terminal Annex Bldg., Dallas, Tex.
No. 11	The State of Arizona; the county of Clarke in the State of Nevada; and the counties of Imperial, Inyo, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara and Ventura of the State of California.	1105 Rives-Strong Building, Los Angeles, Calif.
No. 12	The State of California except that part lying in District 11; the State of Nevada except the county of Clarke.	328 Customhouse, San Francisco, Calif.
No. 13	The State of Oregon; and the State of Idaho except that part lying in District 14.	207 New U. S. Courthouse Bldg., Portland, Ore.
No. 14	The Territory of Alaska; the State of Washington; the counties of Benewah, Bonner, Boundary, Clearwater, Idaho, Kootenai, Latah, Lewis, Nez Perce and Shoshone of the State of Idaho; the counties of Beaverhead, Broadwater, Cascade, Deerlodge, Flathead, Gallatin, Glacier, Granite, Jefferson, Lake, Lewis & Clark, Lincoln, Madison, Meagher, Mineral, Missoula, Pondera, Powell, Ravalli, Sanders, Silver Bow, Teton and Toole of the State of Montana.	808 Federal Office Building, Seattle, Wash.
No. 15	The States of Colorado, Utah and Wyoming; and the State of Montana except that part lying in District 14.	504 Customhouse, Denver, Colo.
No. 16	The States of North Dakota, South Dakota and Minnesota; the counties of Alger, Baraga, Chippewa, Delta, Dickinson, Gogebic, Houghton, Iron, Keweenaw, Luce, Mackinac, Marquette, Menominee, Ontonagon and Schoolcraft of the State of Michigan; and the State of Wisconsin except that part lying in District 18.	927 New P. O. Bldg., St. Paul, Minn.
No. 17	The States of Nebraska, Kansas and Missouri; and the State of Iowa except that part lying in District 18.	609 Pickwick Bldg., 903 McGee Street, Kansas City, Mo.
No. 18	The States of Indiana and Illinois; the counties of Allamakee, Buchanan, Cedar, Clayton, Clinton, Delaware, Des Moines, Dubuque, Fayette, Henry, Jackson, Johnson, Jones, Lee, Linn, Louisa, Muscatine, Scott, Washington and Winneshiek of the State of Iowa; the counties of Columbia, Crawford, Dane, Dodge, Grant, Green, Iowa, Jefferson, Kenosha, Lafayette, Milwaukee, Ozaukee, Racine, Richland, Rock, Sauk, Walworth, Washington and Waukesha of the State of Wisconsin.	246 U. S. Courthouse Bldg., Chicago, Ill.
No. 19	The State of Michigan except that part lying in District 16; the States of Ohio, Kentucky and West Virginia.	1025 New Federal Bldg., Detroit, Mich.
No. 20	The State of New York except that part lying in District 2, and the State of Pennsylvania except that part lying in District 3.	514 Federal Building, Buffalo, N. Y.
No. 21	The Territory of Hawaii, Guam and American Samoa.	Aloha Tower, Honolulu, T. H.
No. 22	Puerto Rico and Virgin Islands	303 Ochoa Bldg., San Juan, P. R.

World Radio History



RELATION BETWEEN INDUCTANCE, CAPACITY AND FREQUENCY

With this chart and a straight-edge any of the above quantities can be determined if the other two are known. For example, if a condenser has a minimum capacity of 15 $\mu\mu$fd. and a maximum capacity of 50 $\mu\mu$fd., and it is to be used with a coil of 10 μh. inductance, what frequency range will be covered? The straight-edge is connected between 10 on the left-hand scale and 15 on the right, giving 13 Mc. as the high-frequency limit. Keeping the straight-edge at 10 on the left-hand scale, the other end is swung to 50 on the right-hand scale, giving a low-frequency limit of 7.1 Mc. The tuning range would, therefore, be from 7.1 Mc. to 13 Mc., or 7100 kc. to 13,000 kc. The center scale also serves to convert frequency to wavelength.

World Radio History

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EXPERIMENTAL RADIO, *by Prof. R. R. Ramsey.* Fourth Edition. A splendid book for the experimenter. This is a laboratory manual, describing 132 excellent experiments designed to bring out the principles of radio theory, instruments and measurements. 167 illustrations, 196 pp., 5¼ x 7. 1937. . . . . **$2.75**

RADIO FREQUENCY ELECTRICAL MEASUREMENTS, *by Hugh A. Brown.* A laboratory course in r.f. measurements for communications students. Contains much practical information on methods of measurement. 384 pages, 177 illustrations, 1938. . . . . . . **$4.00**

COMMERCIAL EQUIPMENT AND OPERATING

PRACTICAL RADIO COMMUNICATION, *by A. R. Nilson and J. L. Hornung.* A new modern treatment meeting the expanded scope of today's technical requirements in the various commercial fields. The first six chapters are devoted to principles, the remaining nine to latest practice in broadcasting, police system, aviation radio and marine communication. 754 pages, including an appendix of tabulated data and a complete topical index. 434 illustrations, 1935. Price **$5.00**

THE RADIO MANUAL, *by George E. Sterling.* Another excellent practical handbook, especially valuable to the commercial and broadcast operator, and covering the principles, methods and apparatus of all phases of radio activity. Over 900 pp., 1938 . . . . **$6.00**

RADIO TRAFFIC MANUAL AND OPERATING REGULATIONS, *by Duncan and Drew.* A book for students, amateurs or radio operators who contemplate entering the commercial field; it will enable you to learn quickly and easily all the government and commercial traffic rules and operating regulations. 181 pp. **$2.00**

RADIO OPERATING QUESTIONS AND ANSWERS, *by Nilson and Hornung.* A companion volume to "Practical Radio Telegraphy" by the same authors. The latest Revised Edition is very complete, covering Commercial and Broadcasting, Amateur, Aeronautical and Police Radio, Beacons, Airways, Meteorology, and Teletype Operating. 389 pp. 5¼ x 8. 1936. . . . . **$2.50**

HOW TO PASS RADIO LICENSE EXAMINATIONS, *by Charles H. Drew.* Question and answer material on various types of commercial operator examinations. The commercial equivalent of the A.R.R.L. License Manual. 201 pages, 73 illustrations, 1938. . . . **$2.00**

RADIO OPERATOR'S MANUAL, *by the Radio Dept., G. E. Co.* Primarily a manual to qualify an applicant for the radiotelephone classes of license (including police), but also provides material of general interest to users of commercial radio equipment. 181 pages, 56 illustrations, 1938. . . . . **$1.00**

MISCELLANEOUS

THE RADIO AMATEUR CALL BOOK. Lists all U. S. and foreign amateur radio stations, s.w. commercials and broadcasters. **$1.25** (Foreign **$1.35**)

MAKING A LIVING IN RADIO, *by Zeh Bouck.* 222 pages, 25 illustrations. A worth-while book for the radio amateur who is considering entering the Commercial Radio field in its many branches; explodes the bunk, points out the pitfalls **$2.00**

RADIO DATA CHARTS, *by R. T. Beatty.* A series of graphic charts for solving, without the use of mathematics, most of the problems involved in receiver design. 82 pp., 8¼ x 11. . . . . **$1.50**

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SERVICING SUPERHETERODYNES, *by John F. Rider.* Theory and practice of superheterodynes, with adjustment and trouble-shooting data. 278 pages, 94 illustrations. **$1.00**

The following books published by the American Radio Relay League, *The Radio Amateur's Handbook, The License Manual, Hints & Kinks, How to Become a Radio Amateur, 200 Meters and Down, Building an Amateur Radiotelephone Transmitter,* and of course *QST,* comprise the foundation of every Amateur library.

AMERICAN RADIO RELAY LEAGUE, INC., WEST HARTFORD, CONNECTICUT

World Radio History

To Handbook Readers Who Are Not A.R.R.L. Members

AMATEUR RADIO OF TO-DAY IS THE RESULT OF THE EFFORTS OF A.R.R.L.

For More Than Twenty Years

the A.R.R.L. has been the organized body of amateur radio, its representative in this country and abroad, its champion against attack by foreign government and American commercial, its leader in technical progress.

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Have YOUR part in the A.R.R.L., which has at heart the welfare of all amateurs.

JOIN THE LEAGUE!

AMERICAN RADIO RELAY LEAGUE
West Hartford, Conn., U. S. A.

I hereby apply for membership in the American Radio Relay League, and enclose $2.50 ($3.00 outside of the United States and its Possessions, and Canada) in payment of one year's dues, $1.25 of which is for a subscription to *QST* for the same period. Please begin my subscription with the............issue. Mail my Certificate of Membership and send *QST* to the following:

Name..

Street or Box..

City and State...

World Radio History

To Handbook Readers Who Are Already A.R.R.L. Members:

FOR members who hold amateur licenses, who are interested in radio activities and Communications Department operating work (explained fully, Chap. 18, 19, 20), here is an application blank which may be filled out for appointment as either Official Relay Station (for telegraphing members) or Official Phone Station (for voice operated member-stations). Copy this, or cut and fill it out, and send it direct to your Section Communications Manager (address in *QST*) or to A.R.R.L. Headquarters, 38 LaSalle Road, West Hartford, Conn. for routing to the proper S.C.M. for attention if you are interested.

The Communications Department field organization includes only the United States and its territories, and Canada, Newfoundland, Labrador, Cuba, the Isle of Pines, and the Philippine Islands. Foreign applications, that is, those from outside these areas, cannot be handled.

APPLICATION FOR APPOINTMENT AS OFFICIAL.......STATION

(Relay or Phone?)

To: Section Communications Manager............................Section, A.R.R.L.

Name...*Call*................

Street and Number....................................*Date*................

City...........................*State*.................*County*..................

Transmitting frequencies:...*kilocycles*

My membership in the A.R.R.L. expires...

month year

In making application for appointment as Official Relay Station, I agree:

—— to obey the radio communication laws and regulations of the country under which this station is licensed, particularly with respect to quiet hours and observance of our frequency allocations.

—— to send monthly reports of station activities to the Section Communications Manager under whose jurisdiction this station comes.

—— to handle messages in accordance with good operating procedure, delivering messages within forty-eight (48) hours when possible, mailing to destination whenever impossible to relay to the next station in line within a 48-hour period.

—— to participate in every A.R.R.L. communication activity to the best of my ability, always trying to live up to those ideals set forth in "The Amateur's Code."

In making application for appointment as Official Phone Station, I agree:

—— to obey the radio communication laws of the country under which my station is licensed, particularly with respect to the regulations governing quiet hours and frequencies.

—— to send monthly reports of station activities to the Section Communications Manager under whose jurisdiction this station comes; to use such operating procedure as may be adopted by the O.P.S. group; to test outside busy operating hours or using dummy antennas.

—— to handle such messages as may come to me, as accurately, promptly and reliably as possible.

—— to participate in all amateur communication activities to the best of my ability, always trying to live up to those ideals set forth in "The Amateur's Code" and to carry on amateur operation in a constructive and unselfish spirit.

—— to use circuits and adjustments that avoid frequency modulation and over modulation by proper transmitter adjustment (accomplished by use of proper indicating devices) to avoid causing interference unnecessarily.

I understand that this appointment requires annual endorsement, and also may be suspended or cancelled at the discretion of the Section Communications Manager for violation of the agreement set forth above

Please send detailed forms to submit in connection with this application.

Signed...

World Radio History

INDEX

World Radio History

World Radio History

World Radio History

World Radio History

INDEX

World Radio History

The Catalog Section

☆ ☆ ☆

In the following pages is a catalog-file of products of the principal manufacturers who serve the short-wave field. Appearance in these pages is by invitation—space has been sold only to those dependable firms whose established integrity and whose products have met with the approval of the American Radio Relay League.

World Radio History

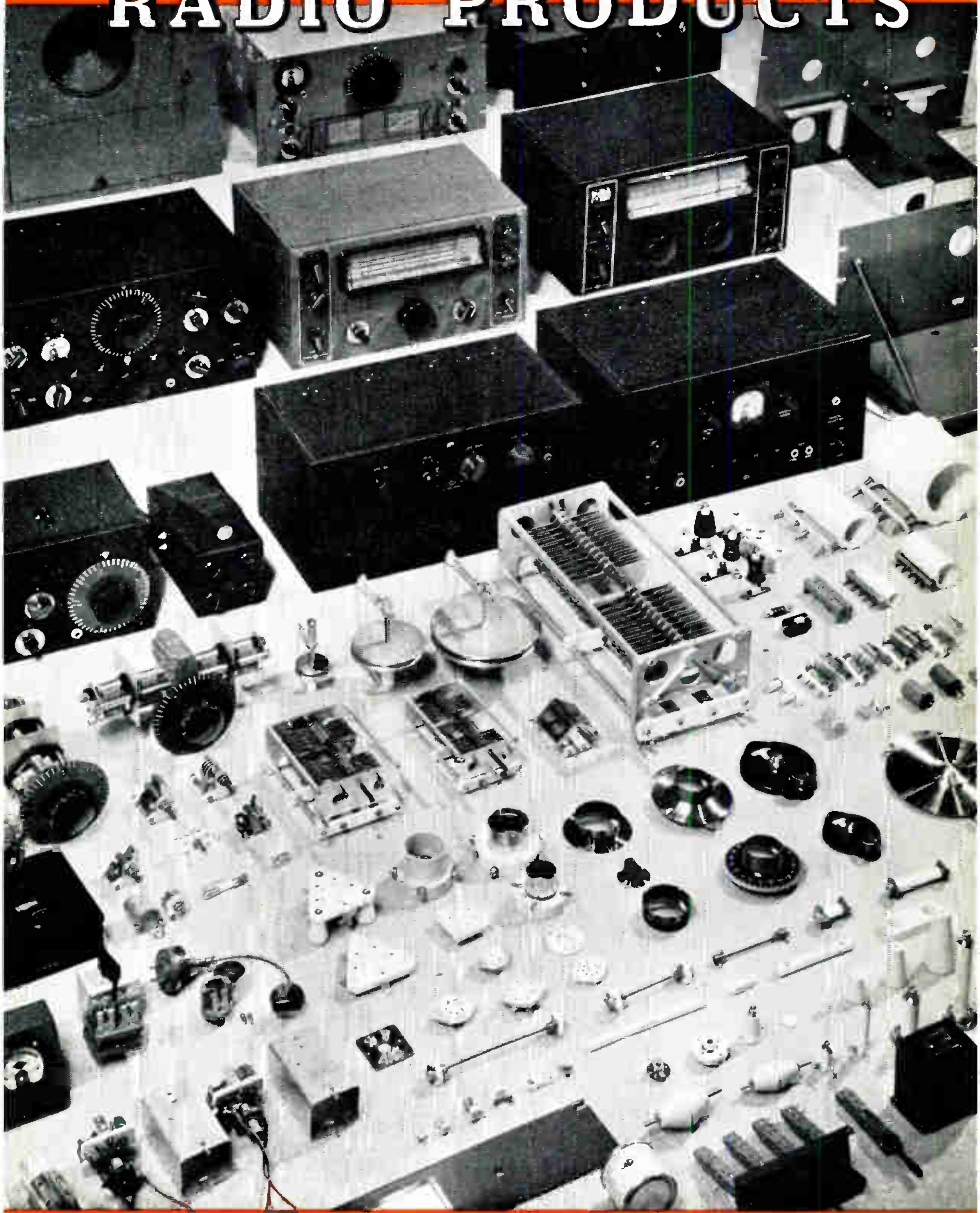
INDEX OF MANUFACTURERS

★ CATALOG SECTION ★

The Radio Amateur's Handbook

World Radio History

NATIONAL RADIO PRODUCTS



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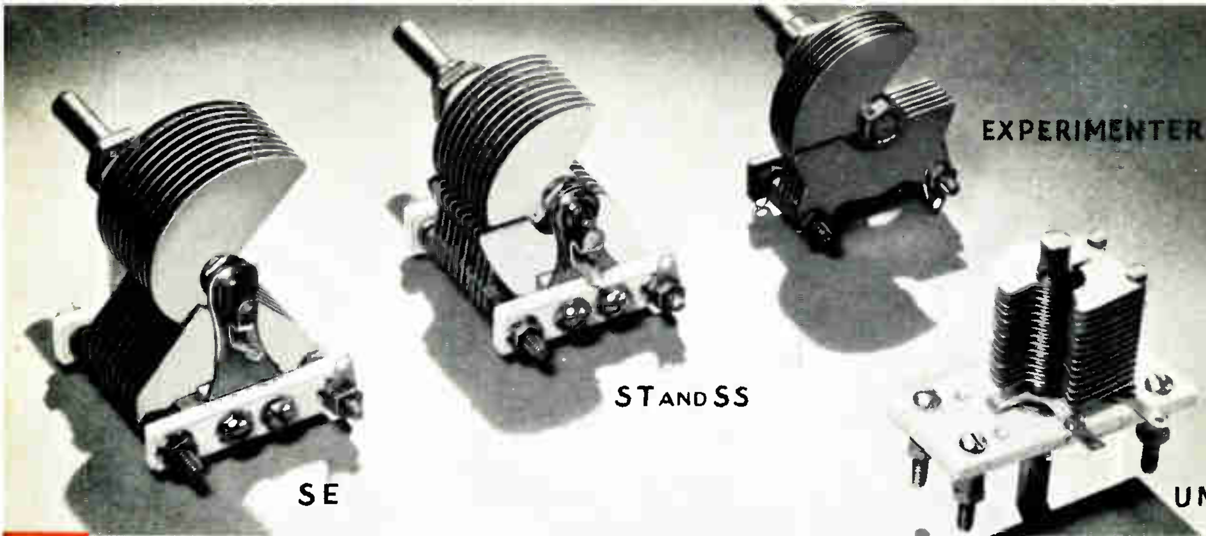
World Radio History



NATIONAL CONDENSERS

RECEIVING TYPES

Capacity	Air Gap	Plates	Cat. Symbol	List Price
15 Mmf.	.018″	3	STHS- 15	$1.40
25	.018″	4	STHS- 25	1.50
50	.018″	7	STHS- 50	1.60
35	.026″	8	ST- 35	1.50
50	.026″	11	ST- 50	1.80
75	.026″	15	ST- 75	2.00
100	.026″	20	ST-100	2.25
140	.026″	28	ST-140	2.50
150	.026″	29	ST-150	2.50
200	.018″	27	STH-200	2.75
250	.018″	32	STH-250	3.00
300	.018″	39	STH-300	3.25
335	.018″	43	STH-335	3.50
50–50	.026″	11–11	STD- 50	3.50
100–100	.018″	14–14	STHD-100	4.50
15 Mmf.	.055″	6	SEU- 15	$2.50
20	.055″	7	SEU- 20	2.75
25	.055″	9	SEU- 25	2.75
50	.026″	11	SE- 50	3.00
75	.026″	15	SE- 75	3.25
100	.026″	20	SE-100	3.50
150	.026″	29	SE-150	3.75
200	.018″	27	SEH-200	3.75
250	.018″	32	SEH-250	4.00
300	.018″	39	SEH-300	4.00
335	.018″	43	SEH-335	4.25
15 Mmf.	.017″	6	UM- 15	$1.25
35	.017″	12	UM- 35	1.50
50	.017″	16	UM- 50	1.60
75	.017″	22	UM- 75	1.70
100	.017″	28	UM-100	1.90
25	.050″	14	UMA- 25	1.85
25	.017″	4-4-4	UMB- 25	1.85
15 Mmf.	.045″	5	EX- 15	$ .85
25	.045″	7	EX- 25	.85
35	.045″	10	EX- 35	1.00
50	.017″	6	EX- 50	.90
100	.017″	12	EX-100	1.00
140	.017″	15	EX-140	1.25

TRANSMITTING TYPES

Capacity	Peak V.	Plates	Cat. Symbol	List Price
100 Mmf.	1,000	10	TMS-100	$2.50
150	1,000	14	TMS-150	2.75
250	1,000	23	TMS-250	3.00
300	1,000	27	TMS-300	3.60
50–50	1,000	5–5	TMS-50D	3.75
100–100	1,000	9–9	TMS-100D	4.50
35	2,000	8	TMSA-35	3.00
50	2,000	11	TMSA-50	3.25
50–50	2,000	11–11	TMSA-50D	4.00
50 Mmf.	3,000	7	TMC-50	$4.00
100	3,000	13	TMC-100	4.50
150	3,000	21	TMC-150	5.25
300	3,000	39	TMC-300	6.50
100–100	3,000	13–13	TMC-100D	7.50
300 Mmf.	3,000	23	TMA-300	$12.00
200–200	3,000	16–16	TMA-200D	15.00
50	6,000	8	TMA-50A	6.50
100	6,000	17	TMA-100A	10.00
150	6,000	23	TMA-150A	12.00
230	6,000	35	TMA-230A	16.00
50–50	6,000	9–9	TMA-50DA	11.00
100–100	6,000	15–15	TMA-100DA	17.50
100	9,000	23	TMA-100B	13.50
150	9,000	35	TMA-150B	17.00
60–60	9,000	15–15	TMA-60DB	18.50
50	12,000	13	TMA-50C	8.00
100	12,000	27	TMA-100C	14.50
40–40	12,000	11–11	TMA-40DC	13.50
75 Mmf.	20,000	17	TML-75E	$26.00
150	15,000	27	TML-150D	26.50
100	15,000	19	TML-100D	23.50
50	15,000	9	TML-50D	16.50
245	10,000	35	TML-245B+	28.50
150	10,000	21	TML-150B+	26.00
100	10,000	15	TML-100B+	25.00
75	10,000	11	TML-75B+	18.00
500	7,500	49	TML-500A+	35.00
350	7,500	33	TML-350A+	28.00
250	7,500	25	TML-250A+	26.00
30–30	20,000	7–7	TML-30DE	26.50
60–60	15,000	11–11	TML-60DD	28.50
100–100	10,000	15–15	TML-100DB+	31.50
60–60	10,000	9–9	TML-60DB+	27.50
200–200	7,500	21–21	TML-200DA+	35.00
100–100	7,500	11–11	TML-100DA+	28.50

World Radio History

NATIONAL CONDENSERS

All National Condensers are characterized by low losses and rigid construction. Insulation is Isolantite, carefully placed when the field intensity is low. Their sturdy frames, accurately fitted bearings and careful assembly insure permanent calibration and long life.

Particular care has been taken to make them easy to use. All models listed on these pages can be mounted directly on the panel, and most can be also mounted on standoff insulators or directly on the chassis.

RECEIVING TYPES

National Receiving Condensers are particularly suited to use at the higher frequencies. All double bearing models have one bearing insulated from the rotor to prevent noise from circulatory currents. The SE, ST and SS models feature a "constant impedance pigtail" that provides a low and constant impedance connection to the rotor. The SEU models in addition, have thick plates with rounded and polished edges.

The Type UM condensers are designed for use at ultra high frequencies, and are very compact. They will mount reading inside one of our small square shield cans. A shaft extension at each end permits easy ganging.

The "Experimenter" models are primarily low priced models for experimental use. Unlike other National Condensers they use brass plates and Bakelite insulation.

NATIONAL TRANSMITTING CONDENSERS

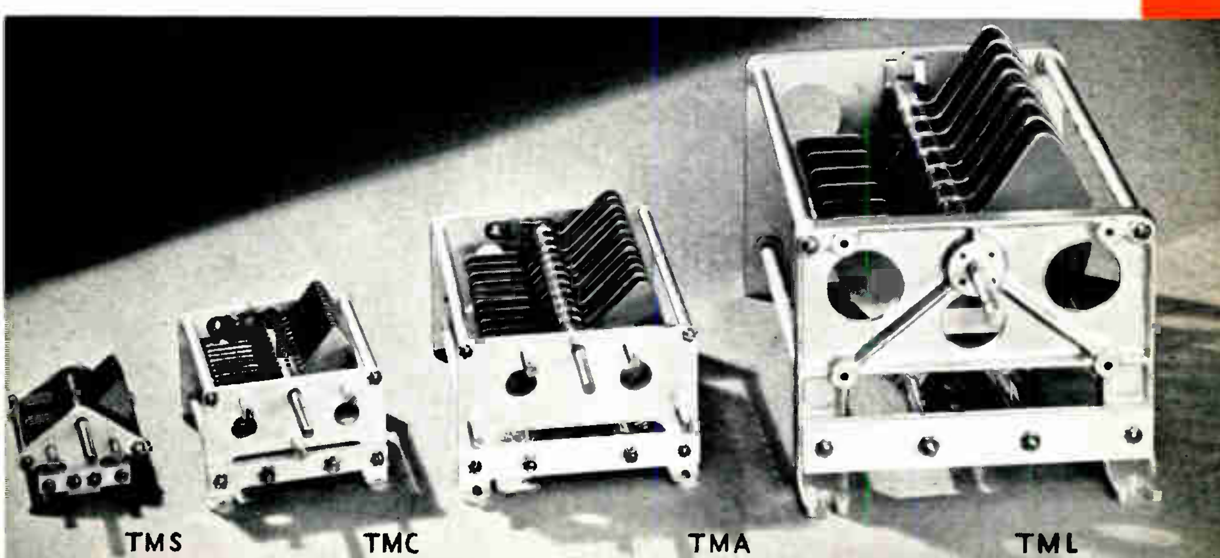
The Type TMS Conaenser, smallest of the Transmitting Types is designed for use in low power stages. It is compact, rigid and dependable. Provision has been made for mounting either on the panel, on the chassis or on two standoff insulators. Voltage ratings are conservative. Insulation is Isolantite.

The larger transmitting condensers, Types TMC, TMA, and TML are of heavy duty construction. Plates are of heavy gauge aluminum with rounded and polished edges. In split stator models, each rotor is supported at both ends. Insulation is Isolantite, located outside the end plates where the electrostatic field is weak.

The Type TML condenser is designed to be used with the PWL Worm Drive Unit listed on Page 4, if desired.

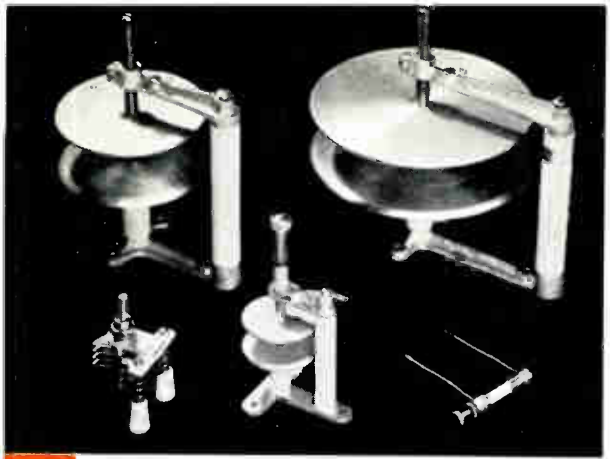
PLATE SPACINGS

Peak Volts	Spacing	Peak Volts	Spacing
1,000	.026"	9,000	.265"
2,000	.065"	10,000	.344"
3,000	.077"	12,000	.359"
6,000	.171"	15,000	.469"
7,500	.219"	20,000	.719"



TMS TMC TMA TML

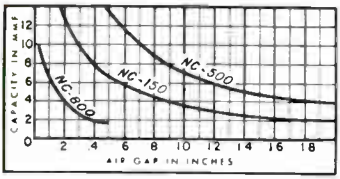
World Radio History



NATIONAL NEUTRALIZING CONDENSERS

In the group above, the Type NC-600 is shown at the lower right. It is suitable for 6L6's and similar beam tubes and has a range of adjustment from ½ mmf to 5 mmf. Type STN, lower left, has a capacity of 18 mmf (3000 V) making it suitable for tubes such as the 10, 45 and 47. Of the disk type condensers, the smallest is the NC-800 with micrometer type thimble and clamp, suitable for the RCA-800. The medium sized model, Type NC-150, is for the HK-345, RK-36, 300T and 852. Type NC-500 is the largest, and is for the WE-251A and similar tubes. The capacity of these disk type condensers is given in the chart at left. In addition, the Type TCN, similar to TMC on the preceding page, is available for the 203A, 852, 204A, etc. (Max. Cap. 25 mmf, 6000V). All National Neutralizing Condensers have Isolantite insulation.

Type NC-600	List Price, $ .45
Type STN	List Price, 2.00
Type NC-800	List Price, 3.00
Type NC-150	List Price, 6.50
Type NC-500	List Price, 12.50
Type TCN	List Price, 4.00



NATIONAL PRECISION CONDENSERS

The Micrometer dial reads direct to one part in 500. Division lines are approximately ¼" apart. The dial revolves ten times in covering the tuning range, and the numbers visible through the small windows change every revolution to give consecutive numbering by tens from 0 to 500. The condenser is of extremely rigid construction, with four bearings on the rotor shaft. The drive, at the mid-point of the rotor, is through an enclosed preloaded worm gear with 20 to 1 ratio. Each rotor is individually insulated from the frame, and each has its own individual rotor contact, of the multifingered brush type. Stator insulation is Steatite.

PW Ganged Condensers are available in 2, 3 or 4 sections, in either 160 or 225 mmf per section. Larger capacities cannot be supplied. The single-section PW condenser is supplied in capacities of 150, 200, 350 and 500 mmf, single spaced. Capacities up to 125 mmf can be supplied double spaced. The rotor is not insulated on the single section model. Plate shape is straight-line-frequency when the frequency range is 2:1.
PW condensers and drives are all with rotor shaft parallel to the panel, as in the HRO receiver. N-PW units are also available, as used in original type NC-100 and NC-101X receivers, with rotor shaft perpendicular to panel, as listed at right:

PW-1, Single Section. **List Price, $15.00**

PW-2, Two Section. **List Price, $20.00**

PW-3, Three Section. **List Price, $24.00**

PW-4, Four Section. **List Price, $27.50**

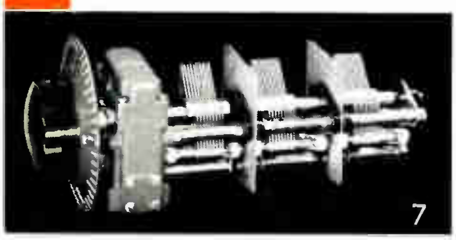
PW-0, Dial and Worm Drive, only, with TX-9 Coupling. **List Price, $13.50**

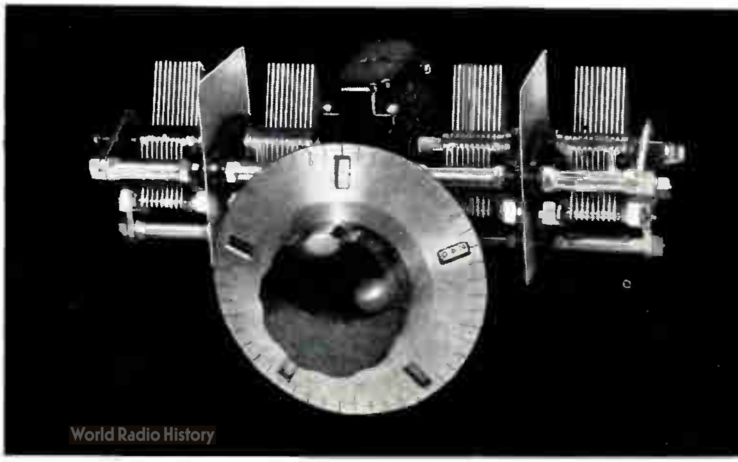
N-PW3 (Fig. 7), capacity per section 225 mmf. **List Price, $24.00**

N-PWX, capacity per section 25 mmf. **List Price, $20.50**

Other sizes of N-PW condenser, or drive alone, not available.

PWL, Worm Drive Unit in special housing for TML Condensers. **List Price, $9.50**





World Radio History

NATIONAL "HRO" & "O" DIALS FIGS. 1a & 1b

The 1⅝″ dia. HRO dial (Fig. 1a) is etched nickel silver and fits ¼″ shafts. Reads from 0 to 10 over 180°.

List Price, each $.75. Knob alone, List Price, $.25

The insulated 3½″ dia. O dial (Fig. 1b) is circular-grained German Silver and fits ¼″ shafts. Available with No. 2 scale.

List Price, each $1.50

The type HRK Knob used on the O dial is also available alone. Fits ¼″ shafts. **List Price, $.85**

The type ODL locking device with thumbscrew control is available for use with the type "O" dial. Ideal for transmitter applications. **List Price, each $.50**

NATIONAL "N" & "NW" DIALS FIGS. 2 & 3

Precision Dials, Type N, have engine divided scales and verniers of solid German Silver. The Verniers are flush, eliminating errors from parallax.

The four-inch Type N dial (Fig. 3) employs a smooth and powerful planetary mechanism with a 5 to 1 ratio. No. 2, 3, 4 or 5 scale.

List Price, each $6.75

The six-inch Type NW dial (Fig. 2) has a variable ratio drive that is unusually powerful at all settings. It is recommended for use on large transmitters and precision instruments. No. 2, 3, 4 or 5 scale.

List Price, each $15.00

NATIONAL "A" DIAL FIG. 4

The original "Velvet Vernier" Dial, Type A, is still an unchallenged favorite for general purpose use. It is exceptionally smooth and entirely free from backlash. The mechanism is contained within the bakelite knob and shell. Ratio 5 to 1. No. 2, 4 or 5 scale in 4″ diameter. No. 2 scale in 3⅜″ diameter.

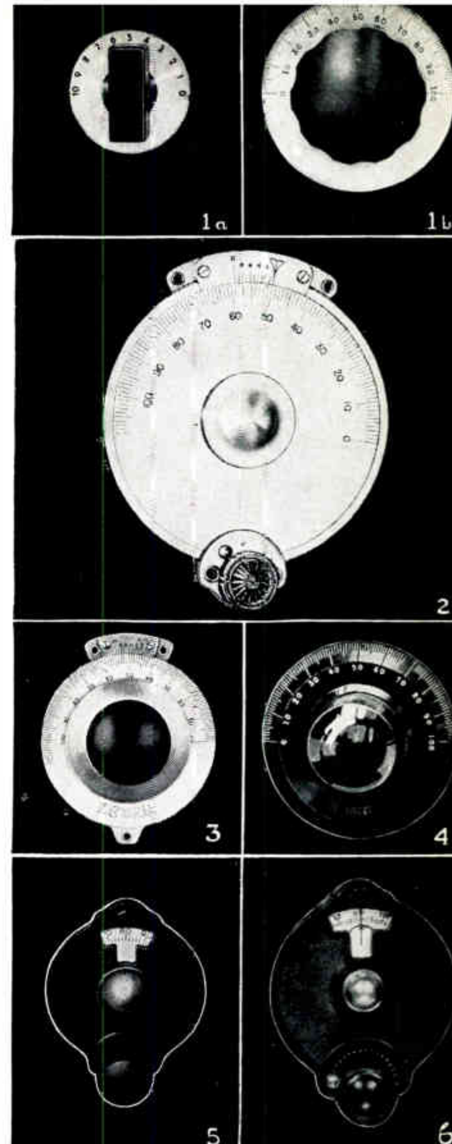
List Price, each $3.00

NATIONAL "B" & "BM" DIALS FIGS. 5, 6

"Velvet Vernier" Dial, Type B (Fig. 6) provides a compact variable-ratio drive that is smooth and trouble free. The mechanism is inclosed in a black bakelit case, the dial being read through a window. No. 1 or 5 scales.

List Price, each $2.75. Illuminator $.50 extra

The Type BM Dial (Fig. 5) is a smaller version of the Type B Dial for use where space is limited. It is similar to the Type B Dial in appearance and mechanism, but does not have the variable-ratio device. No. 1 or 5 scales. **List Price, each $2.50**



1a 1b 2 3 4 5 6

DIAL SCALES

Scale	Divisions	Rotation	Direction of Condenser Rotation for increase of dial reading
1	0–100–0	180°	Either
2	0–100	180°	Counter Clockwise
3	100–0	180°	Clockwise
4	150–0	270°	Clockwise
5	200–0	360°	Clockwise
6	0–150	270°	Counter Clockwise

PADDING CONDENSERS

National Air-Dielectric Padding Condensers are extremely compact and have a very low temperature coefficient. The aluminum shield is 1¼″ diameter by 1¼″–1½″ high.

A very small mica Padding Condenser is also available, mounted on an Isolantite base and designed to be supported by the circuit wiring. The maximum capacity is 30 mmf, and the overall dimensions are 13/16″ long x 9/16″ wide x ½″ high.

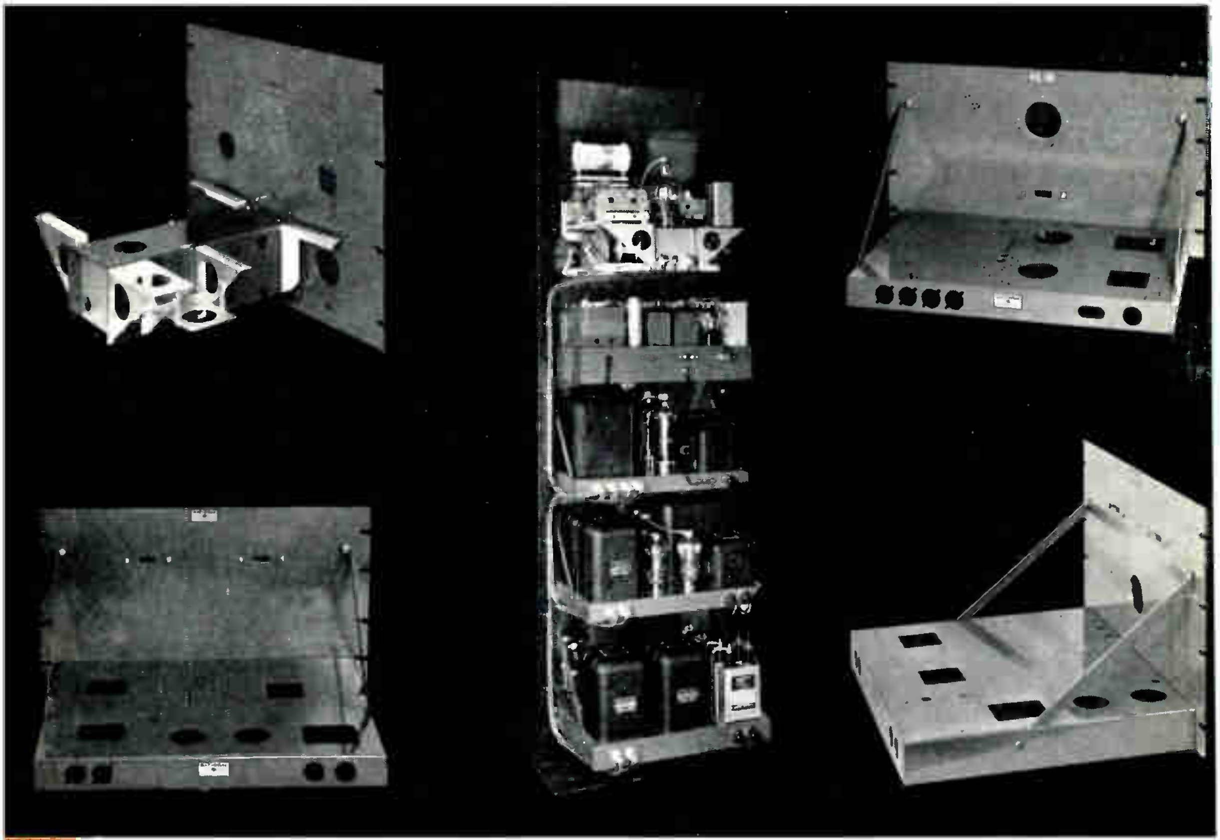
W 75 (75 Mmf. Air)	**List Price, $2.25**
W 100 (100 Mmf. Air)	**List Price, 2.50**
M 30 (30 Mmf. Mica)	**List Price, .30**

ROTOR SHAFT LOCK

This small cast aluminum clamp is designed to provide a means for locking the rotors of TMA or TMC condensers. It will fit any ¼″ shaft, and may be fitted to some other condensers. Holes are 1″ apart.

Type RSL **List Price $.85**

World Radio History



NATIONAL FOUNDATION UNITS

National Foundation Units consist of panels and chassis completely finished and ready for assembly, together with the necessary special parts and hardware. They form the basis of the 600 watt transmitter shown above. This is so thoroughly engineered that even the newcomer can proceed with confidence, yet the units are so flexible that they allow the constructor almost complete freedom in building to suit his own particular requirements.

Standard Thordarson CHT units are used in the modulator and power supplies, and the chassis are punched with the necessary mounting holes. If it desired to use other makes of transformers and chokes, the chassis are also supplied with the mounting surface blank but with other details finished.

The various units in the 600 watt transmitter can be supplied completely wired and tested.

THE HIGH VOLTAGE POWER SUPPLY is the unit at the bottom of the rack illustrated above. It delivers 300 MA at 2000 volts for the final.

High Voltage Power Supply Foundation Unit, for use with Thordarson CHT Components, Type NT2000PC. **List Price $12.00**

Same, but for various makes of transformers and chokes, Type NT2000PU. **List Price, $12.00**

High Voltage Power Supply, completely wired and tested, Type NT2000PCW. **List Price, $210.00**

THE MEDIUM VOLTAGE POWER SUPPLY UNIT is next to the bottom in the rack. It provides 1250 volts for the buffer and modulator.

Medium Voltage Power Supply Foundation Unit, for Thordarson CHT Components, Type NT1200PC. **List Price, $12.00**

Same, but for various makes of transformers and chokes, Type NT1200PU. **List Price, $12.00**

Medium Voltage Power Supply, completely wired and tested, Type NT1200PCW. **List Price, $135.00**

THE CLASS B MODULATOR UNIT is at the center of the rack. It employs a pair of zero bias tubes in Class B, which are driven from the output of the NTE Exciter-Speech Amplifier just above it. (The NTE is described on Page 7, opposite.)

Class B Modulator Foundation Unit, for use with Thordarson CHT Components, Type NT300PC. **List Price, $12.00**

Same, but for various makes of transformers, Type NT300PU. **List Price, $12.00**

Class B Modulator, completely wired and tested, Type NT300PCW. **List Price, $110.00**

THE FINAL AMPLIFIER FOUNDATION UNIT is at the top of the rack, and features a compact, open construction that results in short leads, symmetry of the push-pull circuit, easy wiring and complete accessibility. It employs a pair of 100TH'S driven by a single 35T.

Final Amplifier and Buffer Foundation Unit, Type NT100PC. **List Price, $16.00**

Final Amplifier and Buffer, completely wired and tested, Type NT100PCW. **List Price, $235.00**

A PI NETWORK ANTENNA COUPLER may be mounted at the top of the rack. It is not illustrated.

Antenna coupling panel, drilled for mounting coils and condensers, Type NT-AP. **List Price, $2.00**

Antenna coupling network, wired and tested, Type NT-APW. **List Price, $58.00**

NOTE: The prices given above do not include tubes. Mounting screws, grommets, spacers, brackets, lockwashers and similar hardware are furnished with each foundation unit. For convenience in shipping foundation units are packed disassembled. Panels are of 1/8" steel finished in black moire. Aluminum panels 3/16" thick, finished in either black leatherette or gray enamel, are available at an additional list price of $8.00 for the NT100PC, and $7.50 for the NT300PC, NT1200PC and NT2000PC.

World Radio History

NATIONAL NTE EXCITER—SPEECH AMPLIFIER

The National NTE Exciter and Speech Amplifier is the ideal answer to transmitter control at the operating position. It includes a versatile multi-band exciter unit with a choice of frequencies in each band, and a high-gain speech amplifier. The exciter can be used with either a conventional single crystal, a variable frequency holder, or a four-crystal multiple holder. The crystal oscillator is followed by three frequency-multiplier stages using 6L6's, with an RF output of at least 5 actual watts on each band. The crystals can be controlled from the front panel, and the same is true of the frequency multiplier stages which are selected by a convenient interlocking push switch of special low-loss design. The four stage speech amplifier delivers 10 watts output from PP 2A3's with an input of .005 Volts. Although the power supply is entirely self-contained, the hum level is exceedingly low. A meter is provided for circuit adjustments.

The front panel of the NTE is shown in the illustration at the lower left corner of this page

Table models are furnished in black wrinkle-finish steel cabinets to match the NC-101X Receiver, at prices listed. Relay rack models can be supplied at an increased price of $6.00 net for black wrinkle-finish steel panels 1/8 inch thick, or at an increase of $9.00 net for black leatherette or gray enamel panels of aluminum 3/16 inch thick.

Type NTE Exciters are available in three models as follows:

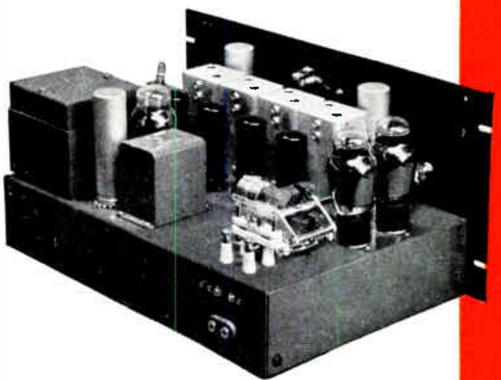
Exciter-Speech Amplifier, for 5, 10, 20 and 75 meters, table model, Type NTE-A. **List Price, $215.00**

Same as NTE-A, but for 10, 20, 40 and 75 meters, Type NTE-B. **List Price, $215.00**

Same as NTE-B, but without speech amplifier, Type NTE-C. **List Price, $155.00**

Shipping Weight Approx. 70 Lbs.

NATIONAL NTX-30 TRANSMITTER



The NTX-30 is an exceedingly compact and convenient transmitter for CW or Phone, having an output of 30 watts on 10, 20, 40 and 80 meters. It employs the same exciter system used so successfully in the NTE, and like the NTE features a special interlocking push switch in the exciter circuits. In the output stage, a plug-in coil is used, similar to the Type AR coils described on the following page. Four 6L6's are used as crystal oscillator and doublers, and two 6L6G's are used in the final.

The unit is a self-contained transmitter for CW operation. For phone an external speech amplifier must be used. The NSA described below is ideal for this purpose. Terminals are provided at the rear of the NTX-30 for connecting the amplifier.

Structurally, the NTX-30 consists of an NTE Exciter with a final stage substituted for the speech amplifier, and it is very similar in appearance to the NTE illustrated at the left. All of the features of the NTE are retained, including panel control of crystal frequency, interlocking push switch, meter for circuit adjustments, etc. The NTX-30 thus has the advantages of a proven design in its most important circuits, and is ideally suited for use as an exciter-buffer combination whenever higher power is desired.

Table models are furnished in black wrinkle-finish steel cabinets to match the NC-101X Receiver, at the price listed. Relay rack models can be supplied at an increased price of $6.00 net for black wrinkle-finish steel panels 1/8 inch thick, or at an increase of $9.00 net for black leatherette or gray enamel panels of aluminum 3/16 inch thick.

NTX-30 transmitter, complete with all coils, tubes, and crystal holder, but less crystal, for operation on 10, 20, 40, and 80 meter bands. **List Price, $195.00**

Shipping Weight Approx. 70 Lbs.

World Radio History

NATIONAL NSA SPEECH AMPLIFIER

The new National Speech Amplifier has two input channels with an electronic mixer. One input circuit provides an over all gain of 125 db, and is suitable for crystal microphones, etc. The other input circuit has one less amplifier stage and is intended for high level sources such as phonograph pickups, etc. The frequency characteristic is flat within less than 1 db from 25 to 10,000 cycles. A separate rectifier supplies bias voltage for the PP 2A3's, which deliver 15 watts output. A tone control is provided.

Speech Amplifier, table model, in wrinkle-finish steel cabinet, including tubes, Type NSA.
List Price, $115.00

Extra for relay rack mounting, with black wrinkle-finish steel panel 1/8 inch thick. **List Price, $10.00**

Extra for relay rack mounting, with black leatherette or gray enamel aluminum panel 3/16 inch thick.
List Price, $15.00

Approx. Shipping Weight 50 Lbs.

NATIONAL OSCILLOSCOPES

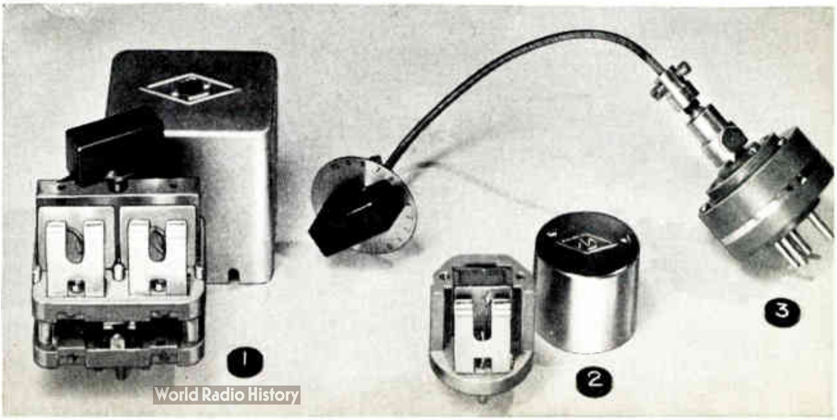
Cathode Ray Oscilloscopes are available in two models. The Type CRR, is mounted on a standard 3½" relay rack panel and employs a two-inch screen RCA-902 and 6X5 rectifier. Type CRM is mounted in a small steel cabinet (4⅛" x 6⅛" x 8") and uses a one-inch screen RCA-913 with 6X5 rectifier. Both models are self contained and power supply and input controls are built in. A panel switch permits use of built-in 60 cycle sweep or external audio sweep for securing the familiar trapezoid pattern, which is more convenient for modulation measurements.

Type CRR Oscilloscope, 2" screen, less tubes. **List Price, $32.50**
Type CRM Oscilloscope, 1" screen, less tubes. **List Price, $18.50**

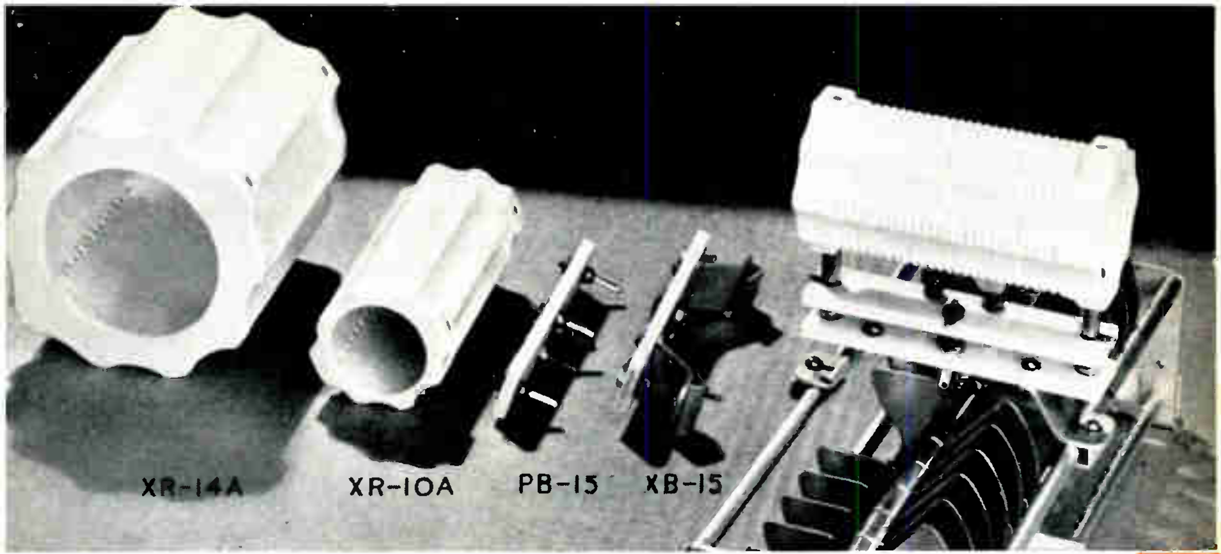
NATIONAL CRYSTAL HOLDERS

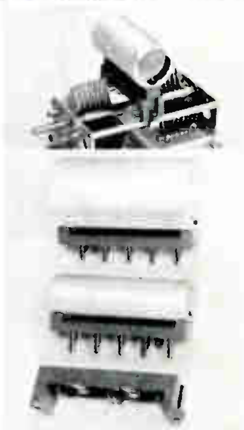
National Crystal Holders are available in three types. All use R-39 insulation for low losses and all are carefully designed for maximum crystal activity. The newest holder (Figure 1) is the Type 4-in-1 and is very convenient where a choice of frequencies is desired. It is designed to hold four separate crystals up to 1" square which may be selected by a built-in low capacity switch. The CHV Crystal Holder (Figure 3) is of the variable gap type and, when used with a suitable crystal, permits tuning the crystal over a range of 1 part in 600. The small holder shown in Figure 2 is available in three forms. Type CHR for receivers, resonator type. Type CHS for transmitters, constant air-gap type. Type CHT for transmitters, pressure type.

Type 4-in-1	**List Price, $7.50**
Type CHR	**List Price, $2.50**
Type CHS	**List Price, $2.50**
Type CHT	**List Price, $2.50**
Type CHV, less crystal	**List Price, $9.50**
Type CHV, with 80-meter crystal that will double into the 20-meter phone band	**List Price, $32.50**



World Radio History





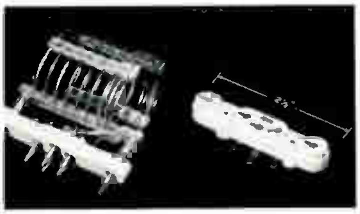
NATIONAL TRANSMITTER COIL FORMS

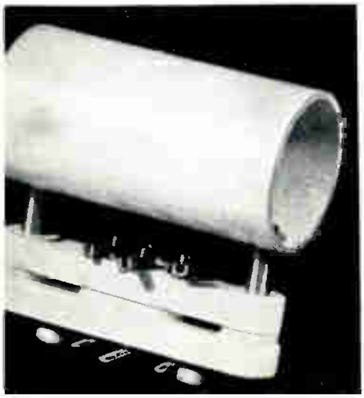
The two transmitter coil forms illustrated above both fit the PB-15 plug and the XB-15 socket and mount readily on the tie bars of a TMA condenser. The larger form, Type XR-14A, is for the 80 meter band. Its winding diameter is 5" and its length 5". The smaller, Type XR-10A, is intended for the 20 and 40 meter bands and is 5" long with a 2½" winding diameter.

The two buffer coil forms at the right fit the PB-5 plug and the XB-5 socket and mount on the tie bars of a TMC condenser. The larger form, XR-13, is 1¾" diameter and 3½" long. The smaller, Type XR-13A, is 1" diameter and 3½" long.

In addition to mounting on condensers, the sockets are designed for convenient use in breadboard layouts, etc.

Type XR-10A Coil Form only	List Price, $1.50
Type XR-14A Coil Form only	List Price, 3.50
Type PB-15 Plug only	List Price, 1 35
Type XB-15 Socket only	List Price, 1.75
Type UR 10A Coil Form Assembly	List Price, 4.60
Type UR-14A Coil Form Assembly	List Price, 6.25
Type XR-13 Coil Form only	List Price, $1.10
Type XR 13A Coil Form only	List Price, .60
Type PB-5 Plug only	List Price, .75
Type XB-5 Socket only	List Price, .75
Type UR-13 Buffer Coil Assembly	List Price, 2.50
Type UR-13A Buffer Coil Assembly	List Price, 2.00





NATIONAL EXCITER COILS AND FORMS

These coils are suitable for use in exciters, buffers, and low power finals. The series of Victron insulated, air spaced coils all fit the same plug-in mount. In addition an unglazed Isolantite form, drilled for leads, also fits the same base. All of the listed sizes will tune over their respective bands with 30 mmf and all have separate windings for link coupling. Add the letter E to symbol for end link, and C to symbol for center link.

Type PB-16 Plug
List Price, $.40

Type XB-16 Socket
List Price, $.50

Type XR-16 Coil Form
List Price, $.60

Type UR-16 Assembly
List Price, $1.50

AIR SPACED COILS

Type AR16-80
(80 meters)
List Price, $1.50

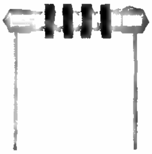
Type AR16-40
(40 meters)
List Price, $1.50

Type AR16-20
(20 meters)
List Price, $1.50

Type AR16-10
(10 meters)
List Price, $1.50

World Radio History

NATIONAL R. F. CHOKES



R-100. Isolantite mounting, continuous universal winding in four sections. For pigtail connections or standard resistor mountings. Inductance 2½ m.h.; distributed capacity, 1 mmf.; D.C. resistance 50 ohms; Current rating, 125 M.A. For low powered transmitters and high frequency receivers. **List Price, $.60**

R-152, R-154, R-154U. These transmitter chokes have honeycomb coils (0.6 amps. rating) wound on Isolantite cores. The R-152 is designed for the 80 and 160 meter bands; inductance 4 m.h., D.C. resistance 10 ohms. The R-154 and R-154U give maximum impedance on the 20, 40 and 80 meter bands; inductance 1 m.h., D.C. resistance 6 ohms. The R-152 and R-154 are as illustrated. The R-154U does not have the small insulating pillar and the third mounting foot.

R-152 or R-154. **List Price, $2.25.** R-154U **List Price, $1.75**

R-201. A two-section honeycomb-wound choke in R-39 case, suitable for output circuit of second detector in H.F. receivers (475 KC Intermediate Frequency). Inductance, approximately 12 m.h., D.C. resistance approximately 120 ohms. **List Price, $1.25**

NATIONAL I. F. TRANSFORMERS

This new I.F. Transformer has air dielectric condensers (isolated from each other by an aluminum shield) and Litz would coils mounted on an Isolantite base which is treated against moisture absorption. The aluminum shield can, housing the assembly, measures 4⅛" x 2⅜" x 2". These transformers are available with or without Iron Cores in the 450–550 KC model; the 175 KC model is air core only. For iron core add $.30 to price.

An additional model, Type IFD, having a tuned primary and a closely-coupled, untuned, push-pull secondary is intended for operation with diode rectifiers. It is particularly suitable for use in noise silencing circuits. It is available only with an air core, and for 450–550 KC use.

Type IFC Transformer (air core). **List Price, $5.00**
Type IFCO Oscillator (air core only). **List Price, $5.00**
Type IFD Diode Transformer (air core only). **List Price, $3.50**

NATIONAL FIXED TUNED EXCITER TANK

Similar in general construction to the I.F. transformer described above, this unit has two 25 mm., 2000 volt air condensers and an unwound XR-2 coil form.

Type FXT, without plug-in base. **List Price, $4.50**
Type FXTB, with base (either 5- or 6-prong). **List Price, $4.90**

NATIONAL PLUG-IN BASE AND SHIELD

The low-loss R-39 base is ideal for mounting condensers and coils when it is desirable to have them shielded and easily removable. Shield can is 2" x 2⅜" x 4⅛". Two models are available; 5- or 6-prong.

Type PB-10, (Base and Shield). **List Price, $.75**
Type PB-10A, (Base only). **List Price, $.40**

NATIONAL HIGH FIDELITY TRF UNITS

For broadcast reception of the highest possible tone quality, the simplest circuit gives the best results. The new National Tuners are based on a high performance TRF circuit reduced to its simplest terms. Similar in construction to an IF Amplifier, each chassis provides a three-stage RF Amplifier tuned to one station only. A group of four or more separate chassis are usually used in each installation to receive a like number of stations. A push switch, relay system, etc., is used to select the desired station.

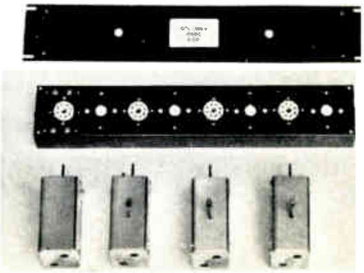
Each RF Transformer has an individual coupling adjustment and is tuned both primary and secondary (8 tuned circuits). The coupling is adjustable to include 10 KC with less than 1 db variation in the audio range. Sensitivity is adjustable from 5 microvolts to one volt. For best efficiency, three models have been made available covering ranges of 540–875, 740–1230, and 1100–1700 KC. Complete filtering eliminates regeneration which causes lop-sided resonance curves. The triode power detector is linear and capable of handling large percentages of modulation. For circuit simplicity, there is no AVC. The chassis fits a standard 3½" relay rack panel.

Drilled and formed chassis, Type DLC. **List Price, $2.50**

As above, but with sockets and terminals riveted in place, Type DLCA. **List Price, $4.60**

Steel ⅛" panel. Type DLPS. **List Price, $1.50**
Aluminum 3 16" panel. Type DLPA. **List Price, $5.00**
RF Transformer, set of four required. Type DLT. **List Price, each, $6.50**

(Specify approximate operating frequency)



World Radio History

NATIONAL COIL FORMS

RECEIVER COIL FORMS. The two coil forms at the right are of low-loss R-39 and have excellent form factor. They can be drilled and grooved easily. The larger is 2¼" long and 1½" diameter. It is available with 4, 5, or 6 prongs and is known as Type XR-4, XR-5 or XR-6 respectively. **List Price, $.75**

The smaller form is 1½" long and 1" diameter and has four prongs, Type XR-1. **List Price $.50.** Type XR-2, same but plain (no prongs). **List Price, $.35.** Type XR-3 (not illustrated) is similar but is 9 16" diameter and ¾" long. It has no prongs. **List Price, $.30.**

PLUG-IN COIL FORMS. These R-39 coil forms, plug-in through the front panel of a receiver, monitor, etc. The coil shield listed is bolted to the back of the panel, and supports the Isolantite socket.

XR-39A Coil Form, Air Tuned. **List Price, $4.75**

XR-39M Coil Form, Mica Tuned. **List Price, $3.65**

XCS Coil Shield and Socket. **List Price, $1.75**

NATIONAL L. F. OSCILLATOR COIL

LOW FREQUENCY OSCILLATOR COIL. Two separate inductances, closely coupled, in an aluminum shield. It is used in the SRR and other super-regenerative receivers for the interruption-frequency oscillator. Sec. Inductance 6.25 m.h. Tunes to 100 KC with .00041 mfd.

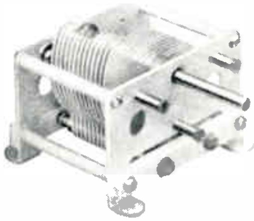
Type OSR. **List Price, $1.50**

NATIONAL SCREEN GRID DETECTOR COUPLER

SCREEN GRID DETECTOR COUPLING UNIT. This impedance coupling unit, when employed to couple the output of a screen grid detector to an audio amplifier tube, will give from two to three times as much amplification as resistance coupling. Plate choke, 700 henries. Coupling condenser, .01 mfd. Grid leak, 250,000 ohms.

Type S-101. **List Price, $6.00**

NATIONAL GENERAL PURPOSE CONDENSERS



National EMC Condensers have high electrical efficiency, and calibrations may be relied on. Insulation is of Isolantite, and Peak Voltage Rating is 1000 volts. Plate Shape is SLW.

Capacity	No. of Plates	Cat. Symbol	List Price
150	9	EMC 150	**$3.25**
250	14	EMC 250	**3.75**
350	18	EMC 350	**4.25**
500	26	EMC 500	**4.75**
1000	56	EMC 1000	**7.25**
Split-Stator Models			
350–350	18–18	EMCD–350	**7.50**

NATIONAL JACK SHIELD

The new National Jack Shield accommodates small standard jacks. It is primarily designed for mounting behind the panel, where it is held in place by the bushing of the jack, but may also be used on the ends of extension cords, etc.

National Jack Shield, Type JS-1. **List Price, $.35**

NATIONAL TUBE AND COIL SHIELDS

These aluminum shields are listed in order from left to right

Type	List Price
HRO coil shield, 2" x 2⅜" x 4⅛" high	**$.35**
J30 coil shield, 2½" dia. x 3¾" high	**.35**
B30 coil shield, 3" dia. x 3¾" high	**.35**
B30 coil shield, with mounting base	**.50**
TS Tube Shield, with cap and mounting base	**.40**
T58 Tube Shield, with cap and mounting base	**.40**
T78 Tube Shield, with cap and mounting base	**.40**

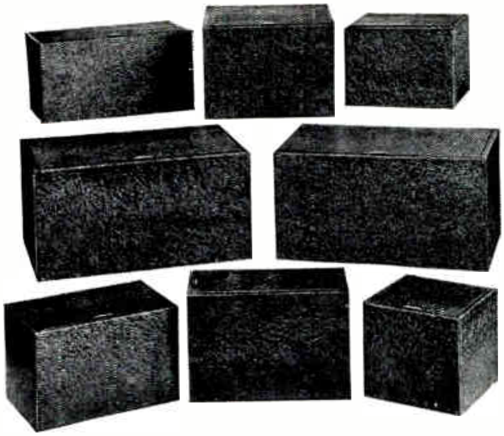
The T58 and T78 fit such tubes as the 57, 58, 77, 78, etc.

World Radio History

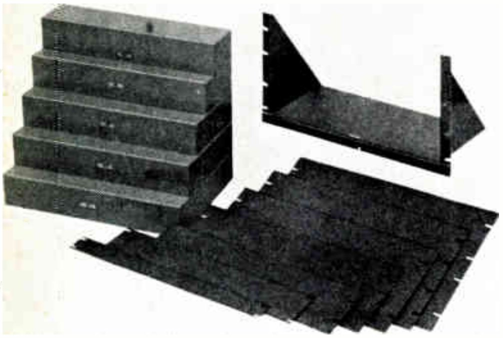
NATIONAL CABINETS

The National Receiver Cabinets illustrated above, are for use in constructing special equipment. List Prices include sub-bases and bottom covers. Reading left to right:

	Width	Height	Depth	List Price
Top Row				
Type C-HWR	13½"	7"	7¼"	$5.00
Type C-FB7	11½"	8"	12"	7.00
Type C-SW3	9¾"	7"	9"	5.50
Middle Row				
Type C-NC100	17¼"	8¾"	11¼"	8.50
Type C-HRO	16¾"	8¾"	10"	8.50
Bottom Row				
Type C-One-Ten	11"	7"	7¼"	4.50
Type C-PSK	6"	8"	12"	6.00
Type C-SRR	7½"	7"	7½"	3.50



NATIONAL RELAY RACK PANELS AND CHASSIS



THE RECESSED SHELF will fit any standard relay rack, and is particularly useful for supporting portables, instruments, test equipment, etc.

Type RRS. **List Price, $4.00**

UNDRILLED STANDARD RELAY RACK PANELS are available in both ⅛" steel and 3/16" aluminum. The steel panels are finished in black wrinkle, and the aluminum panels in either black leatherette or gray enamel.

Width	Shipping Weight Steel	Shipping Weight Aluminum	List Price Steel	List Price Aluminum
1¾"	——	⅝ lbs.	——	$3.25
3½"	5 lbs.	1¼ lbs.	$1.00	4.50
5¼"	7 lbs.	1¾ lbs.	1.15	5.75
7"	8 lbs.	2½ lbs.	1.20	7.00
8¾"	9 lbs.	3 lbs.	1.60	8.25
10½"	10 lbs.	3¾ lbs.	1.95	9.50

Larger sizes available on special order

GRAY ENAMEL BLANK CHASSIS of 1/16" steel are available in the following sizes:

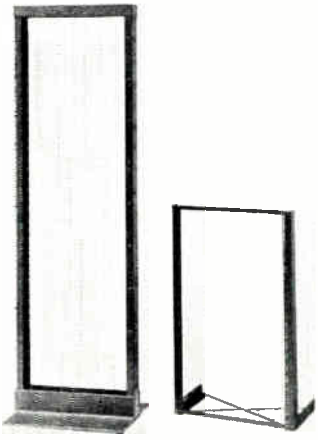
Size	List Price	Size	List Price
4 x 17 x 3"	$2.50	10 x 17 x 3"	$3.50
6 x 17 x 3"	2.75	12 x 17 x 3"	4.50
8 x 17 x 3"	3.15		

NATIONAL RELAY RACKS

These steel relay racks are drilled and tapped to accommodate, up to their capacities, standard relay rack panels of all sizes. At the right is a Type MRR table model rack, at the left a Type RR rack.

Type RR Relay Rack built to government specifications, panel capacity 63", black finish **List Price, $65.00**

Type MRR Relay Rack, panel capacity 24½", gray or black finish. **List Price, $22.50**



NOTICE: All National Relay Rack equipment conforms to standard dimensions known commercially as "Government" or "Western Electric" standard. The unit panel is 1¾" in height, and the holes in the rack are on alternate 1¼" and ½" spacings. Many manufacturers of rack equipment use their own private spacings which are not interchangeable with other makes, but will supply standard spacing when ordered. We cannot guarantee that our panels, receivers, etc., will fit properly unless standard equipment is used throughout.

World Radio History

NATIONAL MOUNTED "S" METER

For use with the NC 80X or 81X Receivers which do not have built-in "S" meters, a meter of the same type as that used in the HRO is now available in a desk mounting. The necessary resistor network is built into all receivers of the NC-80 series, and it is only necessary to connect two wires to install the meter. Complete directions are given in the receiver instruction book. Specify whether gray or black wrinkle finish.

Mounted "S" Meter, Type SM-80 **List Price, $10.00**

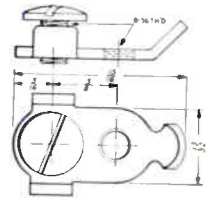
CODE PRACTICE OSCILLATOR

This small audio oscillator is suitable for either code practice, or as an audio signal source for ICW on the Ultra High Frequency Bands.

A type 30 tube is used, and four flash-light cells in the case provide filament and plate current.

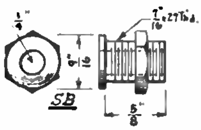
Type CPO, without batteries or tube.
List Price, $6.00

NATIONAL TERMINAL



This heavy duty screw terminal is convenient in making up special terminal panels for power supplies, etc.
List Price, $.15

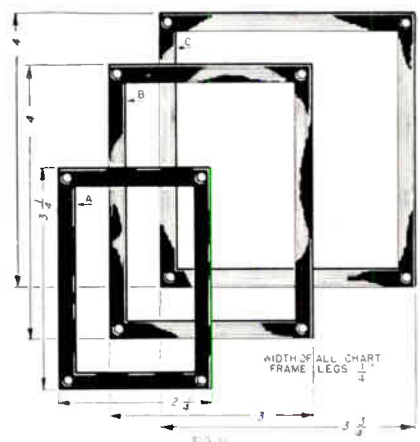
NATIONAL SHAFT BUSHING



A bushing that gives a professional touch to equipment where ¼" shafts have to be brought through panels.

Type SB **List Price, $.25**

NATIONAL CHART FRAMES



Nickel Silver Chart Frames are available in the sizes shown. The largest frame is the same as that used on the AGS, the medium frame is the same size as that on the FB-7, and the smallest is the same as the HRO frame. Prices include celluloid sheet to protect the chart.

Size A.	List Price, $.50
Size B.	List Price, .60
Size C.	List Price, .70

NATIONAL SHAFT EXTENSION

This shaft extension fits over ¼" shafts and is of nickel-plated brass.
List Price, $.25

NATIONAL GRID GRIPS

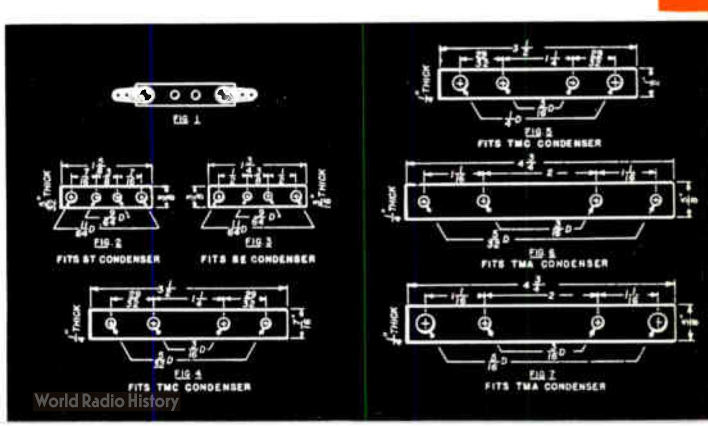
This Grip provides the best means for attaching a wire to the top-cap of tubes. Made in three sizes.

Type 24 — for standard glass tubes **List Price, $.05**
Type 12 — for transmitting tubes **List Price, $.10**
Type 8 — for metal tubes **List Price, $.05**

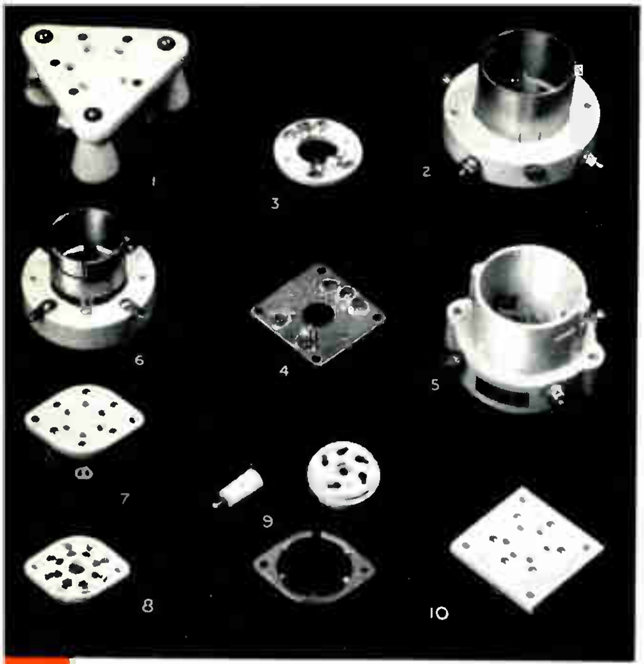
NATIONAL LOW-LOSS INSULATORS

A number of our standard condenser insulators are shown above. In addition to their obvious use as repair parts they may be used for a variety of other purposes such as supports for coils, spreaders, etc. The insulator shown in Fig. 1 is the same as Fig. 3, but has a metal solder lug riveted to each end. It is useful as a 5-meter lead-in spreader, or as a mounting for 5-meter inductances.

Fig. 1	List Price, $.30
Fig. 2	List Price, .15
Fig. 3	List Price, .15
Fig. 4	List Price, .30
Fig. 5	List Price, .30
Fig. 6	List Price, .40
Fig. 7	List Price, .40



World Radio History



NATIONAL LOW-LOSS SOCKETS

1 is a wafer type Isolantite socket for power Pentodes such as the RK-28 and the RCA-803. Type JX-100S, as illustrated. **List Price, $3.60**

Type JX-100, as above but without stand-off insulators. **List Price, $3.00**

2 is a fifty watt socket having sturdy side wipe contacts and conventional bayonet-lock metal shell. Type XM-50. **List Price, $1.75**

3 is an Isolantite socket for the Triode Acorn tube. The socket contacts are of a new design providing very short leads and have a current path nearly independent of tube position. Type XCA. **List Price, $1.50**

4 is for the Pentode Acorn tube and is assembled, with the same type of contacts as the XCA, on a square copper base with built-in by-pass condensers for stable high frequency operation. Type XMA. **List Price, $2.00**

5 is another 50 watt socket made entirely of low-loss Steatite for higher frequencies than the XM-50. Type XC-50. **List Price, $3.50**

6 is a socket, similar in construction to the XM-50, designed for those tubes using the type UX base. Type XM-10. **List Price, $1.25**

7 is one of the complete line of National Isolantite Receiving Sockets that fit all standard receiving tubes. Types 4 prong, 5 prong, 6 prong, 7 prong — small, 7 prong — large. **List Price, $.60 each**

8 is an Isolantite wafer socket for the Octal (metal) tubes. Type 8 prong. **List Price, $.60**

9 is a new socket of Isolantite, modern in every detail; from the contact that grips the tube prong for its full length to the metal ring for six-position mounting. The sockets for glass type tubes have a stand-off insulator for center mounting on bread board layouts. This line also includes an 8 prong socket (for metal tubes) with two metal stand-offs.

Type 4 prong, 5 prong, 6 prong, 7 prong — small, 7 prong — large, 8 prong (octal), CIR Series. **List Price, $.40**

10 is a square Isolantite coil socket designed to fit National 6 pin coils. A wafer type socket, similar to figure 6, is also available.

Type 6 prong Square Coil Socket. **List Price, $.75**

Type 6 prong Wafer Coil Socket. **List Price, $.60**

INTERLOCKING PUSH SWITCH

The new National Interlocking Push Switch was first designed for the NTE Exciter where the requirements of low losses, complete reliability and positive contacts required a special design. This switch fills these specifications so completely that it is now listed separately. Insulation is R-39. The silver-plated contacts are double pole, double throw.

Type ACS-4, Four gang, with trigger bar. **List Price, $5.00**

Type ACS-1, Single section, less trigger bar. **List Price, $1.25**

NATIONAL SHAFT COUPLINGS

1 is a small coupling of Steatite, providing high electrical efficiency when used to isolate circuits.
Type TX-9. **List Price, $1.10**

2 is a popular small coupling, free from backlash. Insulation is canvas bakelite.
Type TX-10. **List Price, $.55**

3 is a coupling providing high insulation with compact size. Insulation is glazed Isolantite.

Type TX-1 (leakage path 1"). **List Price, $1.00**

Type TX-2½ (leakage path 2½"). **List Price, $1.10**

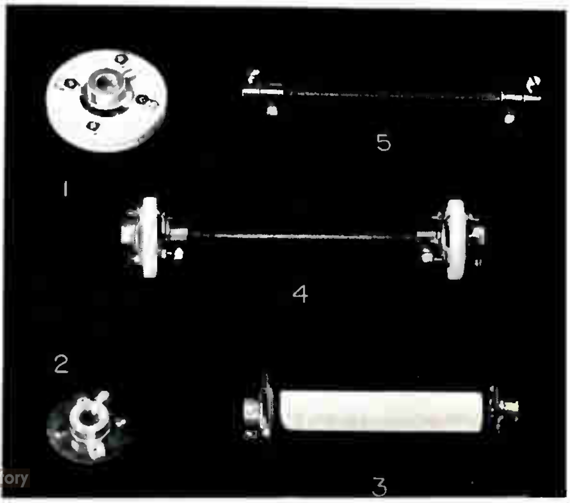
4 is a flexible shaft which provides a driving means between offset shafts, or shafts at angles up to 90 degrees, and virtually eliminates mis-alignment problems. Isolantite insulators are provided at each end.

Type TX-12, overall length 4⅝". **List Price, $1.25**

Type TX-13, overall length 7⅛". **List Price, $1.50**

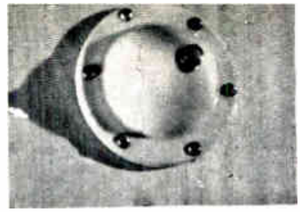
5 is a flexible shaft without the insulation of the TX-12, but otherwise the same.

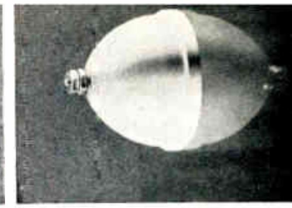
Type TX-11. **List Price, $.60**



World Radio History

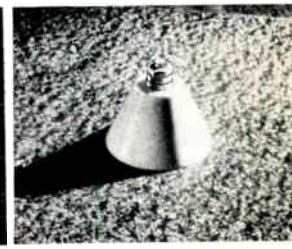
NATIONAL BOWLS





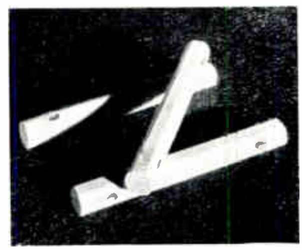
Larger in size than the bushings listed above, these Steatite bowls are suitable for lead-in purposes and high voltages. Type XS-3 (Fits 2¾" Hole) **List Price, per pair, $5.00**. Type XS-4 (Fits 3¾" Hole) **List Price, per pair, $6.50**. Type XS-5 (with flange for bolting down, 5¼" Dia.) **List Price, each, $7.50, per pair with metal fittings, $15.50**

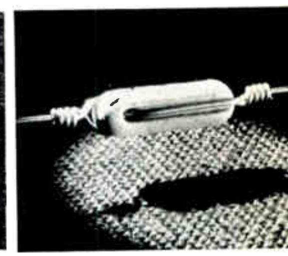
NATIONAL LEAD-THROUGHS



The combination lead-through bushing and stand-off insulator pictured at the right is available either plain (Type GS-8, **List Price, $.35**) or with a jack (Type GS-9, **List Price, $.50**). The bushings shown at the left are made in two sizes and are sold in pairs with the necessary metal fittings. Type XS-1 (Fits 1" Hole) **List Price, per pair, $.75**. Type XS-2 (Fits 1½" Hole) **List Price, per pair, $.90**

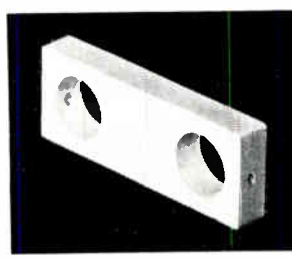
NATIONAL STRAIN INSULATORS

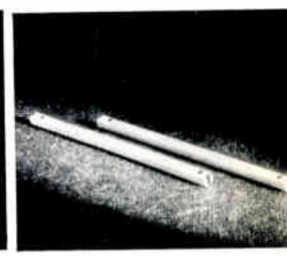




The antenna insulator illustrated at the left is particularly suited to general use. It has a long leakage path, ample strength for all but the heaviest loads, and high efficiency. Made of Steatite. Type AA-6, **List Price, $.35**. The small aircraft-type insulator at the right is ideal where compactness is desirable. Type AA-5, **List Price, $.30**

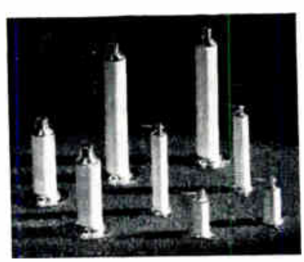
NATIONAL SPREADERS





The Steatite spreaders at the right provide a six-inch line spacing, and when used with No. 12 wire will give feeders having a surge impedance of 600 ohms. Type AA-3, **List Price, $.30**. The Isolantite insulators at the left when used to space ¾" tubes 2" apart will give a "Q" transformer matching a 72 ohm center-fed half-wave antenna to a 600 ohm line. Type QB, **List Price, $.35**

NATIONAL STAND-OFFS



With metal base and cap

Type GS-1 (½" x 1⅜")	**List Price, $ .25**
Type GS-2 (½" x 2⅞")	**List Price, $ .35**
Type GS-3 (¾" x 2⅞")	**List Price, $ .90**
Type GS-4 (¾" x 4⅞")	**List Price, $1.10**
Type GS-4A (¾" x 6")	**List Price, $1.60**

Cone type, with internal thread at each end

Type GS-5 (1¼")	**List Price, $.25**
Type GS-6 (2")	**List Price, $.45**
Type GS-7 (3")	**List Price, $.75**
Type GS-10 (¾") Per box of 10	**List Price, $.75**

NATIONAL H.F. BUSHING

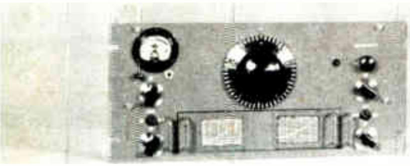
This small Steatite bushing has many uses in Amateur equipment. Type XS-6 **List Price, $.15**

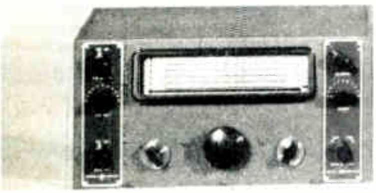
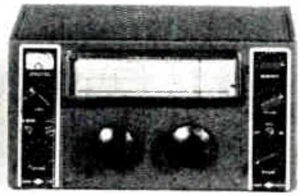
VICTRON SHEET AND COIL DOPE

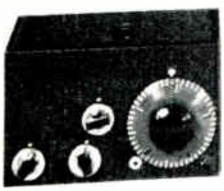
The Loss Factor (0.2) of this non-hydroscopic material is ⅛ of "Low-Loss" rubber and 1/90 of the usual R.F. insulators. Its Power Factor is .06%-.08%. Ideal for mounting high frequency gear and it is readily drilled or sawed. In color it is a transparent amber. National Coil Dope, a special R.F. lacquer using this same Victron as a base, is ideal as a cement for holding windings in place as it will not spoil the properties of the best coil form.

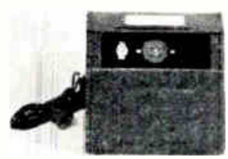
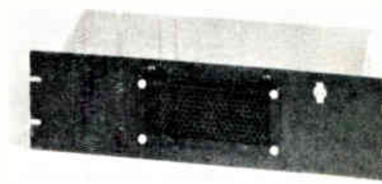
12" x 6" x 3/16" thick sheet.	**List Price, $6.00**
12" x 6" x ⅛" thick sheet.	**List Price, 5.00**
6" x 3" x 3/16" thick sheet.	**List Price, 1.50**
6" x 3" x ⅛" thick sheet	**List Price, 1.25**
Coil Dope, per can.	**List Price, 1.50**

World Radio History





HRO *A professional receiver, designed for maximum performance.* Features include two high-gain preselector stages giving exceptional signal to noise ratio, crystal filter, micrometer dial, S meter, AVC, Beat Oscillator. Approximate List Price $350*. (Top row, left.)

NC-100A & NC-101X *Fine Communication Receivers with splendid tone.* These 11 tube superheterodynes are self-contained except for the speaker. The NC-100A series (Top row, center) is ideal for broadcast reception as well as communication work. The NC-101X (Top row, right) covers only the amateur bands. Features include one stage of preselection, as well as complete communication equipment. Approximate List Price $200*

NC-80 & NC-81 *Excellent Communication Receivers at a moderate price.* This inexpensive 10 tube receiver uses a 1560 KC IF amplifier, giving excellent image suppression. Features include crystal filter and communication equipment. The NC-80 is for general coverage. The NC-81 covers only the amateur bands. (Middle row, left.) Approximate List Price $165*.

NC-44 *For capable performance at a very low price.* A seven tube superheterodyne with continuous coverage from 550 KC to 30 MC. A CW Oscillator is provided. (Middle row, right.) Approximate List Price $83*.

NC-510 *A specialized superheterodyne covering 28 to 64 MC.* The NC-510 (Middle row, center) is strictly a communication receiver, embodying all the features commonly needed in such work, but is specialized to give maximum performance in the range from 28 to 64 MC. Acorn tubes are used. Approximate List Price $250.00.

ONE-TEN *A specialized receiver for the range from 1 to 10 meters.* (Bottom row, left.) The ONE-TEN Receiver is intended primarily for the Experimenter. It is a thoroughly satisfactory receiver for the ultra-high frequencies. Four tubes are used; RF, Superregenerative Detector, 1st Audio, and Output Audio.

SW-3 *A dependable regenerative receiver.* (Bottom row, second from left.) The SW-3's seven year reputation for performance and dependability give it preference for many classes of work. It uses three tubes in a highly developed circuit that provides maximum sensitivity and flexibility.

POWER SUPPLIES National Power Supplies are specially designed for powering high frequency receivers, and include efficient filters for RF disturbances as well as hum frequencies. They are made in a variety of types.

★ *The List Prices given above are approximate only, and are intended only to show the price range in which each receiver falls. Complete specifications and prices will be given on request.*

NATIONAL COMPANY, INC.
MALDEN, MASS., U.S.A.

World Radio History

FOR AMATEUR RADIO

HY25 $1.45 Net

R.F. Power Amplifier, Oscillator, Class "B" Modulator, Frequency-Doubler, Ceramic Base and Insulation.

Plate Dissipation . . . . 25 watts max.
Plate Voltage (D.C.) . . . . 800 max.
Filament Voltage 7.5
Filament Current . . . . 2.25 amp.
Average Amp. Factor 55
Grid to Plate Cap . . . . 4.6 $\mu\mu f$

HY40 $2.75 Net

R.F. Power Amplifier, Oscillator, Class "B" Modulator, General Purpose High-Efficiency Triode, Graphite Anode, Lava Insulation, Ceramic Base.

Plate Dissipation . . . . 40 watts max.
Plate Voltage (D.C.) . . . . 1000 max.
Filament Voltage 7.5
Filament Current . . . . 2.25 amp.
Average Amp. Factor 25
Grid to Plate Cap . . . . 6.3 $\mu\mu f$

HY51A-HY51B $5.00 Net

R.F. Power Amplifier, Oscillator, Class "B" Modulator, Frequency-Doubler, Graphite Anode, Lava Insulation, Ceramic Base.

Plate Dissipation . . . . 65 watts max.
Plate Voltage (D.C.) . . . . 1000 max.
Filament Voltage . . . . 7.5 on HY51A, 10.0 on HY51B
Filament Current . . . 3.5 amp. on HY51A, 2.25 amp. on HY51B
Average Amp. Factor 25
Grid to Plate Cap . . . . 7.5 $\mu\mu f$

HY57 $3.50 Net

R.F. Power Amplifier, Oscillator, Class "B" Modulator, Frequency-Doubler, Graphite Anode, Lava Insulation, Ceramic Base.

Plate Dissipation . . . . 40 watts max.
Plate Voltage (D.C.) . . . . 800 max.
Filament Voltage 6.3
Filament Current . . . . 2.25 amp.
Average Amp. Factor 50
Grid to Plate Cap . . . . 5.1 $\mu\mu f$

HY60 $2.50 Net

Beam-Tetrode, R.F. Amplifier, Oscillator, Class AB1 Audio Amplifier, Frequency-Doubler, Ceramic Base. NO NEUTRALIZATION REQUIRED FOR USE AT RADIO FREQUENCIES.

Heater Voltage (A.C. or D.C.) 6.3
Heater Current . . . . 0.5 amp.
D.C. Plate Voltage . . . . 425 max.
Plate Current . . . . 60 ma. max.
Grid Current . . . . 4 ma. max.
R.F. Output (Class "C") . . . . 16 watts approx.

HY61 $3.00 Net

Beam-Tetrode, R.F. Amplifier, Oscillator, Class AB2 Audio Amplifier, Frequency-Doubler, Ceramic Base. NO NEUTRALIZATION REQUIRED FOR USE AT RADIO FREQUENCIES.

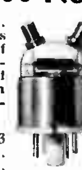
Heater Voltage (A.C. or D.C.) 6.3
Heater Current . . . . 0.9 amp.
D.C. Plate Voltage . . . . 600 max.
Plate Current . . . . 100 ma. max.
Grid Current . . . . 5 ma. max.
R.F. Output (Class "C") . . 37.5 watts approx.

6L6GX $1.55 Net

Beam-Tetrode, Power Amplifier. (LOW-LOSS REPLACEMENT FOR 6L6 AND 6L6G.) Ceramic Base.

Heater Voltage 6.3
Heater Current . . . . 0.9 amp.

HY615 TRIODE $2.00 Net



Ultra-High Frequency Oscillator, R.F. Amplifier, Detector. Plate and Grid leads are brought out to caps in the dome of the bulb. The HY615 features short connection leads, small internal elements and low inter-electrode capacities resulting in efficient operation at ultra-high frequencies. Ceramic Base.

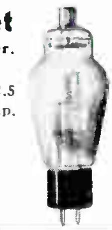
Heater Voltage (A.C. or D.C.) 6.3
Heater Current . . . . 0.15 amp.
Plate Voltage . . . . 250 max.
Plate Dissipation . . . . 3.5 watts max.

866 JR. $1.05 Net

Half-Wave, Mercury Vapor Rectifier, Ceramic Base.

Filament Voltage 2.5
Filament Current . . . 2.5 amp.

866 $1.50 Net



Half-Wave, Mercury Vapor Rectifier, Heavy Duty.

Filament Voltage 2.5
Filament Current . . . . . 5 amp.

HYTRON
TRADE MARK REG

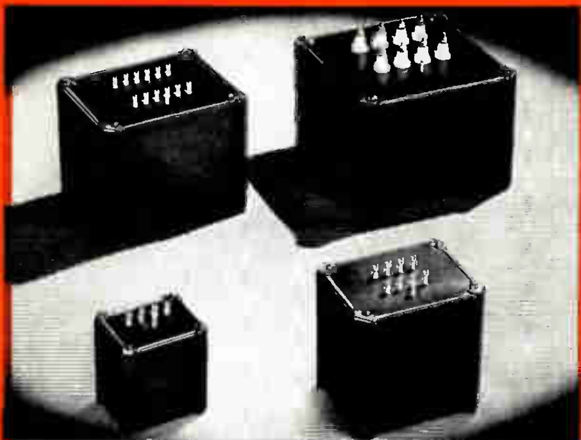
HYTRONIC LABORATORIES
SALEM MASS.
A DIVISION OF THE HYTRON CORP.

World Radio History

COMPLETE TRANSFORMER LINE

DESIGNED TO THE APPLICATION

FOR THE BROADCAST STATION



★ **LINEAR STANDARD** transformers have guaranteed linear response from 30 to 20,000 cycles, ideal shielding and dependability.

TYPICAL ITEMS:

LS-10X, tri-alloy shielded, multiple line to grid. Net **$12.00**
LS-50, low level plate to multiple line. Net **9.00**
LS-55, 2A3's to multiple line and voice coil. Net **12.00**

★ **HIPERM ALLOY** units are similar to LINEAR STANDARD components but employ a light-weight case, making them ideal for highest fidelity compact equipment.

TYPICAL ITEMS:

HA-100X, tri-alloy shielded, multiple line to grid. Net **$10.50**
HA-111, crystal mike or pickup to line. Net **7.50**
HA-105, single plate to single grid. Net **5.40**

FOR PORTABLE SERVICE

★ **ULTRA-COMPACT** units weigh only 5½ ounces but have broadcast fidelity, within 2 DB from 30 to 20,000 cycles . . . ideal for remote pickup equipment.

TYPICAL ITEMS:

A-10, universal line to grid. Net . . **$6.00**
A-24, low level plate to universal line. Net **6.00**
A-16, single plate to single grid. Net **4.80**

★ **UTC OUNCER UNITS** weigh but 1 ounce yet have high fidelity characteristics. Ideal for hearing aid, concealed service and aircraft.

TYPICAL ITEMS:

O-1, line to grid. Net **$6.00**
O-6, plate to two grids. Net **5.40**
O-15, 10 to 1 interstage (voice). Net **6.00**

World Radio History

Complete Transformer Line

FOR COMMERCIAL AND AMATEUR EQUIPMENT

★ **VARIMATCH** components include universal driver and output units for every transmitting and PA application.

TYPICAL ITEMS:

VM-4, 300 watts audio to any RF load. Net.... **$19.50**
PVM-2, 30 watts audio to line and voice coil impedances. Net **4.80**
PA-53AX, P.P. driver tubes to 100/300 watt grids. Net **4.50**

★ **PA POWER COMPONENTS** are designed to commercial standards, incorporating low temperature rise, and ample insulation safety factors.

TYPICAL ITEMS:

PA-108, Choke, 10 Hy. 500 MA. Net... **$12.00**
PA-303, Plate transformer, 1500-1235 V. at 300 MA. 400 V. at 175 MA. for 2A3-203A modulator. Net.......... **15.00**
PA-311, High power plate transformer. 1500-1235 V. at 500 MA. Net........ **21.00**

FOR THE AMATEUR

★ **SPECIAL SERIES** components are shielded units designed specifically for amateur service and represent unprecedented value.

TYPICAL ITEMS:

S-5, line or mike to grid. Net.......... **$1.80**
S-15, 12 watt universal output to line and voice coil. Net **2.10**
S-28, 100 MA filter choke. Net **1.65**
S-48, plate transformer, 1500 E. S. — 500 MA. Net **11.70**

★ **UTC KITS** are available for PA and transmitting applications up to 300 watts. PA units include VARITONE control, volume limiting and many other unique features. The SPECIAL SERIES units represent extreme value, specifically designed to the requirements of the amateur.

UNITED TRANSFORMER CORP.
72 SPRING STREET • NEW YORK, N. Y.
EXPORT DIVISION 100 VARICK STREET NEW YORK, N.Y. CABLES "ARLAB"

IRC RESISTORS

POWER WIRE WOUNDS

Power type resistors for high voltage bleeders, bias supply, grid, and filament dropping resistors, etc., featuring:

1. Tough, non-hygroscopic tubes.
2. High grade alloy wire, largest practical diameter, uniformly wound.
3. Rugged terminals, firmly attached.
4. Special cement coating, protecting resistor in humid climates and severe overloads.

The use of fixed and adjustable resistors is noted in many of the preceding pages of this handbook and in January 1938, *QST*, Page 59, and February *QST*, Page 127.

The non-inductive resistors listed below employ the Ayrton-Perry method of winding, consisting of two interleaved windings in opposite directions. The small NAB is useful as a parasitic suppressor when power tubes are paralleled. It should be mounted as close as possible to the socket terminal.

Wattage Rating (Free Air)	IRC Type	Dimensions	Type Term.	Ranges Ohms	List Price
			FIXED TYPE		
10	AB	1¾" x 5/16"	Pigtails	1– 50,000	$.40
(Rating 5 watts above 25,000 ohms)					
20	DG	2" x 9/16"	Soldering	1– 15,000	.65
(Rating 10 watts above 50,000 ohms)			Lugs	20,000– 50,000	.75
				60,000–100,000	1.00
50	EP	4½" x ¾"	Lugs	5– 5,000	1.10
				6,000– 25,000	1.25
				30,000–100,000	1.45
80	ES	6½" x ¾"	Lugs	5– 5,000	1.25
				6,000– 25,000	1.50
				30,000– 50,000	1.75
				60,000– 75,000	2.00
			Lugs	100,000	2.25
100	HA	6½" x 1⅛"	Lugs	25– 5,000	1.50
				7,500– 25,000	1.75
				30,000– 50,000	2.00
				60,000– 75,000	2.25
				100,000	2.50
200	HO	10½" x 1⅛"	Lugs	25– 10,000	2.50
				15,000–100,000	3.00
			ADJUSTABLE TYPE *See Note		
10	ABA	1¾" x 5/16"	Lugs	1– 10,000	$.60
25	DHA	5/16" x 2½"	Lugs	1– 5,000	.85
				6,000– 15,000	.95
				20,000– 25,000	1.10
50	EPA	¾" x 4½"	Lugs	5– 5,000	1.35
				6,000– 25,000	1.50
				30,000– 50,000	1.70
				60,000– 75,000	2.00
80	ESA	¾" x 6½"	Lugs	5– 5,000	1.75
				6,000– 25,000	2.00
				30,000– 50,000	2.25
				60,000–100,000	2.50
100	HAA	6½" x 1⅛"	Lugs	100– 5,000	2.00
				6,000– 25,000	2.25
				30,000– 50,000	2.50
				60,000–100,000	2.75
200	HOA	10½" x 1⅛"	Lugs	100– 10,000	3.00
				15,000–100,000	3.50
			NON-INDUCTIVE TYPE		
10	NAB	1¾" x 5/16"	Lugs	50	$.90
50	NEP	4½" x ¾"	Lugs	5– 5,000	3.00
100	NHA	6½" x 1⅛"	Lugs	5– 5,000	4.00
200	NHO	10½" x 1⅛"	Lugs	25– 5,000	5.00

Mounting brackets on all resistors 25 watts and up.

**Note*: Wattage rating noted is for whole resistor. Rating for any section in proportion. Prices include one adjustable band. Extra bands: 10c each for 10, 25, 50, and 80 watt sizes. 15c each for 100 and 200 watt sizes.

MOLDED WIRE WOUNDS

For filament center tap and low power bleeder and bias resistors. See page 89, October 1938, *QST*.

Molded in special heat resisting bakelite, insulated for 1000 volts to ground, and supplied with convenient clamp for mounting flat against the chassis; they are handy where space is important. The soldering lugs are convenient for mounting bypass condensers and wiring.

Rating on Chassis	Rating Free Air	IRC Type	Bracket Mounting Centers	Width	Overall Resistance	Tapped at	List Price
(18 Watts 28 Mills)	(9 Watts 19 Mills)	M-1034	5⅛"	11/16"	25,000	7500 10000 12500 15000	$1.25
5 Watts	2½ Watts	MW-2J	2⅛"	11/16"	10, 20, 50, 75, 100, or 200	Center	.35

Power Type High Frequency Resistors

For dummy and Rhombic Antennas, or wherever a resistor is needed with constant impedance up to a frequency of 100 megacycles; a new development consisting of a high grade ceramic tube with an extremely thin film of "Metallized" resistance material bonded to the outer surface — Discussed on Page 83, *QST*, May 1938. Ratings shown represent dissipation in free air — a maximum temperature of 140° C.

Type MPO — 800 ohms, 50 watts, 1⅛" diam. x 10½" long.
Net Price .... $ 5.00
Type MPR — 800 ohms, 150 watts, 2" diam. x 18½" long.
Net Price 10.00
Type MPR — 400 ohms, 150 watts, 2" diam. x 18½" long.
Net Price 10.00

POWER RHEOSTATS

TYPE PR-25 WATTS

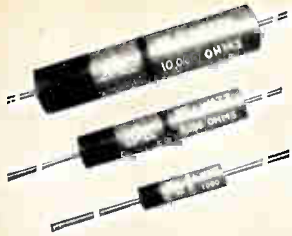
Total Ohms Resistance	Max. Current in Milliamps.	List Price
1	5,000	$4.50
2	3,450	4.00
3	2,880	4.00
6	2,040	4.00
8	1,770	4.00
10	1,580	4.00
15	1,290	4.00
25	1,000	4.00
35	845	4.00
50	709	4.00
75	575	4.00
100	500	4.00
125	445	4.00
175	375	4.00
250	315	4.00
350	267	4.00
500	222	4.00
750	173	4.00
1,000	155	4.50
1,500	129	4.50
2,500	100	4.50
3,500	84	4.75
5,000	70	4.75

TYPE PR-25 WATTS

For filament, or any voltage control. The all-metal construction of these units makes it possible to use them safely at full rated load. The 25 watt rating is based on a hottest spot temperature rise of only 140° C. Units are 1 21/32" diam., 31/32" deep. Insulated shaft, positive pigtail connection to rotor arm, alloy contact shoe, smooth rotation, supplied complete with knob.

World Radio History

INSULATED METALLIZED



TYPE BT. An IRC development. For all general requirements. We have manufactured approximately one hundred million of these resistors. Stable under varying conditions of voltage, temperature, and humidity. Extremely low noise level. Molded in bakelite. Available individually or in handy kit form in a steel Resist-O-Cabinet.

INSULATED WIREWOUND

TYPE BW. For low range applications. Molded in bakelite. Stable, stand severe overloads.

HIGH FREQUENCY METALLIZED

TYPE F. For U.H.F. receivers, low power transmitters and television sets. Approximately flat frequency characteristic. See QST, March 1938, Page 77.

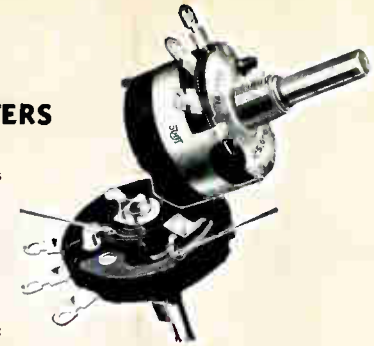
Wattage Rating	IRC Type	Dimensions	Minimum Range Ohms	Maximum Range Ohms	Recommended for Frequencies	Maximum Voltage Rating	Construction	Price List
½	BT-½	3/16 x 5/8	50	20,000,000	Below 7 megacycles	350	Metallized insulated	$.17
1	BT-1	¼ x 1⅛	150	20,000,000	"	500	"	.20
2	BT-2	5/16 x 1¾	200	20,000,000	"	500	"	.30
½	BW-½	3/16 x 5/8	.05	750	"		Wire wound insulated	.17
1	BW-1	¼ x 1¼	1.0	5,000	"		"	.20
2	BW-2	5/16 x 1¾	1.0	7,000	"		"	.30
½	F-½	9/32 x 1 [illegible]	50	10,000,000	Above 7 megacycles, television	350	High frequency metallized	.17
1	F-1	11/32 x 1 [illegible]	100	10,000,000	"	500	"	.20
2	F-2	13/32 x 1 [illegible]	50	10,000,000	"	500	"	.30

Note: Standard Tolerances ± 10%. — Special ± 5% Tolerances Available.

PRECISION WIRE WOUNDS

TYPE WW. For meter multipliers and shunts and precision test equipment. Standard throughout the industry. Non-inductive "pie" windings on grooved ceramic forms, constant impedance up to 50,000 cycles, lowest possible temperature coefficient, thorough impregnation, die cast terminal connections. Standard tolerance ± 1%, closer tolerances available to ± 1/10 of 1%. Twelve types and sizes. See them at your jobbers — or write for catalog. Discussed in QST, April 1938, Page 65.

VARIABLE POTENTIOMETERS



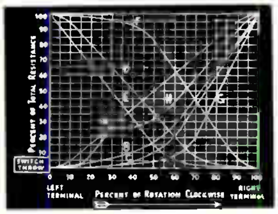
For Volume, Tone, Sensitivity, and Variable Bias Controls in Receivers, Amplifiers, and Oscilloscopes. The Type "CS" Control comprises a hard, smooth, "Metallized" film bonded to bakelite, a 5 finger contact arm (each finger independent), and a positive pigtail connection to the rotor arm. Special attention is given to the assembly of these parts in a molded base, completely shielded. Rated dissipation ½ watt over whole element. This control represents, in our opinion, the very latest advances in the art.

STOCK RANGES

Resistance	Type No. Without Switch	Taper	Usual Application
500 Ohms	11-103	A	Potentiometer Voltage Divider
1,000 "	11-108	A	Potentiometer Voltage Divider
2,000 "	11-110	A	Potentiometer Voltage Divider
3,000 "	11-112	A	Potentiometer Voltage Divider
4,000 "	11-113	A	Potentiometer Voltage Divider
5,000 "	11-114	A	Potentiometer Voltage Divider
5,000 "	13-114	C	Antenna Control
7,500 "	11-115	A	Potentiometer Voltage Divider
10,000 "	11-116	A	*Antenna Grid Bias Control
10,000 "	13-116	C	Antenna Control
10,000 "	14-116	D	*Antenna Grid Bias of 2 Tubes
10,000 "	16-116	F	*Antenna Grid Bias of 1 Tube
15,000 "	14-118	D	*Antenna Grid Bias Control
15,000 "	16-118	F	*Antenna Grid Bias Control
20,000 "	16-119	F	*Antenna Grid Bias Control
25,000 "	11-120	A	Potentiometer Voltage Divider
25,000 "	14-120	D	*Grid Bias Control
25,000 "	16-120	F	Antenna Control
50,000 "	11-123	A	Potentiometer Voltage Divider
50,000 "	13-123	C	Tone Control
75,000 "	13-125	C	Tone Control
75,000 "	14-125	D	*Grid Bias Control
100,000 "	11-128	A	Potentiometer Voltage Divider
100,000 "	13-128	C	Tone or Audio Circuit Control
200,000 "	11-129	A	Potentiometer Voltage Divider
200,000 "	14-129	D	*Grid Bias Control
250,000 "	13-130	C	Tone or Audio Circuit Control
250,000 "	†13-130X	H	Tapped Tone Compensation
250,000 "	14-130	D	*Grid Bias Control
500,000 "	11-133	A	Potentiometer Voltage Divider
500,000 "	13-133	C	Tone or Audio Circuit Control
500,000 "	†13-133X	H	Tapped Tone Compensation
1.0 Meg.	13-137	C	Tone or Audio Circuit Control
1.0 "	†13-137X	H	Tapped Tone Compensation
1.0 "	†VC-539X		Fader Control for fading out of one circuit into another
2.0 "	13-139	C	Tone or Audio Circuit Control
2.0 "	†13-139X	H	Tapped Tone Compensation
3.0 "	13-140	C	Tone or Audio Circuit Control
5.0 "	11-141	A	Potentiometer Voltage Divider
7.0 "	11-142	A	Potentiometer Voltage Divider
10.0 "	11-143	A	Potentiometer or Rheostat

* A 300 ohm BT-½ (½-Watt) Insulated Metallized Resistor is included without additional charge with every Control indicated by an asterisk (*) for use as external grid bias resistor.

† All Controls marked with an "X" following the part number are tapped.



Standard Control List Prices

Standard Single Controls, without switch (plain cover)......$1.00

Standard Tapped Controls, without switch (plain cover)......$1.50

L-PADS and T-PADS

L-PADS (dual). Type J-976. 500 ohms. List $2.50

T-PADS (triple). Type J-977. 500 ohms. List $3.50

SWITCHES

No. 21 — Single Pole — Single Throw. List Price ....$.50
No. 22 — Double Pole — Single Throw. List Price .... .60
No. 23 — Single Pole — Double Throw. List Price .... .60
No. 24 — Three Point. List Price .... .60
No. 25 — Four Point. List Price .... .60

INTERNATIONAL RESISTANCE CO., 401 N. Broad St., Phila., Pa.

IN CANADA: 187 DUCHESS ST., TORONTO, ONTARIO

MAKERS OF RESISTANCE UNITS OF MORE TYPES, IN MORE SIZES, FOR MORE APPLICATIONS THAN ANY OTHER MANUFACTURER IN THE WORLD!

World Radio History

Presenting...The RCA POWER

Every amateur requirement is capably filled by these outstanding RCA tubes. Not only do they give you the advantages of advanced engineering design—they provide the finest in quality at prices you can afford to pay!

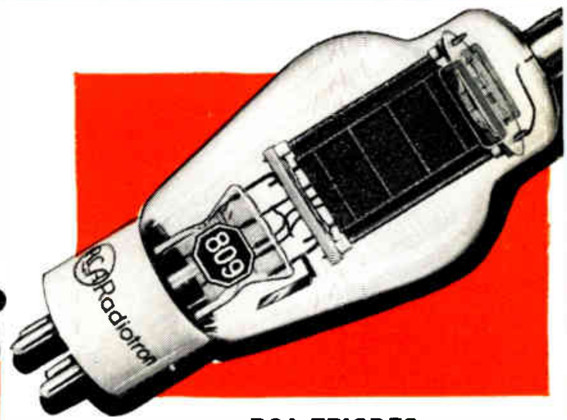
RCA PENTODES

The RCA Pentodes are extremely popular for power amplifiers where suppressor-grid modulation is employed. They also make excellent crystal oscillators. In many circuits, Pentodes reduce number of tubes.

The RCA-802 is a power amplifier pentode that is popularly used as a crystal oscillator. In r-f amplifiers the low grid-plate capacitance of the RCA-802 eliminates the need for neutralization in adequately shielded circuits. Price $3.50.

The RCA-803 is a heavy duty pentode. In Class "C" service, it has a power output of 210 watts with 4.4 watts driving power. Price $34.50.

The RCA-804 (illustrated) may be used as an r-f amplifier, frequency multiplier, oscillator, and suppressor-grid or plate-modulated amplifier. In shielded circuits, neutralization is generally unnecessary. Price $15.00.



RCA TRIODES

Amateurs have found that the RCA Triode Group of Power Tubes is excellent for general purpose use. They are suitable for use as oscillators, amplifiers, frequency multipliers, and a-f modulators.

The RCA-808 is a medium-power triode of the high-mu, thoriated-tungsten filament type. The plate connection is brought out through a separate seal at the top of the bulb, while the grid connection is brought out by a separate seal in the lower part of the bulb near the base. This insures good insulation and low interelectrode capacitances. In Class C telegraphy service, the RCA-808 has a power output of 140 watts and requires only 9.5 watts driving power. Price $7.75.

The RCA-809 (illustrated) is an unusually popular tube with the Transmitting Amateur. It may be operated at maximum ratings at frequencies as high as 60 megacycles. Two RCA-809's in a push-pull circuit deliver over 100 watts of r-f power to the antenna. An outstanding value for $2.50.

The RCA-833 is a high-mu triode of the thoriated-tungsten filament type. Because of its high perveance, it may be operated at high plate efficiency with low driving power. Its new design with post terminals provides a rugged structure and makes bases unnecessary. It contains a minimum amount of insulation within the tube. Price $85.00.

RCA *Radio Tubes*

World Radio History

Stars of the TUBE LEAGUE!

REMEMBER—RCA makes tubes for every amateur application—providing the finest in quality at prices you can afford to pay!

RCA BEAM POWER TUBES

The outstanding feature of the RCA Beam Power Group is their high power output with low driving power requirements.

The RCA-807 is the smallest RCA Beam Power Amplifier available in the transmitting tube line. It has the inherent feature of high power sensitivity characteristic of beam power amplifiers which makes it especially suitable for use as an r-f or a-f amplifier, crystal oscillator, and frequency multiplier. It may be operated up to maximum ratings in all classes of service at frequencies as high as 60 megacycles. In Class AB_2 audio service two tubes are capable of delivering an output of approximately 80 watts. $3.50.

The RCA-813 is the largest of the Beam Power transmitting tube group. It will deliver over 260 watts output per tube with less than 1 watt driving power—a truly remarkable performance. As a result of its construction, the 813 can be operated at maximum ratings at frequencies as high as 30Mc and at reduced ratings as high as 120Mc. $28.50.

The RCA-814 transmitting Beam Power Amplifier (illustrated) has the unusual characteristic of delivering 130 watts output in Class C telegraphy service with only 1.5 watts driving power. It features a new design involving the use of directed electron beams. The RCA-814 may be operated at frequencies as high as 30 megacycles. $17.50.

RCA RECTIFIERS

RCA Rectifiers furnish the "power behind the signal" wherever amateur radio is found. They are outstanding in performance—low in cost.

The RCA-866 (illustrated) and 866-A are half-wave, mercury-vapor rectifier tubes that are popular for many amateur uses. The 866 has a maximum peak inverse rating of 7500 volts, while the 866-A has a rating of 10,000 volts. RCA-866—$1.50. RCA-866-A—$4.00.

The RCA-872 is a half-wave, mercury-vapor rectifier tube of the coated-filament type. It is a husky, high-powered rectifier, ideal for supplying that one-kilowatt rig. It has a maximum peak inverse rating of 10,000 volts. Price $14.00.

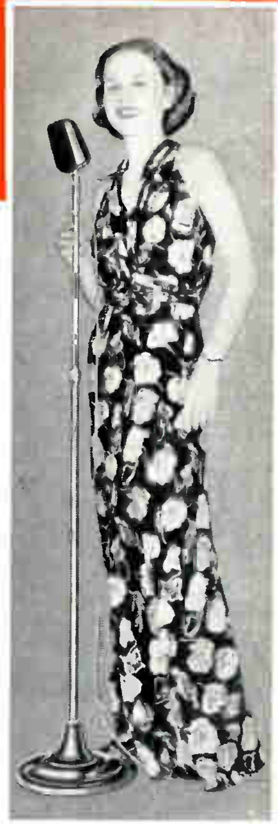
RCA presents the Magic Key every Sunday, 2 to 3 P.M., E.S.T., on the NBC Blue Network.

FIRST IN METAL · FOREMOST IN GLASS · FINEST IN PERFORMANCE

RCA MANUFACTURING COMPANY, INC., CAMDEN, NEW JERSEY
A SERVICE OF THE RADIO CORPORATION OF AMERICA

World Radio History

ASTATIC



New MULTI-UNIT Microphones

Cannot be Acoustically Overloaded

It is with pride that Astatic presents the new "MU" Series . . . microphones comparable with the finest, regardless of type. Most appropriate frequency response for every broadcast requirement and public address installation. Veteran amateurs, along with professional and commercial users are praising the performance of this microphone which meets most exacting and critical demands.

Dual Diaphragm Construction

"MU" Crystal Microphones provide maximum amplification with greatly reduced feedback tendencies and cannot be acoustically overloaded. Made in two models: MU-2 with two dual diaphragm crystal units (four diaphragms) and MU-4 with four dual diaphragm crystal units (eight diaphragms). Chrome and black. Complete with interchangeable locking connector and 25-ft. shielded rubber covered cable.

LIST PRICES

MU-2, $29.50 MU-4, $39.50

Famous Crystal Pickups

B-10 Astatic Tru-Tan Model B-10 Crystal Pickup for records to 12". True tone reproduction. List Price $17.59.

B-16 Astatic professional Model B-16 Crystal Pickup for records to 16". List Price $27.50.

O-7 Astatic's new Streamlined Model O-7 Crystal Pickup for radio-phonograph installations. List Price $6.50.

Directional or Non-Directional

Model T-3 Microphone

In beauty, flexibility and performance, Model T-3 Crystal Microphone is a proven leader in its price field. Its directional and non-directional characteristics add great practicability to remarkable performance.

Unique Tilting Mount

Suspended crystal assembly prevents vibration or shock and offers improved frequency response. By rotating or tilting the head attached to unique tilting mount, acoustic feedback may easily be controlled and the pickup made directional or non-directional, as desired. Complete with interchangeable plug and socket connector, 25-ft. shielded rubber covered cable and spring protector. Polished chromium finish.

List Price, $25.00

ASTATIC MICROPHONE LABORATORY, Inc. YOUNGSTOWN, O.

Pioneer Manufacturers of Quality Crystal Products

Licensed Under Brush Development Co. Patents. Astatic Patents Pending

World Radio History

HAMMARLUND

"MC" MIDGET CONDENSERS

Ideal variable for ultra-short wave and short wave tuning, laboratories, etc. Isolantite insulation. All contacts riveted or soldered. Vibration proof. New improved Hammarlund split type rear bearing, and noiseless wiping contact. Cadmium plated soldered brass plates. Shaft—¼″.

CODE	CAPACITY	LIST
MC-20-S	20 mmf.	$1.40
MC-35-S	35 mmf.	1.50
MC-50-S	50 mmf.	1.60
MC-50-M	50 mmf.	1.60
MC-75-S	80 mmf.	2.00
MC-75-M	80 mmf.	2.00
MC-100-S	100 mmf.	2.25
MC-100-M	100 mmf.	2.25
MC-140-S	140 mmf.	2.50
MC-140-M	140 mmf.	2.50
MC-200-M	200 mmf.	2.75
MC-250-M	260 mmf.	3.00
MC-325-M	320 mmf.	3.50

"M"—Midline Plates "S"—Straight Line Cap. Plates

"MCD" SPLIT-STATOR CONDENSERS

Like single midgets, these incorporate every requirement imperative to highest quality. Specifications identical to single types except that shield plate is located between stator sections. Also equipped with new Hammarlund noiseless wiping contact and split type rear bearing. Overall length behind panel—3⅜″. Strong Isolantite base. Single hole panel mount.

CODE	CAPACITY	LIST
MCD-50-M	50 mmf. per sect	$3.00
MCD-50-S	50 mmf. per sect	3.00
MCD-100-S	100 mmf. per sect	3.50
MCD-100-M	100 mmf. per sect	3.50
MCD-140-M	140 mmf. per sect	4.00
MCD-140-S	140 mmf. per sect	4.00

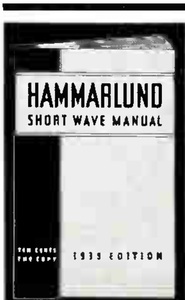
"M"—Midline Plates "S"—Straight Line Cap. Plates

"MCB" BAND SPREAD CONDENSERS

For perfect band spreading or for amateur band frequency meters. Tank section may be set and locked to any desired capacity. Tuning sections spread narrow frequency range over entire dial regardless of range of bands or coils used. Tank capacity—100 mmf., Tuning cap. type "120-B"—20 mmf., type "150-B"—50 mmf. Isolantite insulation at front and rear. Plates rigidly held in place.

CODE	LIST
MC-120-B	$3.00
MC-150-B	3.25

"SWM" SHORT WAVE MANUAL

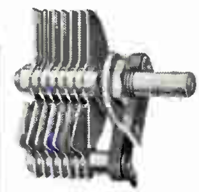


ENTIRELY NEW!

Contains up-to-the-minute constructional data on short and ultra-short wave receivers—power supplies—transmitters—preselectors—converters—tuning hints and SW station list. All sets were built in the Hammarlund laboratories and thoroughly tested. Illustrated with photographs and wiring diagrams. Ideal for the beginner and old-timer alike.

CODE	LIST
SWM.39	$.10

"SM" STAR MIDGET CONDENSERS

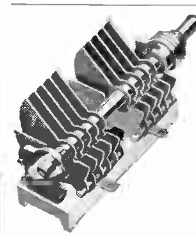


For receiving and transmitting, for short wave tuning, regeneration, antenna coupling, vernier, etc. Low loss, natural bakelite insulation. Non-corrosive aluminum plates. Phosphor bronze spring plate affords proper tension and smooth control and also provides perfect contact. Single hole mounting. ¼″ shaft. 5/16″ mounting bushing. 1 9/16″ wide x 1¾″ high. Depth behind panel from 11/16″ to 1⅞″ depending on capacity. Exceptionally light in weight and strong and compact in construction. Tinned soldered lugs on the front end are supplied to simplify wiring. Plates of straight line capacity types.

CODE	CAPACITY	LIST
SM-15	15 mmf.	$ .85
SM-25	25 mmf.	.85
SM-50	50 mmf.	.90
SM-100	100 mmf.	1.00
SM-140	140 mmf.	1.25
*SM-35-X	35 mmf.	1.00
*SM-50-X	50 mmf.	1.25

* Double Spaced Transmitting Types

"MCDX" DOUBLE SPACED CONDENSERS



Identical to split stator condensers except that plates are widely spaced—actual air gap between rotor and stator plates—.0715″. No shield between stators. Equipped with new Hammarlund noiseless wiping contact, and split type rear bearing. Condenser ideal for ultra-high frequency transmitters using up to 245's or 210's in push-pull.

CODE	CAPACITY	LIST
MCD-35-MX	31 mmf. per sect	$3.50
MCD-35-SX	31 mmf. per sect	3.50

"MX"—Midline Plates "SX"—Straight Line Cap. Plates

"MCX" DOUBLE SPACED CONDENSERS

Exceptional unit for ultra-s.w. receivers and transmitters particularly compact transmitters. Plate spacing—.0715″. Great for tuning crystal controlled transmitter amplifier stages or for neutralizers up to 210's and 50 watters. In midline (MX) and straight line cap. types (SX).

CODE	CAPACITY	LIST
MC-20-SX	20 mmf.	$2.00
MC-20-MX	20 mmf.	2.00
MC-35-MX	32 mmf.	2.25
MC-35-SX	32 mmf.	2.25
MC-50-MX	50 mmf.	2.75
MC-50-SX	50 mmf.	2.75
MC-100-SX	100 mmf.	3.50

"APC" MICRO CONDENSERS

For S.W. and ultra-S.W. For I.F. tuning, trimming R.F. coils or gang condensers, general padding, etc. Constant capacity under any conditions of temperature or vibration. Size 100 mmf. 1 7/32″ x 15/16″ x 1 7/32″. Isolantite base. Cadmium plated soldered brass plates.

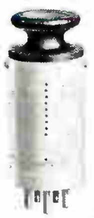
CODE	CAPACITY	LIST
APC-25	25 mmf.	$1.30
APC-50	50 mmf.	1.50
APC-75	75 mmf.	1.70
APC-100	100 mmf.	1.90
APC-140	140 mmf.	2.25

HAMMARLUND MANUFACTURING CO., INC., 424-438 West 33rd Street, New York City

World Radio History

HAMMARLUND

"CF" ISOLANTITE COIL FORMS



Popular coil forms so many fans are using today. Black enameled wooden knob. Removable paper indicating disc protected by celluloid. Surface "non-skid." Plenty of holes—eliminates drilling. Slotted bottom for primary or tickler. Four, five, and six prong types. 1½" diameter. 2½" long exclusive of knobs and prongs.

CODE	LIST
CF-4 (four prongs)	$1.25
CF-5 (five prongs)	1.25
CF-6 (six prongs)	1.25

"XP-53" COIL FORMS AND KITS

Outstanding forms using new low loss insulation material—XP-53. Natural coloring eliminating losses. Groove-ribbed for air spaced windings. Flange grips, meter indexes. Moulded threaded shelf in form. 1½" diameter and 2⅞" long exclusive of prongs. Kits with wound coils for MC-140-M condenser also available.

CODE	LIST
SWF-4 (four prongs, coil form only)	$ .35
SWF-5 (five prongs, coil form only)	.35
SWF-6 (six prongs, coil form only)	.40
No. 40 coil (wound coil, 4 prongs, 10-20 meters)	1.00
No. 41 coil (wound coil, 4 prongs, 17-41 meters)	1.00
No. 42 coil (wound coil, 4 prongs, 33-75 meters)	1.00
No. 43 coil (wound coil, 4 prongs, 66-150 meters)	.75
No. 44 coil (wound coil, 4 prongs, 135-270 meters)	.75
BCC-4 (wound coil, 4 prongs, 250-560 meters)	1.25
No. 60 coil (wound coil, 6 prongs, 10-20 meters)	1.25
No. 61 coil (wound coil, 6 prongs, 17-41 meters)	1.25
No. 62 coil (wound coil, 6 prongs, 33-75 meters)	1.25
No. 63 coil (wound coil, 6 prongs, 66-150 meter)	1.00
No. 64 coil (wound coil, 6 prongs, 135-270 meters)	1.00
BCC-6 (wound coil, 6 prongs, 250-560 meters)	1.50
SWK-4 (kit—4, four-prong coils, 17-270 meters)	3.00
SWK-6 (kit—4, six-prong coils, 17-270 meters)	3.75

"TCF" COIL FORM

A transmitting coil form of XP-53 dielectric is also available. This may be permanently mounted on special brackets supplied, or in plug-in coil fashion. 2¼" diameter. 3⅞" long exclusive of prongs.

CODE	LIST
TCF-4 (4 prongs)	$.70
TCF-5 (5 prongs)	.70

"CF-M" ULTRA S. W. FORMS

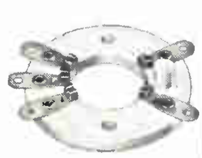
Unusual coil form for maximum efficiency at ultra-high frequencies or within the 28-56 megacycle band. Isolantite with correct form factor and resultant minimum high frequency resistance guaranteeing absolute stability. Plenty of holes to facilitate any inductance desired and any type of wiring. Form is 1⅛" in diameter and 2" long exclusive of prongs.

CODE	LIST
CF-5-M	$1.00

"S" ISOLANTITE SOCKETS

Standard socket at left. Lowest losses. Constant resistivity. Gripped prongs—cannot shift. Guide groove. Rust-proof side gripping contacts. Glazed top and sides. Sub-panel or base mounting. 2¼" x 1⅝".

CODE	LIST
S-4 (4 prongs)	$.60
S-5 (5 prongs)	.60
S-6 (6 prongs)	.60
S-7 (large base, 7 prongs)	.60
S-7-B (small base, 7 prongs)	.60
S-8 (8 prongs)	.75



Acorn socket at right. Isolantite. For new high frequency acorn tubes—954 or 955. 1⅞" diameter. Five double grip silver plated phosphor bronze prongs. Top, sides, and plug glazed.

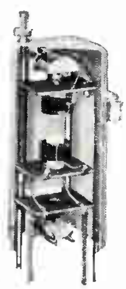
CODE	LIST
S-900	$1.50

"ATT" AIR TUNED I. F. T.

Air tuned primary and secondary units with plate and grid coils of Litz wire. Exceptional "Q" of 115. Coupling co-efficient 0.77%. Gain in excess of 200 per stage together with unequalled selectivity. For 57's, 58's, 24's, 35's, etc. Center tapped units also for split input tubes. Shield 2 3/32" x 5" high.

CODE	FREQUENCY	LIST
ATT-175	175 kc.	$4.50
ATT-465	465 kc.	4.50
ATT-175-CT	175 kc. (center tapped)	4.50
ATT-465-CT	465 kc. (center tapped)	4.50
ATO	465 kc. (beat oscillator)	4.50

"VT" VARIABLE COUPLING I. F. T.



Outstanding transformers with new variable coupling feature. Approximate range of variation from ⅓ critical coupling to over 3 times critical coupling with circuit constants unaffected. Continuous variation between these limits controllable from panel. Thumb screw lock for any desired setting. Impregnated 3-pie Litz windings on Isolantite core. Exceptionally high "Q" of 130. 2" x 2" x 5". Transformer without variable coupling feature (minimum coupling) also available. Same size as model just described known as VTF. A beat oscillator type to match this fixed type also available, known as VTO. CT types—center tapped.

CODE	FREQUENCY	LIST
VT-465	465 kc.	$5.50
VT-175	175 kc.	5.50
VTC (variable coupling mechanism for panel control of up to 4 transformers)		2.50
VTF-465	465 kc.	4.50
VTF-175	175 kc.	4.50
VTO-465	465 kc.	4.50
VTF-465-CT	465 kc.	4.50
VTF-175-CT	175 kc.	4.50

"T" AND "ST" I. F. T.

For experimental and replacement in superheterodyne midgets, automobile sets, etc. "T" and "ST" type with tuned grid, tuned plate, lattice wound impregnated coils. "ST" type—2¾" high x 1 7/16" square. Type "T" model—2⅛" diam. x 3⅛" high. Type "ST" illustrated at left. Litz wire in 465 kc. type.

CODE	FREQUENCY	LIST
ST or T-465	465 kc.	$1.65
ST or T-175	175 kc.	1.65
ST or T-465-CT	465 kc. (center tapped)	1.65
ST or T-175-CT	175 kc. (center tapped)	1.65
ST-262	262 kc.	1.65
TBO-465	465 kc. (beat oscillator)	1.65

ALUMINUM TUBE AND COIL SHIELDS

Complete isolation afforded by this tube shield shown at left, for full use of enormous amplification available from new high gain 2.5 and 6.3 volt R.F. pentodes. Special drawn-in neck completes shielding between control grid and plate. Removable top entirely shields control grid cap. Body, cap, and base all of heavy aluminum and designed for maximum cooling. Measures 4⅝" high x 1⅝" diameter. Mounting center 1 27/32".

CODE	LIST
TS-50	$.40

The Hammarlund coil shield shown at right is a very effective housing for coils. It is constructed of heavy aluminum and is a 2-piece affair. It is 3" in diameter. Base has mounting holes.

CODE	LIST
CS-3	$.50

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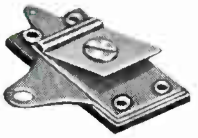
World Radio History

HAMMARLUND

"EC" AND "MEX" EQUALIZERS



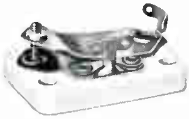
Standard type illustrated at left, popular model for neutralizing, balancing and trimming. Mica dielectric—phosphor bronze flexible plates, bakelite base 1¼" x 11/16.

CODE	CAPACITY	LIST
EC-35	3-35 mmf.	$.30
EC-80	25-80 mmf.	.40

The midget equalizer shown at right is an extremely small condenser designed expressly for trimming R.F. coils, but useful, of course, for many other purposes. Self-supporting in wiring. Isolantite base—⅝" x ¾". Mica dielectric, phosphor bronze spring plates.

CODE	CAPACITY	LIST
MEX	3-30	$.30

"MICS" PADDING CONDENSERS



New improved type—with Isolantite base. Most expensive imported mica used. Tested for capacity, power factor and breakdown at 500 V. D.C. 1" x 1⅝". Base mounting centers 1¼".

CODE	CAPACITY	LIST
MICS-70	10- 70 mmf.	$ .50
MICS-140	70- 140 mmf.	.60
MICS-220	140- 220 mmf.	.70
MICS-1000	600-1000 mmf.	1.00

"CTS" PADDING CONDENSERS

Compact Isolantite base padder or trimmer for use in all R.F. and oscillator circuits. Metal parts plated to eliminate corrosion. Base is treated against moisture absorption. Heavy India ruby mica insulation for 500 volts. Dimensions 1 3/16" x 1 1/16". Mounting centers 15/16.

CODE	CAPACITY	LIST
CTS-85	25-135 mmf.	$.50
CTS-160	45-260 mmf.	.60
CTS-230	65-350 mmf.	.60
CTS-380	175-550 mmf.	.75
CTS-525	230-800 mmf.	.80

"QTD" DUAL R.F. TRIMMERS

Same precision construction as CTS. Designed especially for tuning I.F. transformers but sections can be connected in series or parallel for a wide range of capacities and voltages. Mounted on moisture-proof Isolantite. Size is 1 11/32" x 1 11/32"; mounting centers ⅞". Also single hole mounting.

CODE	CAPACITY	LIST
QTD-100	20-100 mmf.	$ .70
QTD-250	55-250 mmf.	.80
QTD-450	100-450 mmf.	.90
QTD-600	170-600 mmf.	1.00

"FC" FLEXIBLE COUPLINGS

This coupling permits tandem operation of any number of independent units without requiring exact shaft alignment. A great convenience and time saver. The sides of the coupling are insulated from each other, allowing instruments in gang to be operated as independent electrical units. Bakelized canvas with brass bushings for ¼" shaft. Four rust proofed and hardened steel set screws provide against shaft slipping. Overall diameter 1½".

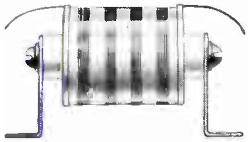
CODE	LIST
FC	$0.60

"CH-500" TRANSMITTING CHOKES

Designed for use in high powered transmitters—10- 20- 40- 80- and 160-meter amateur bands. High equivalent impedance more than 500,000 ohms. Effective from 1,500 to 30,000 kc. with exception of frequencies between 5,300 and 6,400 and between 8,000 and 9,000. Six thin universal pies. Isolantite core. Insulated mounting brackets secured to Isolantite core with short machine screws. Brackets removable and choke mounted with a single machine screw. Ind.—2.5 mh. Dist. cap. less than 1.5 mmf. D.C. res.—8 ohms. Max. recommended D.C. (continuous) 500 ma. Overall size, less brackets—1 3/16" x 2½".

CODE	LIST
CH-500	$1.75

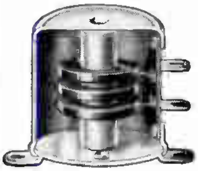
"CH-8" ISOLANTITE R.F. CHOKES



For S.W. and ultra-S.W. receivers and transmitters. Effective over broadcast band too. Recommended as grid choke for multistage transmitters. Isolantite spool. Four sectionalized windings, moisture proofed, protected by radio frequency lacquer and cellophane covering. Choke 1⅜" x ⅞". Flexible leads. Removable brackets. Ind.—8 mh. D.C. res.—70 ohms. Dist. cap.—3 mmf. Current carrying cap.—125 ma.

CODE	LIST
CH-8	$1.10

"CH-10-S" R.F. SHIELDED CHOKES



For use in high gain circuits. Universal impregnated wound pies enclosed in an aluminum shield 1½" high x 1⅜" in diameter. Mounting legs on 1 11/16" center. Connections to terminal are on one side of the can properly indicated. Inductance—10 mh. D.C. resistance—65 ohms. Current carrying cap.—100 ma.

CODE	LIST
CH-10-S	$1.00

"RFC" HIGH IMPEDANCE CHOKES

Popular R.F. choke with special impregnated helical winding enclosed in bakelite case, 1 13/16" high and 1 5/16" in diameter. Ideal for detector plate circuit and R.F. filtering systems in general. Two types—85 mh. with dist. cap. of 3 mmf. and D.C. res. of 215 ohms, and 250 mh. with dist. cap. of 2 mmf. and D.C. res. of 420 ohms. Current carrying cap. of both types 60 ma.

CODE	LIST
RFC-85	$2.00
RFC-250	2.25

"CH-X" R.F. MIDGET CHOKES

Invaluable item where space is at a premium. It is so small in size and light in weight that it can be supported by own leads. Five impregnated universal wound pies ¼". Impregnated Isolantite core insuring ruggedness and stability. Ind.—2.1 mh. D.C. res.—35 ohms. Dist. cap.—1 mmf. Current carrying cap. 125 ma. Length across caps 1½". Dia. ½".

CODE	LIST
CH-X	$.60

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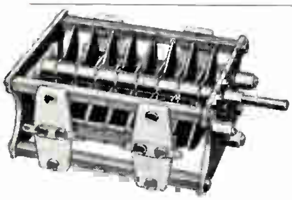
World Radio History

HAMMARLUND

"TC" TRANSMITTING CONDENSER

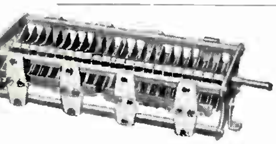


An entirely new moderately priced, heavy duty transmitting condenser, featuring heavy aluminum end plates, Isolantite insulation, non-inductive, self-cleaning silver plated beryllium contacts, full floating rotor bearing, non-magnetic rotor assembly, polished heavy aluminum plates accurately spaced. All, except type "L," have round edge plates of .040" thickness. Type "L" has .025" plates with plain edges. Type "F" has .230", 7500 V. air gap. Type "G," .200", 6750 V. Type "H," .171", 6000 V. Type "J," .100" 4250 V. Type "K," .084", 3750 V. Type "L," .070", 2000 V. air gap.

Available in a wide variety of capacities and peak voltages, these condensers are ideal for modern up-to-date transmitters with power outputs ranging from 200 watts to 1 kw.

TYPE	CAPACITY	OVERALL LENGTH	LIST
TC-220-L	220 mmf.	4 1/16	$ 4.50
TC-440-L	465 mmf.	5⅞	7.70
TC-90-K	95 mmf.	2 15/16	4.50
TC-165-K	170 mmf.	4 1/16	6.50
TC-220-K	225 mmf.	4⅝	8.00
TC-290-K	300 mmf.	5⅞	9.50
TC-330-K	340 mmf.	6½	10.00
TC-240-J	250 mmf.	6½	10.20
TC-25-H	25 mmf.	2 15/16	3.50
TC-50-H	53 mmf.	4 1/16	6.00
TC-110-H	115 mmf.	6½	9.00
TC-18-G	20 mmf.	2 15/16	5.20
TC-40-G	45 mmf.	4 1/16	7.00
TC-65-G	72 mmf.	5⅞	8.80
TC-100-G	110 mmf.	7½	11.20
TC-150-G	165 mmf.	10⅝	14.80
TC-55-F	60 mmf.	5⅞	8.00

"TCD" SPLIT-STATOR TYPES



These split-stator transmitting condensers are identical to the singles shown above, except that the stator sections are individual. Ideal for push-pull power amplifiers ranging in power up to 1 kw. They are of convenient size and lend themselves to construction of compact apparatus. Overall dimensions in back of panel are given in the accompanying table. The capacity values listed are for each section. The last letter in the code represents plate spacing and peak voltage. These are identical to those given above. Type "M" — plain plates, .030" air gap.

TYPE	CAPACITY	OVERALL LENGTH	LIST
TCD-500-M	505 mmf.	4 1/16	$ 6.50
TCD-80-L	88 mmf.	4 1/16	5.50
TCD-210-L	215 mmf.	5⅞	8.25
TCD-90-K	95 mmf.	4⅝	7.50
TCD-165-K	170 mmf.	6½	11.00
TCD-325-K	335 mmf.	11 1/16	20.50
TCD-240-J	250 mmf.	11 1/16	19.00
TCD-50-H	53 mmf.	6½	9.80
TCD-110-H	115 mmf.	11 1/16	16.00
TCD-40-G	48 mmf.	7½	10.50
TCD-75-G	82 mmf.	11 1/16	14.50
TCD-55-F	60 mmf.	11 1/16	13.50

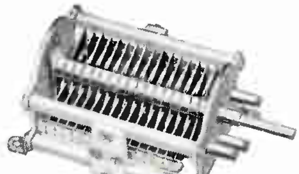
"HF" MICRO CONDENSERS

For tuning or trimming on high frequencies. Cadmium plated soldered brass plates. Isolantite. Base mounting, single hole panel mount, or panel mounting with bushings. 140 mmf. size 1 9/32" high x 17/32" behind panel.

CODE	CAPACITY	LIST
HF-15	17.5 mmf.	$1.25
HF-35	35 mmf.	1.50
HF-50	50 mmf.	1.60
HF-100	100 mmf.	1.90
HF-140	140 mmf.	2.25
*HF-15-X	15 mmf.	1.60
*HF-30-X	30 mmf.	1.85

* Double spaced

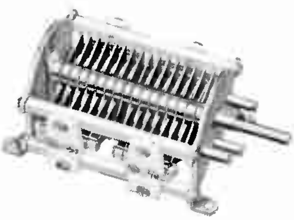
"MTC" TRANSMITTING CONDENSERS



Compact types, Isolantite insulation. Base or panel mounting. Polished aluminum plates. Stainless steel shafts. Size of 150 mmf. with .070" plate spacing only 4⅝" behind panel. "A" model has .040" plate thickness, all others .025". "A" and "B" models—rounded plates. "C" types—plain plate edges. Self-cleaning wiping contact.

CODE	CAPACITY	LIST
MTC-35-A	35 mmf.	$6.00
MTC-20-B	20 mmf.	3.25
MTC-35-B	35 mmf.	3.50
MTC-50-B	50 mmf.	3.90
MTC-100-B	100 mmf.	5.00
MTC-150-B	150 mmf.	6.10
MTC-50-C	50 mmf.	2.80
MTC-100-C	100 mmf.	3.05
MTC-150-C	150 mmf.	3.20
MTC-250-C	260 mmf.	3.60
MTC-350-C	365 mmf.	4.00

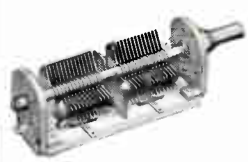
"MTCD" SPLIT-STATOR TYPES



Same outstanding features as MTC singles except that stator sections are separate. Model 110-B with .070" plate spacing, only 5¾" behind panel. "B" models—rounded plates "C" models—plain plate edges.

CODE	CAPACITY	LIST
MTCD-20-B	20 mmf. per sect.	$5.25
MTCD-35-B	35 mmf. per sect.	5.75
MTCD-50-B	50 mmf. per sect.	6.50
MTCD-100-B	100 mmf. per sect.	8.75
MTCD-50-C	50 mmf. per sect.	4.50
MTCD-100-C	100 mmf. per sect.	5.00
MTCD-150-C	150 mmf. per sect.	5.25
MTCD-250-C	265 mmf. per sect.	6.00

"HFD" MICRO DUAL CONDENSERS



A compact dual—ideal as a high frequency tuning condenser, for tuning and neutralizing low-powered short wave and ultra-short wave transmitters, etc. Heavy Isolantite base. Equipped with new outstanding Hammarlund split rear bearing and individual noiseless wiping contact for each section. Rotor contacts variable to several positions for shortest leads. Shield between sections for grounding. The 140 mmf. size is only 1½" high x 3¾" long behind panel. ¼" shaft. Cadmium plated soldered brass plates.

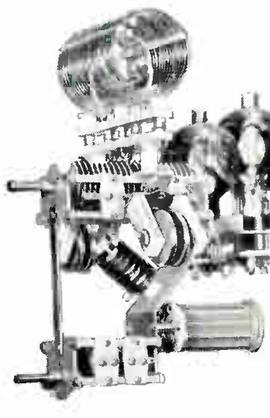
CODE	CAPACITY	LIST
HFD-50	50 mmf. per sect.	$2.75
HFD-100	100 mmf. per sect.	3.25
HFD-140	140 mmf. per sect.	3.75
*HFD-15-X	15 mmf. per sect.	3.00
*HFD-30-X	28.5 mmf. per sect.	3.25

*Double-Spaced

HAMMARLUND MANUFACTURING CO., INC., 424-438 West 33rd Street, New York City

World Radio History

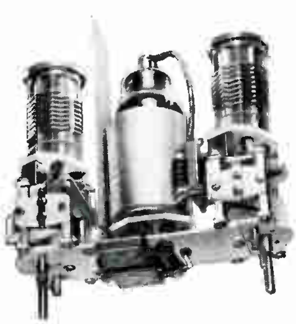
PA-300 FOUNDATION UNIT



This foundation kit is designed to make it easier for the amateur to build his own transmitter. The entire unit is self-supporting and can be bolted to the front panel of the transmitter. No chassis is required; thus the difficult task of drilling and machining is eliminated. The only tools necessary to put the PA-300 together are a screw-driver and soldering iron. The parts are placed so that connecting leads are short and direct, making the amplifier extremely efficient. It can be used with any of the popular triodes, such as 808's, RK-37's, 35-T's, T-55's, HK-54's, and many others. The output varies between 100 and 300 watts depending upon the type of tubes employed. The PA-300 consists of all brackets, screws, nuts, lockwashers, etc., and is packed complete with instructions and drilling template. Other Hammarlund parts needed: 1—MTCD-100-B; 1—MTCD-100-C; 2—N-10; 1—CH-500; 2—S-4; 1—S-5; 4—SWF-5. Overall dimensions 13" x 8½" x 8".

CODE	LIST
PA-300—Foundation Unit	$3.25

BD-40 BUFFER-DRIVER



The BD-40 is a driver unit intended for use with the PA-300 but can also be used as a low power output stage in a beginner's transmitter. Employs either an 807 or RK-39 beam tube. The output in either case is approximately 40 watts. A multistage transmitter can be constructed around these units providing an economical compact all-band transmitter. All brackets are drilled for standard Hammarlund parts. Holes for mounting the by-pass condensers and other parts such as R.F. choke and plate blocking condenser are provided. The BD-40 includes all hardware such as brackets, shield plate and tube shield, screws, nuts, lockwashers, instructions and drilling template. Other Hammarlund parts needed: 2—MTC-100-C; 2—S-4, 1—S-5, 1—CH-X; 8—SWF-4. Overall dimensions 8¼" x 7½" x 3½".

CODE	LIST
BD-40—Foundation Unit	$3.60

PTS POWER TUBE SHIELD

This tube shield is used in the BD-40. It is designed for transmitting pentodes and tetrodes such as the 807, RK-39, 804, RK-20, and many other similar tubes which require an external shield for best results. Constructed of heavy aluminum, this shield is drilled for standard Hammarlund sockets and has silver-like satin finish. Size 2¼" diameter x 3" high.

CODE	LIST
PTS	$0.40

XS-2 CRYSTAL SOCKET

A very compact crystal socket designed to mount inside SWF coil form for changing coil and crystal in one operation. This is suitable for all tri-tet circuits and is used in our "OD-10" oscillator doubler unit. Two special re-inforced socket clips insure perfect electrical connection. Isolantite base. Can be used with SWF coil forms or separately in apparatus where space is at a premium. Ideal for portable equipment. Measures only 1⅜" in diameter. Two hole mounting centers 15/16".

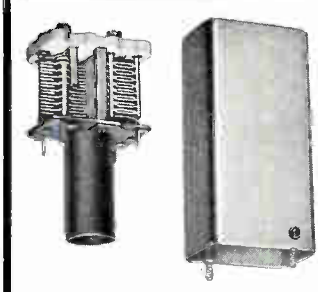
CODE	LIST
XS-2	$0.50

"N" NEUTRALIZING CONDENSERS

Improved neutralizing condensers with heavy polished aluminum plates. Rounded edges. Isolantite. Fine adjusting screw. Positive lock. Horizontal adjustment. Type "N-10", 2⅝" high x 1 3/16" deep. "N-15" 4 15/16" high x 3½" deep. "N-20", 5 11/16" high x 4" deep.

CODE	LIST
N-10—(2.1—10 mmf.)	$3.00
N-15—(3.2—14 mmf.)	6.00
N-20—(3.8—14 mmf.)	6.50

ETU EXCITER TUNING UNIT



These handy exciter tuning units are ideal for constructing high frequency I.F. transformers for U.H.F. superhets and for use in transmitter exciter units. Has two 25 mmf. HF type condensers mounted on an Isolantite block. These are double spaced and have a heavy shield plate between them. The blank coil form is of low loss material ⅞" in diameter and 2" long. Supplied complete with heavy shield can. Measures 2" x 1 7/16" x 4".

CODE	LIST
ETU	$4.00

OD-10 OSCILLATOR-DOUBLER

This unit is essentially the same as the BD-40 except that it uses a 6L6-G tube, has no tube shield, and no vertical coil shield. Has the same overall dimensions and the same panel mounting specifications. This is a "tri-tet" crystal oscillator and doubler. This unit also employs a special crystal holder socket which fits into the top of the cathode coil form. Both coil and crystal are changed in one operation. OD-10 consists of all brackets, screws, nuts, lockwashers, instructions and drilling template. Other Hammarlund parts needed: 2—MTC-100-C; 2—S-4; 1—S-8; 1—CH-X; 2—SWF-4; 1—XS-2. Size 8¼" x 7½" x 3¼".

CODE	LIST
OD-10—Foundation Unit	$2.80

HAMMARLUND MANUFACTURING CO., INC., 424-438 West 33rd Street, New York City

World Radio History

NO "GETTER" NO GAS NO FAILURES

Eimac TUBES

5 ESTABLISHED FACTS . . . (1) Most tube failures are caused by gas released internally. (2) Excessive heat releases gas from certain types of tube elements . . . especially internal insulators. (3) High anode temperatures alone do not destroy emission. (4) The use of a chemical agent or "getter" is not necessary to obtain good vacuum. (5) "Getter" may release gas that *will* destroy emission.

EIMAC DEVELOPMENTS . . . (1) Plates and grids made of tantalum because it has the smallest original gas content of any known metal. (2) Eimac developed a new process which removes this small gas content from tantalum . . . renders it completely degassed. (3) Eimac tubes undergo a long, severe exhaust . . . NO "GETTER" is employed. (4) New, radical design greatly reduces inter-electrode capacities and entirely eliminates the use of internal insulators. (5) A new type thoriated tungsten filament possessing the highest possible thermionic efficiencies, longer life and uniformity. (6) *Eimac tubes are conservatively rated as to plate dissipation and are unconditionally guaranteed against tube failure caused by gas released internally.* Momentary overloads of from 400% to 600%, which are sufficient to cause the anode to become incandescent, will positively not release gas.

For purposes of illustration all tubes are shown the same size. Physical dimensions are as follows: 35T overall height 5½ inches; 100T, 7½ inches; 250T, 9¾ inches; 450T, 12½ inches; 750T, 16½ inches. Vacuum Condensers are 6½ inches long. KY21 and RX21 tubes 7½ inches each.

35T
Net Price $6.00

100T
Net Price $13.50

250T
Net Price $24.50

450T
Net Price $75.00

750T
Net Price $175.00

KY21 GRID CONTROL RECTIFIER *Net Price* $10

KY21 is a mercury vapor rectifier to which has been added a control electrode, or grid. Used as a rectifier and as a power control tube. Very small control power is needed and when properly handled KY21 tubes will eliminate "key clicks," permitting high power operation in congested areas. D.C. output 3500 volts at 1.5 amperes.

RX21 RECTIFIER . . . . . . *Net Price* **$7.50**
A mercury vapor rectifier possessing unusually high inverse voltage capabilities. D.C. output 3500 volts at 1.5 amperes.

VC6
VC12
VC25
VC50

The new VACUUM TANK CONDENSER

This new condenser eliminates the use of the old fashioned open plate type, provides a positive, accurate means to determine the optimum "Q" of your tank circuit, assures proper load balance on each of the tubes and minimizes "splatter" on phone signals. No loss of power on a stray harmonic, no loss of efficiency. The single units are available in 6, 12, 25 and 50 mmfd capacities . . . priced net at $7.50, $8.50, $10.50 and $12.50 respectively.

For information about Ultra High Frequency tubes see your dealer or write EITEL-McCULLOUGH, Inc., SAN BRUNO, CALIF.

World Radio History

HARVEY

HARVEY RADIO

HIGH FREQUENCY

TRANSMITTERS

FOR AMATEUR AND COMMERCIAL SERVICES

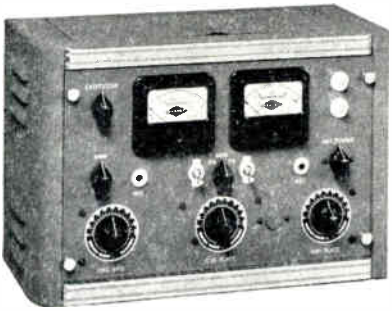
The latest and finest in high frequency radio transmitters — the new Harvey 1939 models — are presented in this catalogue. The cabinets are re-designed for greater beauty, compactness and convenience. Our research laboratories have again led the field in introducing technical improvements and refinements. The most exacting operator, we believe, can find no better equipment for his needs.

CATALOG 53

HARVEY RADIO LABORATORIES, INC.
25 Thorndike St., Cambridge, Mass.

World Radio History

HIGH FREQUENCY TRANSMITTERS



UHX-10 TRANSMITTER

Amateurs, expeditions and airlines in many countries, have all found the UHX-10 to be an ideal unit where a low power, multi-band transmitter is required.

The compact cabinet contains a versatile 6L6 oscillator connected for either pentode, tri-tet or electron coupled control. This tube directly drives a second 6L6 as power amplifier operating at 20 watts input. Two 6N7 tubes as class B modulator and driver respectively complete the tube line-up. Coils for the various bands (5–160 meters) can be quickly and easily changed by lifting the hinged cover of the cabinet which is finished in slate gray with chrome trim. The transmitter can be operated from either an AC pack or 6 volt dynamotor.

Investigate the UHX-10!

700-R TRANSMITTER

Discriminating operators who are satisfied only with the finest in radio equipment will find the 700-R the last word in beauty and performance. Many prominent Amateurs accord this transmitter highest honors when it comes to clear, powerful signals received in all corners of the globe.

All control circuits are so simplified that operation of the 700-R is as easy and straightforward as in any of the lower powered models. Interlock switches protect the operator from injury when making adjustments at the rear of the transmitter and all circuits are under perfect control when the high-low voltage switch is used for tuning up purposes. You will like the appearance of the attractive meters and the convenience of the built-in modulation monitor mounted on the top panel.

Those desiring the peak power possible under present regulations will be pleased to learn that the 700-R can also be furnished for plate modulation permitting a full CW and Phone input of one kilowatt on all bands. For the ultimate in equipment choose the 700-R.

700-R

HARVEY RADIO LABORATORIES, INC.

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HIGH FREQUENCY TRANSMITTERS

75-T TRANSMITTER

The 75-T combines dependability, power and low cost in a table model which meets every requirement for an efficient, attractive installation. This is the transmitter which is so enthusiastically received by amateurs and other services everywhere because it gives you a powerful CW signal on five bands yet has sufficient Phone output to work great distances.

All circuits have been simplified so that there are but three circuits to tune exclusive of the antenna matching network. Changing coils is easily accomplished through the hinged cabinet cover, and, as you might expect, there are no neutralizing adjustments. A 6V6 comprises the crystal oscillator section followed by a 6L6 frequency multiplier driving an RCA 804 tube to 125 watts input. An economical suppressor grid modulator provides an 18 watt phone carrier which will surprise the most skeptical operator as to its power and punch on all bands.

The main power supply is external to the transmitter itself and may be installed in any convenient position where space is available. The power chassis is housed under a grille cover for safety as well as ventilation.

Customers interested in a self-contained transmitter of this type should specify our 80-T model which is identical to the 75-T in every respect except cabinet size.

100-T TRANSMITTER

An aristocrat in every sense of the word, the 100-T will open your eyes to a new high in transmitter performance. Imagine an 85 watt Phone and 125 watt CW transmitter completely self-contained in a cabinet measuring only 19 inches high and 14 inches deep — compact enough to rest on your table, yet capable of the best there is in the way of DX.

The transmitter is comprised of two panel decks, the top portion housing the RF section and its power supply and the lower section containing the complete modulation and audio equipment. The modern cabinet has a hinged cover for easy coil changing. A 6V6 crystal oscillator is followed by a 6L6 frequency multiplier driving a single RCA 814 beam power tube as modulated amplifier on 5 bands. Two 807 tubes are used as class B modulators preceded by a speech amplifier consisting of a 6F6, 6C5 and 6J7.

The excellent design of the 100-T has reduced the number of controls to a minimum yet when you see and operate it you will agree that nothing has been omitted which makes for easier and better performance.

100-T

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HIGH FREQUENCY TRANSMITTERS

UHX-25 TRANSMITTER

The new UHX-25 has everything you could ask for in performance, price and appearance. Nothing has been omitted to detract from your operating enjoyment. From the chrome trimmed cabinet to the rugged chassis, it looks and is an outstanding value in the transmitting field.

For efficiency and high output, the popular 6L6 is used as crystal oscillator followed by a second 6L6 as frequency multiplier which in turn drives an 807 final amplifier to 50 watts input on all bands (5–160 meters). The final amplifier is plate modulated by a pair of 6L6G tubes preceded by a 6C8G and 6J7 as speech amplifiers. This modern combination of tubes permits the use of a high gain crystal microphone which is so important for clear, crisp speech.

You will be pleasantly surprised at the convenient location of all panel controls. Meters, excitation control, Phone-CW positions, and all switches are right before you at your fingertips. Key and microphone jacks as well as antenna posts are at the rear out of sight as they should be. Band changing is but a matter of seconds. No cabinet to pull out from the wall — no rear adjustments to make. Just lift the cabinet cover and choose your band.

Because both RF and audio sections are on one chassis, the UHX-25 has unlimited possibilities as an exciter for higher power whenever desired. You will find the UHX-25 in many prominent stations this year, some as transmitters, some as exciters, but in both cases delivering dependable operation day in and day out.

POLICE EQUIPMENT

We specialize in Two-way Police Radio Equipment properly designed and resonably priced for both large and small Departments. The number of Harvey installations now in operation is positive proof of the satisfactory results obtained under the exacting requirements of Police Service. Quotations gladly furnished upon request.

MARINE RADIO-TELEPHONE

The convenience and safety afforded boat owners using Harvey marine telephone equipment can only be equalled by the utility of the land telephone itself. Call your friends, office and home ashore, or other boats similarly equipped direct from your own cabin — indispensable in times of emergency. Several models are available for boats of all sizes.

NOTE — All Harvey Police and Marine equipment is properly licensed!

Export: 25 Warren Street
New York City
***Cable:* "Simontrice'**

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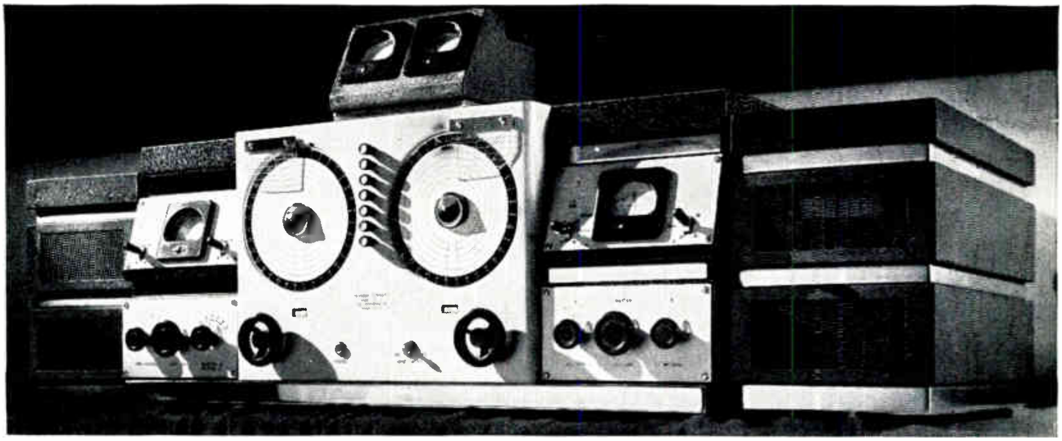
The SKYRIDER DIVERSITY MODEL DD-1



A Dual Diversity Receiving System

Diversity reception is not entirely new to radio engineers. Commercial radio stations have built Diversity Receiving Systems at great expense, with striking improvements in the quality of short wave reception.

Briefly, the advantages of diversity reception are in the practical elimination of fading effects, and a considerably higher average signal-to-noise ratio than can be obtained from any single receiver.

Diversity systems consist usually of individually tuned receivers, each connected to a separate antenna, the second detector outputs of which are tied together across a common load, and the signals combined after rectification with the resulting audio output equalling the average of all receivers. This type of Diversity receiving system is satisfactory for commercial use where reception is mostly on a single frequency for hours at a time — but highly unsatisfactory for amateur communications work, when the individual tuning is entirely too complicated and time consuming to be practical.

In an effort to provide the amateurs with the demonstrated advantages of Diversity reception in practical and easily operable form, Mr. James J. Lamb (Technical Editor *QST*), Mr. J. L. A. McLaughlin and Mr. Karl W. Miles (Hallicrafters) have spent several years in intensive work on this subject.

The SKYRIDER DIVERSITY is the culmination of their efforts, and offers Diversity reception in practical form for amateur operation for the first time. It is a single control Dual Diversity Receiving System consisting of two complete r. f., i. f. and second detector circuits with a common r. f. heterodyne oscillator, common A. V. C. and one audio amplifier. A block diagram showing the tube functions is shown.

The principal advantages of Diversity Reception as demonstrated by the SKYRIDER DIVERSITY can be summed up as follows:

1. The reduction of fading to negligible proportions.
2. An increase of average signal strength over any single receiver.
3. Improvement of Signal to Noise ratio over any single receiver.
4. Reduction of Heterodyne Beat Note Interference.

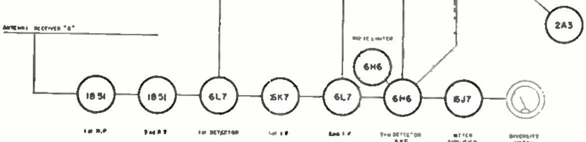
Needless to say, with these advantages, the SKYRIDER DIVERSITY provides a quality of reception that is unequalled in any receiver heretofore available.

Infinite Adjacent Channel Rejection

Another advantage of the SKYRIDER DIVERSITY aside from its Diversity Action, is in the Infinite Rejection Circuit embodied in this system.

It is rather generally understood that selectivity can only be increased to a certain practical degree beyond which phone reception becomes unintelligible. This practical limit of selectivity is not great enough to prevent adjacent channel interference.

However with the Infinite Rejection Circuit, an interfering signal may be completely eliminated. It is so designed that, with a single control, the "rejection slots" may be moved in unison from 20 KC off resonance to within 3 KC of the signal being received, and simply by tuning the rejector to the offending signal, it can be entirely eliminated.



Tube Layout of Skyrider Diversity

In building the SKYRIDER DIVERSITY, the principles of functional design were faithfully adhered to. Every single component received especial attention from the designing engineers, and no expense or effort was spared to bring the SKYRIDER DIVERSITY to a high standard of electrical and mechanical perfection worthy of so advanced a receiving system.

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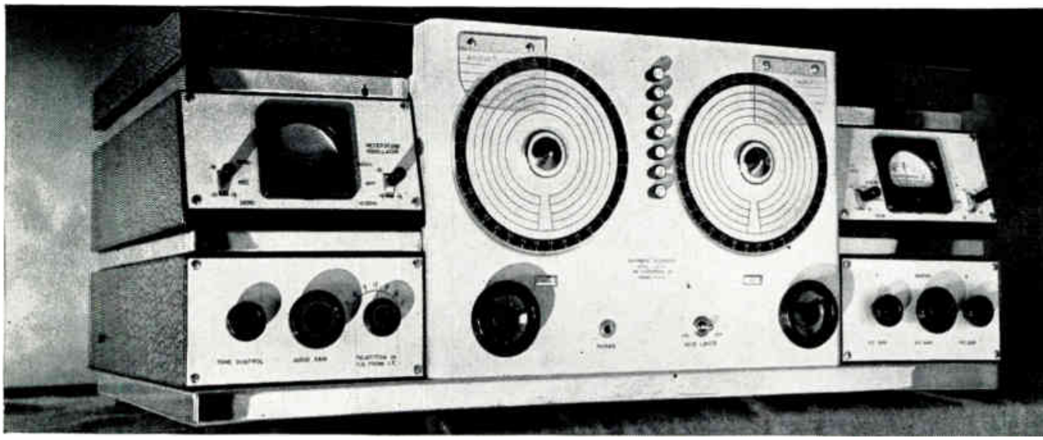
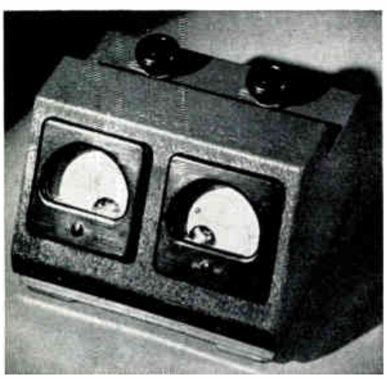
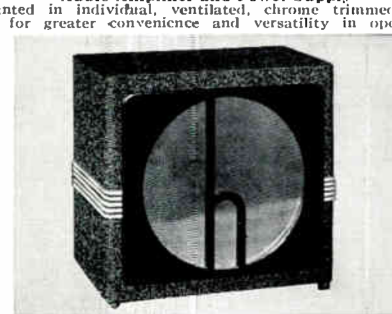




"Diversity Action" Meters
Two Carrier Level Meters mounted in harmonizing black crystal case, indicates strength of signal on the individual receiver circuits.

Audio Amplifier and Power Supply
Mounted in individual, ventilated, chrome trimmed cabinets for greater convenience and versatility in operation.



Dynamic Speaker
12" PM Dynamic Speaker in matching chrome trimmed cabinet. Built to Hallicrafters' specifications by Jensen.

To provide the maximum flexibility and versatility in operation, the Power Supply and Audio Amplifier are supplied as separate units.

The component parts of the system are constructed of heavy gauge, flame-welded metal, sturdy channel construction, finished in black crystal. The channels themselves are finished in chromium, contrasting with the black crystal. The instrument panels are "alumilited," a satin aluminum finish. The entire unit presents a handsome, thoroughly efficient appearance.

FEATURES

- Diversity Reception throughout its tuning range.
- 6 Bands covering from 545 KC to 44 MC and there are 26 tubes in the complete system.
- Separate "Diversity Action" meters.
- Average sensitivity of better than 1 microvolt.
- 2 stages of RF amplification in each receiving section.
- 500 and/or 1,000 cycle Hetrotone oscillator for CW reception.
- Audio amplifier output of 10 watts. (Tuner only 50 milliwatts.)
- Carrier average output meter.
- Current equalizing meter.
- INFINITE ADJACENT CHANNEL REJECTOR.
- Separate electro-mechanical band spread control.

DESCRIPTION

Unit	Dimension Width	Height	Depth	Shipping Weight	Amateurs Net Price
Model DD1 Tuner	29¾"	11¾"	19¼"	125 lbs.	$300.00
Audio Amplifier	7½"	10¾"	16½"	40 lbs.	50.00
Power Supply	7½"	10¾"	16½"	35 lbs.	40.00
"Diversity Action" Meters with Cable	7¼"	4³⁄₁₆"	6"	8 lbs.	20.00
12" Dynamic Speaker in Matching Cabinet	15½"	13"	9¼"	17 lbs.	12.00

Units Above Priced Complete with Raytheon Tubes

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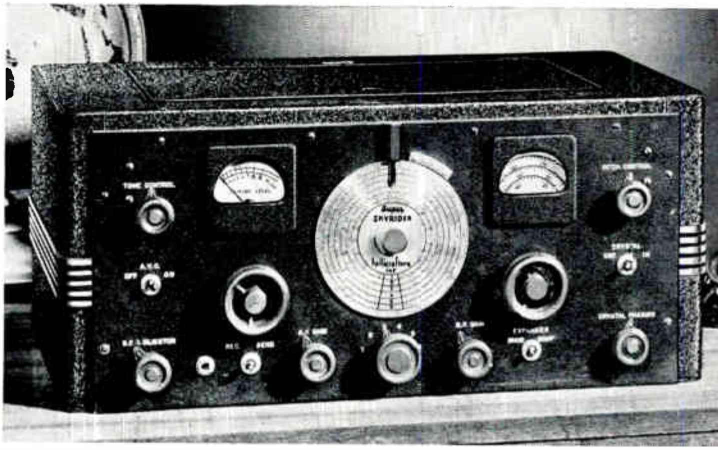
The 1938 SUPER SKYRIDER



America's Leading Communications Receiver

The Super Skyrider has everything any operator could ask for in a single receiver. It tunes from 5 meters to the top of the broadcast band, with an average overall sensitivity of better than 1 microvolt for *all* bands. It has Wide Range, Variable Selectivity with Single Signal razor sharpness to broad high fidelity, a 1000° Band Spread that substantially betters the A.R.R.L. Handbook standards, improved image and signal-to-noise ratio and an "S" meter that works on weak as well as strong signals.

COVERAGE

The Super Skyrider covers a frequency range of 62,000 to 545 KC on 6 bands (all directly calibrated and tuned without charts and tables) as follows: Band 1 — 545 KC to 1550 KC, Band 2 — 1550 KC to 4300 KC, Band 3 — 4.2 MC to 10.2 MC, Band 4 — 9.8 MC to 20.5 MC, Band 5 — 19 MC to 36 MC, Band 6 — 35 MC to 62 MC. All bands are indicated by Band Pointer directly connected to the Band Switch.

SELECTIVITY

New and improved Iron Core I. F. transformer circuits provide Wide Range Variable Selectivity (7.5 KC to 25.5 KC band width at 100 times resonant input). With crystal in the circuits, selectivity is better than 1 KC, offering a total ratio of variable selectivity of 30 to 1.

BANDSPREAD

The Super Skyrider Band Spread is unique in design, highly efficient electrically, smooth in mechanical operation. The Band Spread is an integral part of the specially built High Frequency Variable Condenser, thus eliminating extra wiring and parallel insulation losses in the tuned circuits, and providing a more stable and smoother operating unit both electrically and mechanically. Over 1000° of band spread calibration on a unique spiral dial provides better than 2 KC per division on the 20 meter band and 25 KC for a complete turn of the band spread knob. Large controls and inertia tuning mechanisms make the Super Skyrider one of the smoothest, easiest tuning receivers available.

For 110–120 volts, 50–60 cycle current. Can be operated from 12 volt Battery Current with the addition of Model 501 Electronic Converter. Ask your dealer.

TUBE COMPLEMENT

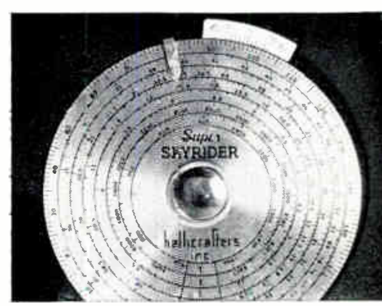
RF — 6K7, 1st Detector — 6L7, 1st IF — 6K7, 2nd IF — 6K7, 2nd Detector, AVC, 1st Audio — 6R7, Power Output — PP 6V6G, H. F. O. — 6J5, Meter Amplifier — 6J7, B. F. O. — 6J7, Rectifier — 5Z3.

Model S-16 SUPER SKYRIDER, including tubes but less crystal....... **$ 99.00**

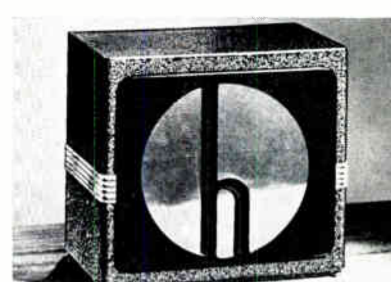
Dimensions — 21⅛" wide, 9¼" high, 11" deep. Shipping weight 60 lbs.

Model SX-16 SUPER SKYRIDER, including tubes and crystal **111.00**

12" PM DYNAMIC SPEAKER in matching cabinet........................$12.00



The Super Skyrider 6 Band Directly Calibrated Dial, characteristic of all Hallicrafters receivers.



12-Inch PM Dynamic Speaker in matching cabinet, built by Jensen to Hallicrafters specifications.

MODEL SX17 A SPECIAL MODEL Super Skyrider

This model was built by special request of many amateurs who wanted two stages of Pre-Selection instead of the single stage in the standard model Super Skyrider. It also incorporates the Dickert Automatic Noise Limiter, for better reception of Ultra High Frequency signals. Built originally upon special order, this model proved so popular that it was incorporated in the Hallicrafters line. For 110–120 Volt, 50–60 cycle current. Can be operated on 12-Volt Battery Current with addition of Model 501 Electronic Converter.

The SX17 Special Model Super Skyrider including crystal and 12" Dynamic Speaker in matching cabinet.................. **$149.50**

Shipping Weight, including speaker, 82 lbs.

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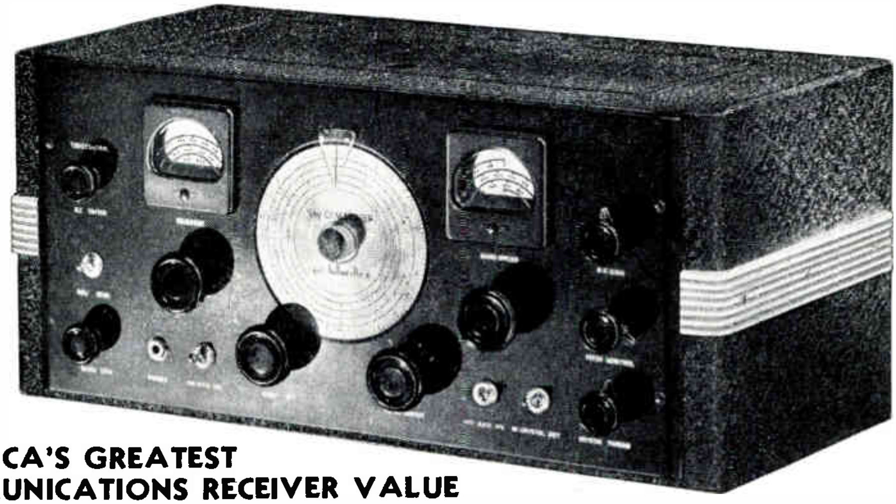
The SKY CHALLENGER II



AMERICA'S GREATEST COMMUNICATIONS RECEIVER VALUE

This receiver offers the amateur and short wave listener a quality of reception that is far beyond its modest price, incorporating as it does many of the exclusive features found on the higher priced Hallicrafters receivers.

The Infinite Image Rejector is an exclusive Hallicrafters development that contributes largely to its superior performance. Annoying image interference is encountered most frequently on the 10 and 20 meter bands. Until the introduction of the Hallicrafters Infinite Image Rejector, several expensive pre-selectors were required to remove this type of interference. An illuminated rejector dial is calibrated for image interference rejection. Months of intensive research by Hallicrafters' engineers showed the way to this revolutionary development, an outstanding and exclusive feature of the SKY CHALLENGER II.

The famous 1000° Spiral Band Spread used on this receiver offers the amateur a Band Spread that equals or exceeds the requirements of the A. R. R. L. Handbook on all bands, mechanically smooth and electrically efficient. An integral part of the main variable condenser, it eliminates extra wiring and parallel insulator losses in the tuned circuits, and provides a more rigid, smoother mechanical construction and more stable electrical operation.

In addition to the new recessed directly calibrated main tuning dial (no charts or tables required) the SKY CHALLENGER II has the following controls:

Tone Control, Send-Receive Switch, A. F. Gain Control, Phone Jack, AVC Switch, Beat Frequency Oscillator, Crystal Filter Circuit, Phasing Control, Pitch Control, R. F. Gain Control.

Facilities are provided for use of either Doublet or Marconi Antenna, and an auxiliary "S" meter.

The SKY CHALLENGER II tunes from 38 MC to 540 KC (7.9 to 557 meters) on five bands, offering complete coverage from the top of the broadcast band through the 10 meter band, with sensitivity and selectivity of a high order.

Tubes used include 6K7 R. F.; 6L7 first detector mixer; 6J5G oscillator; 6K7 first I. F.; 6K7 second I. F.; 6Q7G second detector; 6J7 beat frequency oscillator; 6F6G output tube; 80 rectifier.

Speaker output arranged for both 500 or 5000 ohms. No DC in output terminals.

For operation on 110–120 Volts, 50–60 cycle current. Can be operated with 6 Volt Battery by addition of Model 301 Electronic Convertor.

Cabinet size: 9⅝" high; 21" wide by 11" deep. Shipping weight 40 pounds.

FEATURES

- 9 Tubes.
- Infinite Image Rejector.
- Recessed Main Tuning Dial.
- 1000° Spiral Band Spread.
- 38 MC to 540 KC (7.9 to 557 Meters).
- Iron Core I.F.'s.
- "S" Meter Terminals.
- Doublet or Marconi Antenna.
- Crystal Filter Circuit.

SKY CHALLENGER II —	Model S-18 (with tubes but less crystal)	**$77.00**
	Model SX-18 (with tubes and crystal)	**$89.00**
8-Inch P. M. DYNAMIC SPEAKER in Cabinet		**$10.00**
MODEL SM18 — "S" Meter in matching separate meter housing		**$10.00**

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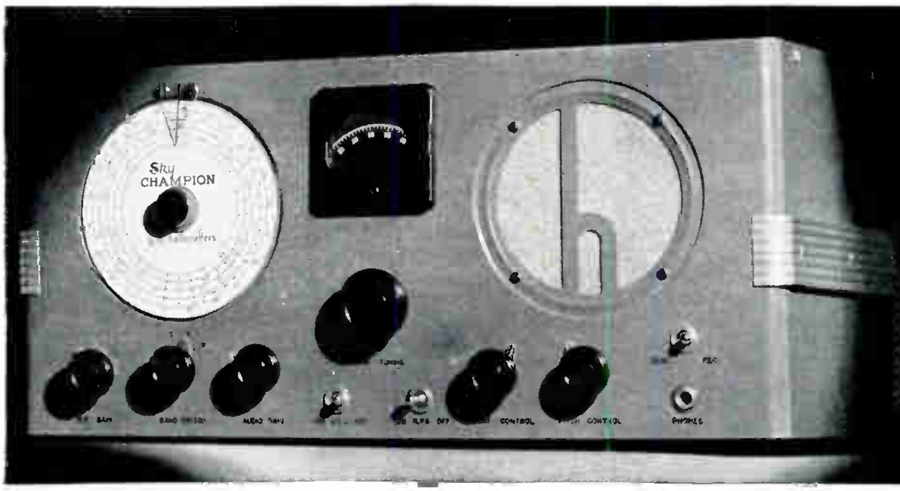
The SKY CHAMPION

FEATURES

- 8 Tubes.
- Complete Coverage (44 MC to 545 KC).
- 4 Bands.
- Separate Band Spread Dial.
- Individual Coils for Each Band.
- Inertia Tuning Mechanism.
- Beat Frequency Oscillator.
- AVC Switch.
- Excellent Sensitivity and Selectivity.
- A. F. Gain Control.
- Band Switch.
- Sensitivity Control.
- "S" Meter Terminals.

Tube Complement

6K7 — r. f. stage. 6L7 — first detector. 6J5 — high frequency oscillator. 6K7 — i. f. amplifier. 6Q7 — second detector, AVC and first audio. 6F6 — power output tube. 80 — rectifier. 6J5 — B. F. O.



THE SKY CHAMPION is an 8-Tube, A.C. Communications Receiver with Pre-Selection and Built-in Speaker, complete in every respect, offering the amateur a quality of performance never before available at this low price. Its sensitivity and selectivity are only to be compared with communications receivers selling at double its price. Provides full coverage from 44 MC to 545 KC, everything from the 10 meter amateur band to the top of the broadcast band. Band No. 1 (545 KC to 1800 KC). Band No. 2 (1.7 MC to 5.8 MC). Band No. 3 (5.8 MC to 18.8 MC). Band No. 4 (17 to 44 MC). The SKY CHAMPION offers all the essential controls for good amateur reception as follows: R.F. Gain Control, Tone Control, Phone Jack, AVC Switch, Beat Oscillator Switch, Send Receive Switch, A.F. Gain Control, Band Switch, BFO Switch and Pitch Control. Sensitivity on all bands is extremely good; which is of especial importance on the popular 10 meter band. The separate Band Spread is better on all amateur bands than A.R.R.L. Handbook recommendations for band spread against calibration. Speaker is an integral part of the receiver — nothing else to buy. For operation on 110–120 Volts, 50–60 cycle, AC current only. Easily adapted for battery operation with the addition of Model 301 Electronic Converter.

Dimensions of Cabinet — 18½" wide, 9⅜" deep, 8½" high. Shipping Weight — 34 pounds.

THE SKY CHAMPION (Model S-20) — Including Speaker and Tubes **$49.50**

MODEL SM20 — "S" Meter in matching separate meter housing $10.00

The SKY BUDDY

FEATURES

- 5 Tubes.
- 3 Bands.
- Complete Coverage 818.4 MC to 545 KC).
- Built-in Speaker.
- Phone Jack.
- Send-Receive Switch.
- AVC Switch.
- Separate Band Spread Dial.
- Beat Frequency Oscillator.
- Pitch Control.

Tube Complement

6K8 — first detector and oscillator.

6P7 — I. F. Amplifier, BFO.

6Q7 — second detector, AVC, first audio.

6K6 — power output tube.

80 — rectifier.

The Sky Buddy is an amateurs' receiver in every respect, covering everything on the air from 18.4 MC to 545 KC including the 20, 40, 80 and 160 meter amateur bands. Band No. 1 (545 KC to 1800 KC). Band No. 2 (1.7 MC to 5.8 MC). Band No. 3 (5.8 MC to 18.40 MC).

The Sky Buddy is an AC set, with conventional Power Transformer Construction. All its components are of the finest quality, and it has sensitivity and selectivity usually found only on communications receivers selling at many times its modest price.

The following controls are incorporated in the SKY BUDDY: AF Gain Control, Band Switch, Combined AVC and Beat Oscillator Switch with AVC on AVC off, and Beat Oscillator on with AVC off positions; Phone Jack, Send-Receive Switch; Pitch Control. The Speaker is an integral part of the receiver, nothing else to buy. Band Spread is better than A.R.R.L. Handbook recommendations for band spread against scale calibration. Equipped for either Doublet or Marconi Antenna. For 110–120 Volt, 50–60 cycle, AC current only. Can be adapted for 6-volt Battery operation with the addition of Model 301 Electronic Converter.

Dimensions of Cabinet: 17½" long, 8½" deep and 8½" high.

THE SKY BUDDY (Model S-19) — Including Speaker and Tubes **$29.50**

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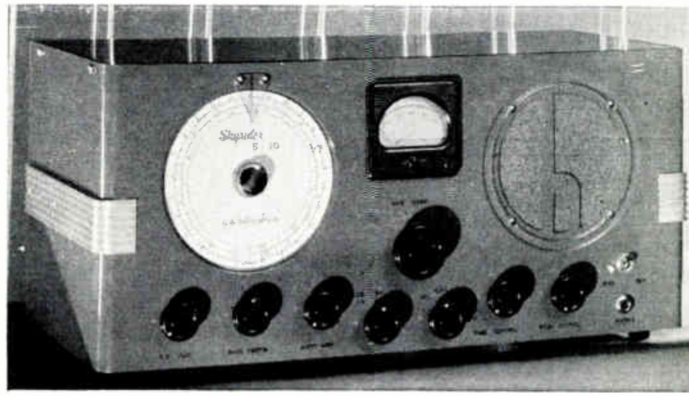
The SKYRIDER 5-10



This receiver is designed for the amateur who needs and wants the exacting performance required for superior ultra high frequency reception. The Skyrider 5–10 covers the radio spectrum from 68 MC to 27 MC (4.4 to 11.1) in two bands with a degree of sensitivity and selectivity that offers unparalleled reception of the ultra high frequencies.
The recently developed RK 1852 tube, with a gain increase of 6 to 1, is used as an R.F. amplifier through which an ultra high frequency sensitivity of better than 1 microvolt is obtained for this receiver.
The coverage by bands is as follows: Band 1 — 27 MC to 42 MC, Band 2 — 40 MC to 68 MC. The separate Band Spread Dial provides easier and more accurate logging, and equipped as it is with an inertia tuning control, makes tuning practically effortless.
1 stage of 1600 KC I. F. amplification is used, providing a band width of 30 KC, at 10 times down. With this selectivity, even frequency modulated 5 meter signals are clearly understandable with the Skyrider 5–10. Mounted in sturdy steel cabinet finished in gray. For the specialist in ultra high frequency reception there is no finer receiver than the Skyrider 5–10.
For operation on 110–120 Volts, 50–60 cycle current. Can be operated on 6-volt Battery current with the addition of Model 301 Electronic Converter. Ask your dealer.

Tube Complement

1852 — r. f. amplifier.
6L7 — first detector.
6J5 — high frequency oscillator.
6P7 — I. F. amplifier B. F. O.
6Q7 — second detector, AVC, first audio.
6H6 — noise limiter.
6F6 — power output tube. 80 — rectifier.

FEATURES

- Noise Limiter.
- Improved Band Spread.
- Built-in Speaker.
- Socket for SM21 Carrier Level Meter.
- Send-Receive Switch.
- 8 Tubes.
- RK 1852 stage of pre-selection.
- Continuous coverage 27 MC to 68 MC on 2 bands.
- 1600 KC I. F. amplification.

SKYRIDER 5–10 (Model S-21), complete with tubes and speaker **$69.50**
SM21 Carrier Level Meter $10.00

Overall Dimensions, 18½" wide, 9⅜" deep, 8½" high. Shpg. Wt. 34 lbs.

The SKYRIDER MARINE

An 8-Tube receiver designed especially for the commercial frequencies that can be readily adapted for marine work. In its design, especial emphasis has been placed on 600 meter and 700 meter operation. Tunes from 16.2 to 2150 meters (18.5 MC to 140 KC) on 4 Bands as follows: Band No. 1 — 2150 to 645 meters (140 KC to 465 KC), Band No. 2 — 645 to 199 meters (465 KC to 1510 KC), Band No. 3 — 177 to 53 meters (1.7 MC to 5.8 MC), Band No. 4 — 54.5 to 16.2 meters (5.8 MC to 18.5 MC). Sensitivity and selectivity are excellent. Improved image rejection at the higher frequencies is achieved through the use of 1600 KC — I. F. transformers. The directly calibrated 338° Main Tuning Dial eliminates the use of complicated charts and tables, and an efficient mechanical band spread with separate dial provides easy and simplified tuning. Mounted in sturdy metal cabinet finished in smooth black. For operation on 110 Volt A.C. or D.C. only.

Tube Complement

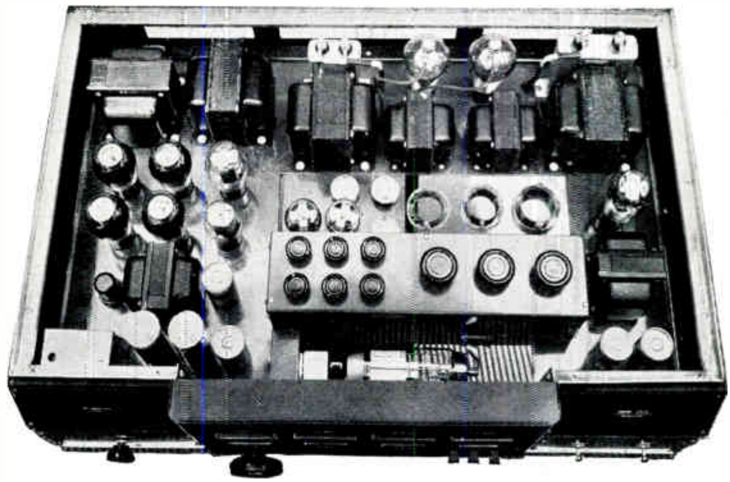
6K7 — r. f. amplifier.
6L7 — first detector.
6J5 — high frequency oscillator.
6K7 — i. f. amplifier.
6Q7 — second detector, AVC and first audio.
25L6 — power output tube.
25Z5 — rectifier.
6J5 — B. F. O.

- Coverage — 16.2 to 2150 meters (140 KC to 18.5 MC).
- 4 Bands.
- 8 Tubes.
- Automatic Volume Control.
- Tone Control.
- Head Phone Jack.
- Beat Frequency Oscillator.
- Built-In Speaker.
- Individual Coils for each Band.
- AF Gain Control.
- Band Switch.
- Sensitivity Control.

THE SKYRIDER MARINE (Model S-22), for operation on 110v. A.C. or D.C. including tubes & speaker **$64.50**

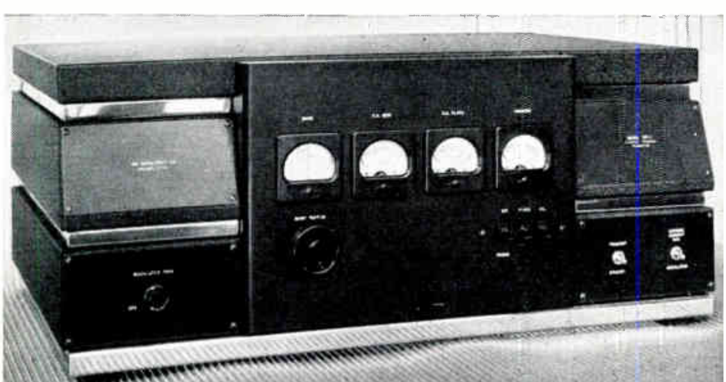
the hallicrafters inc.

MODEL HT HALLICRAFTERS TRANSMITTER



• Amateur transmitters, heretofore, have mostly been built by their owners from their own or suggested designs, or purchased in kit form and assembled. While many of these rigs are models of workmanlike efficiency, the home-built transmitter design must suffer from lack of facilities. In building the first and subsequent transmitters of the Hallicrafters' line, our engineers approached their problem from a fresh viewpoint. They visualized an ideal amateur transmitter, so simple that a novice could operate it — with adequate power at extremely conservative ratings — ruggedly built in the "commercial" style.

• With this goal constantly in mind they attacked their problem, ignoring conventional transmitter construction and adhering strictly to the principles of functional design. The result of their efforts marks a new departure in transmitter design that no more resembles the conventional "kit" transmitter than the modern streamlined plane can be compared to the wartime "crate," in dependability, in performance, or in appearance. However, at no time have the designing engineers, themselves amateurs, lost sight of the amateur's requirements — on the contrary, they have closely approached the ideal amateur transmitter they set out to build.



• The Model HT Transmitter is conservatively rated at 50 Watts Phone Carrier output and 100 Watts CW, but, in operation is equivalent to the performance of the 75 or 100 Watts "input" kit constructed Phone Transmitter. Its operation has been simplified to a degree that makes it understandable even to a beginner. No detail has been neglected to add to its dependability — generously oversized transformers and other components are used — the design was built around the latest, most advanced type Raytheon Tubes; its designers leaned backward in conservatism to give the amateur the very utmost in dependability.

SPECIFICATIONS

• **MODEL RT-1 Phone CW**
50 Watts Phone Carrier (slightly reduced at 30 MC). 100 Watts CW output.
Frequency Range 10–20–40 meters crystal controlled on *one frequency per band.*
Frequency (Band) Switching by single control in front panel, switching all circuits. Individual Tanks are knob controlled inside the cabinet and adjusted for the particular frequency for that band.

• **TUBES**
6A6 — Crystal Oscillator, 1st Doubler. 6A6 — Second Doubler. RK47 — Final Stage Power Amplifier.

• **MODULATOR**
6J7 — 1st Audio. 6J5 — 2nd Audio. 4–6L6 — (Push-Pull Parallel) running Class AB giving 50 Watts of Audio. Modulation capability 100 per cent. Fidelity — plus or minus 2DB 80 to 8000 cycles.

• **RECTIFIERS**
2 — 5Z3 1 — 80 2 — 866

• **METERS**
(1)Cathode Current Exciters (Switched to Modulator Current on Phone). (2) Grid Current, final. (3) Plate Current, final.

• **CONTROLS**
Filament Switch. Plate Switch. Phone — CW Switch. Band Switch (Interstage Tuning Controls Inside Cabinet). Gain Control.

• **CABINET**
Flame-Welded, Painted Steel with provision for ample ventilation.

• **OUTPUT TERMINALS**
From adjustable pick-up coils on separate final plate tank coils. Proper pick-up coil and plate tank automatically selected by Band Switch.

• **EQUIPMENT NEEDED FOR OPERATION**
Microphone (diaphragm type, down not more than 40 DB, Astatic Model D-104 recommended) Key, Bias Battery, and Antenna. (We will gladly furnish suggestions for antenna design and construction.)
Dimensions — 29¾" wide, 11¾" high, 19¼" deep.

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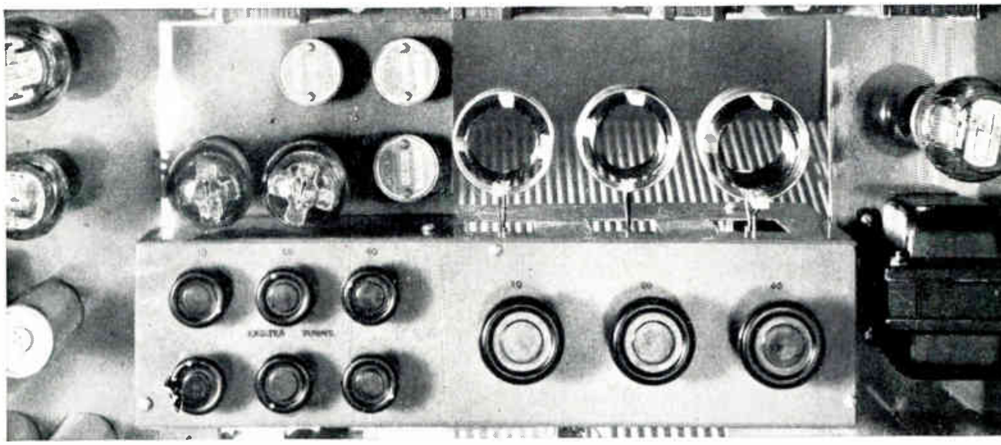

Close-up illustration of R. R. unit of the Model HT transmitter—the "heart" of this efficiently designed transmitter.

A new and efficient method of Band Changing was introduced, offering new simplicity and speed in changing from one band to another with a simple switch.

The Model HT Transmitter is available for CW operation only (100 Watts Output) and for both Phone and CW operation (50 Watts Phone Carrier, 100 Watts CW) on 10, 20 and 40 meter bands. (As a matter of fact, operation for any three bands can be supplied between 10 and 160 meters in any arrangement required; as 80–40–20 meters, or 40–20–10 meters, or 160–80–40 meters with single crystal. Where two crystal operation is required as on 80-20-10, or 160-40-10, or 160-20-10, the price will be slightly higher.)

MODEL HT-1 — Complete with tubes, coils for 3 Bands and one 40 meter crystal................ **$195.00**
Shipping Weight, 145 pounds.

MODEL HT-2 — For CW only, same as above except less Modulator and 1 — 5Z3 rectifier Tube..... **$175.00**
Shipping Weight, 120 pounds.

MODEL HT3 MARINE TRANSMITTER-RECEIVER

The type HT3 consists of a complete 50 watt radiotelephone transmitter, a sensitive receiver, and necessary power units built into a single cabinet and necessitating only a 12 volt storage battery and an antenna for operation.

General Specifications

TRANSMITTER

Carrier output — 50 watts.
Frequency coverage — Any three frequencies in the Marine band 2100–2900 KC.
Frequency control — Low drift crystal controlled oscillator.
Tuning — Tuning adjustments set and locked upon installation. Subsequent choice of frequency by switch on front panel.
Modulation — Substantially complete modulation obtained by high level modulator driven directly from carbon microphone.
Tubes — 1 — 6F6 crystal oscillator. 2 — RK39 Class C amplifiers. 4 — 6L6G Modulators.
Antenna — Provision is made for matching an antenna of reasonable length as encountered in Marine service.
A relay inside the cabinet switches the antenna from receiver to transmitter when operating.

RECEIVER

Tubes used — 1 — 6K7 r. f. stage. 1 — 6L7 1st detector. 1 — 6J5 H. F. oscillator. 1 — 6K7. I. F. stage. 1 — 6Q7 Second Detector, AVC, and 1st audio.
Frequency coverage — Band 1 — Standard Broadcast. Band 2 — 2100–2900 KC.

OUTPUT

3 watts — normally fed to loud speaker on front panel, but switched to telephone receiver during operation.

POWER SUPPLY

Receiver and transmitter filaments supplied directly from 12 volt battery.
Receiver plate supply furnished by vibrapack operating from 12 volt battery.
Transmitter plate power furnished by 450 volt dynamotor of rugged aircraft construction. Provision made for operation from other d.c. voltages to order.

CONTROLS AND OPERATION

On the front panel are mounted a loud speaker, as well as a telephone handset, so arranged that the output of the receiver is normally connected to the speaker. When the handset is lifted from its hook, the receiver output is transferred to the earpiece of the handset. Transmitting is accomplished by pressing a button in the handle of the handset, which starts the transmitter. A single switch on the front panel places the receiver in operation and turns on the transmitter filaments. Subsequent control is as described above. One meter is provided for checking the transmitter operation and for tuning purposes. The meter is arranged to be switched into the various circuits. Other panel controls are the receiver volume control and the frequency switch.
Power drain from 12 volt supply — 9.5 amps for receiver and transmitter filaments during standby. 35 amps while transmitting.
Current drain from other voltage roughly in inverse proportion.
Dimensions — 29¾" wide, 11¾" high, 19¼" deep.
Weight — 155 pounds complete.

PRICE — HT3, Complete................... **$390.00**

(3 crystals for marine channel not included in above price. Frequencies to be determined by service and location of purchaser.)

The Hallicrafters, Inc., are holders of the only license issued by RCA and its associated companies for the construction and sale of amateur radio transmitters, and are independently licensed by A. T. & T. to build transmitters for marine, police, fire department and other municipal and government services. In addition, Hallicrafters, Inc., are holders of RCA and Hazeltine licenses for the manufacture of radio receivers under their patents.

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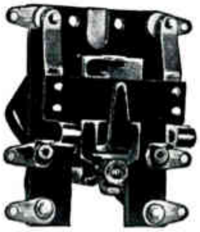
UNCO MEANS DEPENDABILITY

DUNCO RADIO RELAY



These relays have two isolated contacts for operation in low or high voltage circuits at any frequency. For the first time in an inexpensive relay, the two poles are sufficiently spaced and shielded from each other so that the amplifier input may be handled by one pole and the output from the same amplifier may be handled by the other pole without feed back. Similarly 60-cycle power currents may be handled by one pole and voice frequencies by the other without the introduction of hum. Outstanding features include: low contact resistance; single break contacts instead of double break to further reduce resistance; extremely fast operation suitable for bug keying, high voltage and current carrying and breaking capacity, resistance to vibration, making the relay suitable for use on autos, trains, planes, elevators, boats, etc.

Type	Coil Volts	Coil Cycles	Your Cost
RA-1	2.5	60	$2.00
RA-2	2.5	25	2.00
RA-3	6.3	60	2.00
RA-15	110	60	3.50
RD-1	5 to 6.3	DC	2.00
RD-15	10 to 12	DC	3.00

DUNCO RELAYS FOR AMATEUR USE

STRUTHERS DUNN, Inc.
126 N. JUNIPER ST., PHILADELPHIA, PA.

DUNCO MIDGET KEYING RELAY

This midget keying relay is suitable for speeds up to 40 words per minute. Contacts are large fine silver buttons assuring long life and may be easily replaced. Coil consumes only 50 milliamperes at 110 volts 60 cycles, while contacts will interrupt currents of 6 amperes at 110 volts, a.c. The unit is designed for mounting on vertical panel and is recommended for loads up to 660 watts. The contacts are single pole, and close when the coil is energized.

Size: 2¾″ high x 1⅞″ wide x 1¾″ deep

Dunco Relay, Type ASBX1

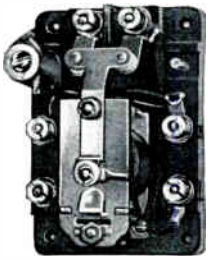
Your Cost, $3.85

Other Dunco Midget Relays (See Note)

Type	Contact Arrangement	Your Cost
ABTX1	S.P.D.B. Front Contact	$3.85
ABTX1P	S.P.D.B. Fr. Cont. with Pigtail	4.40
ADBX1	D.P.S.B. Front Contact	4.95
BSBX1	S.P.S.B. Back Contact	3.85
CSBX1	S.P.S.B. Double Throw	4.68
CDBX1	D.P.S.B. Double Throw	6.60

Note: These relays do not operate as rapidly as Type ASBX1.

DUNCO TEMPERATURE CONTROL RELAY

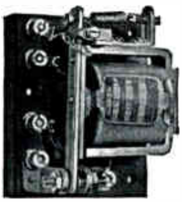


Dunco relay type ABTX10 is for two wire thermostatic control with snap action thermostats. For operation on 110 volts, 60 cycles, it will properly control heater units up to 660 watts. Relay is designed for vertical mounting. Many other types of thermostatic control relays are available, write for information.
Size: 2¾″ high x 1⅞″ wide x 1⅝″ deep

Dunco Relay, Type ABTX10

Your Cost, $4.95

DUNCO VACUUM TUBE RELAY



Relay type CXB51 is an ultra sensitive unit designed for direct current in the coil circuit and either direct or alternating current in the contact circuit. It has single pole, double throw contacts, making one circuit when the coil is energized and another circuit when the coil is de-energized. The coil has a resistance of 10,000 ohms and it will safely carry currents up to 18 milliamperes. Adjustments are provided that will cause the relay to operate on any desired current value down to one milliampere. This unit is particularly adapted to operation in the plate circuit of small vacuum tubes. Contacts are rated 2 amperes at 110 volts, a.c.

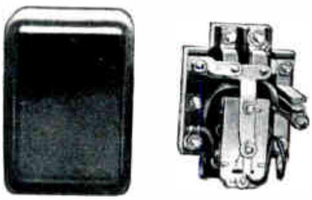
Size: 2⅞″ high x 2¼″ wide x 2″ deep

Dunco Relay, Type CXB51

Your Cost, $5.50

Sequence, ratchet or step by step relays are available for many applications

DUNCO TIME DELAY RELAY



This time delay relay is provided with a snap-on housing and with panel mounting studs for back of panel connections. The input terminals should be connected across the primary of the filament transformer, and the output terminals to the primary of the plate transformer. Power will then be delivered to the plate transformer 30 seconds after the filaments are turned on, greatly increasing the life of tubes, particularly of the hot cathode mercury vapor type. The contacts of this unit are rated 6 amperes at 115 volts A.C.

Size: 3″ high x 2⅛″ wide x 2 5/16″ deep including cover

Other types of Time Delays and Time Controls available. Tell us your requirements

Dunco Relay, Type TD-327

Your Cost, $8.80

DUNCO MECHANICAL LATCH RELAY

This relay is furnished with two coils. Energizing one coil picks up the armature which latches closed. Energizing the other coil picks up the latch and allows the armature to drop out. This relay may be used with normally open push buttons, thermostats, etc. for the remote control of transmitters, receivers, motors or other loads within its rating of 30 amperes at 110 volts, A.C. Standard coils are for operation on 110 volts, 60 cycles but other coils are available. Designed for vertical panel mounting.

Size: 4½″ high x 3¼″ wide x 2¾″ deep

Dunco Relay, Type ABUY5N

Your Cost, $8.80

WE BUILD TO MEET SPECIAL REQUIREMENTS

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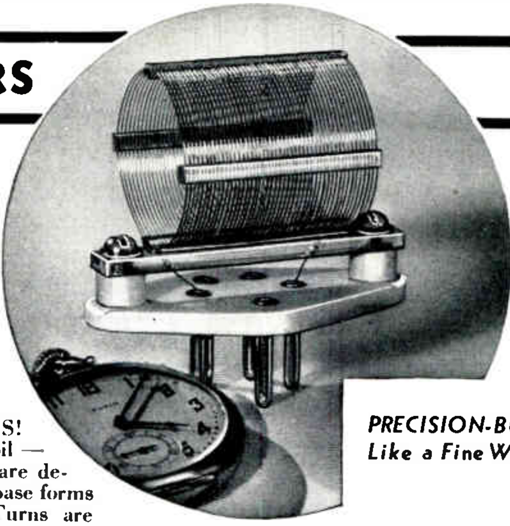
B & W AIR INDUCTORS

NEW!... The B & W "BABY" AIR INDUCTORS

25 WATTS RATING



PRECISION-BUILT
Like a Fine Watch!

HERE'S *more* proof of B & W leadership! . . . the new high-efficiency "BABY" AIR INDUCTORS! They're smaller, more compact than any other coil — 1¼" diameter x 1½" long! B & W "BABIES" are designed and built by *coil specialists* to replace tube base forms having high losses and unsymmetrical leads. Turns are uniformly air-spaced and securely imbedded in tough cellulose acetate strips by a newly developed B & W process. This exclusive B & W winding method provides exceptional mechanical strength, yet requires the use of less insulating material than ever before.

B & W "BABY" Coils are unexcelled for use in all oscillator and buffer stages employing either link or capacity coupling, single-ended or push-pull, pentode or neutralized triode. Available in five types — straight coil (M); center-tapped (MC); end-linked (MEL); center-linked (MCL) and Tri-Tet cathode (MT). Universal 5-prong plug-in bases permit quick, easy band changing.

Compare "BABY" AIR INDUCTORS with ordinary coils — note their smaller size . . . their sturdier construction . . . their neat, business-like *appearance*. For crowded layouts, portables — any application where space is at a premium — any job that calls for fine appearance without sacrificing high efficiency — use B & W "BABIES"!

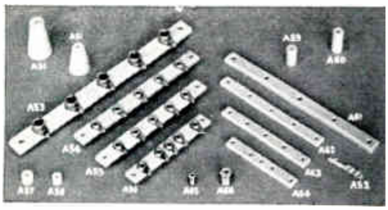
Amateur Net Price of Any B & W "BABY" Coil....$1.00

SPECIFICATIONS

- 5-PRONG MOUNTING
- ALSIMAG 196 BASE
- LENGTH . . . 1½ INCHES
- DIAMETER . . . 1¼ INCHES

Straight Coil / Center Tapped / End Linked / Center Linked / Tri-Tet Cathode	Inductance	* Capacity
160M-MC-MEL-MCL-MT	90	90
80M-MC-MEL-MCL-MT	40	50
40M-MC-MEL-MCL-MT	14	35
20M-MC-MEL-MCL-MT	3.5	35
10M-MC-MEL-MCL-MT	1.1	30

* Total effective capacity required to effect resonance on low frequency end of specified band.



B & W ACCESSORIES

All Ceramic materials shown are ALSIMAG 196

Net Price

A50 — Cone Insulator 2" High, Tapped 10-32 Both Ends.............$ .30
A51 — Cone Insulator 1½" High, Tapped 8-32 Both Ends............ .20
A52 — Inductance Clip for "Air Inductor" — Tinned Phosphor Bronze.. .10
A53 — HD Jack Bar — For All Type HD-HDL-HDVL Coils.............. 1.75
Less Jacks.. 1.25
A54 — T Jack Bar — For All Type T-TL-TVL Coils.................. 1.25
Less Jacks.. 1.00
A55 — BX Jack Bar — For All Type BX-BXL Coils $1.15 Less Jacks.. .90
A56 — B Jack Bar — For All Type B-BL-BVL Coils..$ .85 Less Jacks.. .60
A57 — Steatite Bushing ½" Dia. — ⅜" Long — Drilled 6-32 Clearance.. .03
A58 — Steatite Bushing ⅜" Dia. — ⅜" Long — Drilled 6-32 Clearance.. .02
A59 — Steatite Post Insulator ½" Dia. — 1" Long — Tapped 8-32 Both Ends.. .15
A60 — Steatite Post Insulator ½" Dia. — 1½" Long — Tapped 8-32 Both Ends.. .18
A61 — HD Plug Bar, for All Type HD-HDL-HDVL Coils, Less Plugs.... 1.10
A62 — T Plug Bar, for All Type T-TL-TLV Coils, Less Plugs.......... .30
A63 — BX Plug Bar, for All Type BX-BXL Coils, Less Plugs.......... .25
A64 — B Plug Bar, for All Type B-BL-BVL Coils, Less Plugs.......... .20
A65 — Hexagon Nickeled Brass Post 5/16" x ⅜" Long — Drilled 6-32 Clearance.. .03
A66 — Hexagon Nickeled Brass Post 7/16" x ⅜" Long — Tapped 10-32 .06
A67 — Special Transmitting Band Change Switch — 5 Section — 3 Position — 100 Watt Rating.................................. 3.65

B & W UNMOUNTED COILS

No. 1 — 2½" Dia., 10" Length, 6 turns per inch. No. 12. *Net Price*....................$1.50
No. 2 — 2½" Dia., 10" Length, 8 turns per inch. No. 14. *Net Price*....................$1.50
No. 3 — 2" Dia., 10" Length, 10 turns per inch. No. 16. *Net Price*....................$1.50

SPECIAL COILS and ASSEMBLIES

Let B & W solve your special inductance problems! Years of experience in the design and manufacture of inductors of every conceivable type — for amateur and commercial applications throughout the world — is your guarantee of complete satisfaction.

Call upon B & W engineers . . . they will be glad to study your problem and design the proper inductance unit for your particular need.

CUSTOM BUILT TRANSMITTERS

B & W will build a complete transmitter to your specifications — or work with you in designing a unit to fill your individual requirements. No job is too small — nor too large — to receive full benefit of the comprehensive technical experience of B & W engineers.

Ask your jobber about this type of service

BARKER & WILLIAMSON • ARDMORE, PA.

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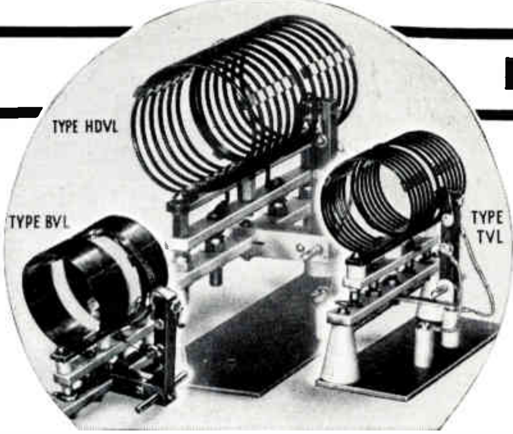
B & W AIR INDUCTORS



SWINGING LINK ASSEMBLIES

For accurate, positive control of loading and excitation in the final stages of transmitters. Available in three sizes — for high, medium and low power. Supplied with four plugs. Split to provide twin metering in the plate circuits of push-pull stages. All Base Assemblies allow front-of-panel coupling control.

TYPE HDVL— 1 K.W. Rating. A heavy duty unit for high power transmitters. Undeniably superior, electrically and mechanically, to any other type of coil on the market.

TYPE TVL— 250 Watts Rating. Highly efficient and exceptionally dependable for medium power applications — under *all* operating conditions.

TYPE BVL— 100 Watts Rating. New! . . . a smaller, more compact assembly designed for direct mounting on condenser. Ideal for low powered Xmitters and exciter stages or in conjunction with TYPE BL Coils in interstage coupling.

Type	*Inductance Microhenrys*	**Capacity MMfd.*	*Wire Size*	*Dia.*	*Outside Plug Centers*	*Net Price*
160HDVL	94.0	90	14	3½"	7½"	**$5.25**
80HDVL	47.0	44	10	3½"	7½"	**4.50**
40HDVL	18.0	28	8	3½"	7½"	**4.00**
20HDVL	5.2	25	8	3½"	7½"	**3.75**
10HDVL	1.3	25	4	2⅝"	7½"	**3.25**
HDV Base Assembly		**$5.00**	HDA Antenna Matching Coil			**4.00**
160TVL	130.0	65	18	2½"	5"	**$2.25**
80TVL	38.0	55	14	2½"	5"	**2.15**
40TVL	15.0	34	12	2½"	5"	**1.90**
20TVL	4.6	28	12	2½"	5"	**1.65**
10TVL	1.5	22	6	2¹¹⁄₁₆"	5"	**1.60**
TV Base Assembly		**$4.00**	TA Antenna Matching Coil			**1.75**
160BVL	55	150				**$2.10**
80BVL	30	70				**1.90**
40BVL	13	40				**1.65**
20BVL	3.1	40				**1.45**
10BVL	1.0	35				**1.40**
5BVL	0.5	25				**1.35**

*Total effective capacity required to effect resonance on low frequency end of specified band.

MODEL B BAND SWITCHING TURRET

For rapid selection of any one of three bands — from front of panel! Any three-band coil combination (160 to 10 meters) may be "plugged-in" the Turret. Designed for use with center-tapped, end-linked or center-linked Type "B" Coils. Ideal for use in crystal-controlled or electron-coupled oscillators as well as buffer, doubler or final amplifier stages with power inputs not exceeding 100 Watts and 1,000 Volts.

Model "B" Turret — Less Coils Net $7.50

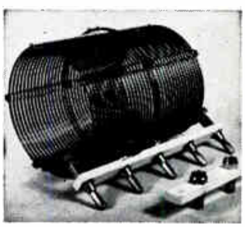
STANDARD and FIXED LINK COILS

TYPE B and BL — 100 Watts Rating. For use in oscillator and buffer-doubler stages developing up to 100 watts of power.

TYPE BX and BXL — 250 Watts Rating. Suitable for neutralized buffer and final tank stages with inputs up to 250 Watts.

TYPE T and TL— 500 Watts Rating. For high powered neutralized buffer and final tank stages where powers of 500 Watts are developed.

TYPE HD and HDL — 1 K.W. Rating. Heavy duty coils, capable of handling a kilowatt with ease. Equipped with oversized plugs of ample current carrying capacity.



TYPE HDL

For minimum dielectric in the field of the coil, extremely low losses, rugged construction, excellent appearance, *highest efficiency at low cost* . . . insist upon B & W AIR INDUCTORS!

Standard Type	*Net Price*	*Linked Type*	*Net Price*	*Inductance Microhenrys*	**Capacity MMfd.*	*Wire Size*	*Diameter*	*Outside Plug Centers*
160B	**$1.75**	160BL	**$2.50**	78.0	110	18	2½"	3⅛"
80B	**1.55**	80BL	**2.30**	39.0	52	16	2½"	3⅛"
40B	**1.30**	40BL	**2.05**	12.0	43	14	2"	3⅛"
20B	**1.05**	20BL	**1.80**	3.0	40	14	2"	3⅛"
10B	**1.00**	10BL	**1.75**	1.1	28	12	2"	3⅛"
160BX	**$1.80**	160BXL	**$2.80**	84.0	100	14	4"	4"
80BX	**1.60**	80BXL	**2.60**	37.0	54	14	3"	4"
40BX	**1.35**	40BXL	**2.35**	10.0	51	14	2½"	4"
20BX	**1.10**	20BXL	**2.10**	2.8	45	14	2"	4"
10BX	**1.05**	10BXL	**2.05**	1.0	35	12	2"	4"
160T	**$1.85**	160TL	**$2.85**	74.0	115	12	5"	5"
80T	**1.65**	80TL	**2.65**	35.0	60	12	3½"	5"
40T	**1.40**	40TL	**2.40**	13.5	38	12	2½"	5"
20T	**1.15**	20TL	**2.15**	4.3	30	12	2½"	5"
10T	**1.10**	10TL	**2.10**	1.3	25	12	2"	5"
160HD	**$4.25**	160HDL	**$6.25**	94.0	90	10	5"	7½"
80HD	**3.50**	80HDL	**5.50**	40.0	50	10	3½"	7½"
40HD	**3.00**	40HDL	**5.00**	15.0	35	8	3½"	7½"
20HD	**2.75**	20HDL	**4.75**	4.2	29	8	3"	7½"
10HD	**2.25**	10HDL	**4.25**	1.3	25	4	2"	7½"

*Total effective capacity required to effect resonance on low frequency end of specified band.
A68-P1 — Network Coil — Complete with clip................................**$1.85**

BARKER & WILLIAMSON • ARDMORE, PA.

World Radio History

"EVEREADY"

No. 585

No. 586

No. 486

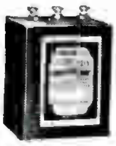
No. 386

The makers of "Eveready" batteries now present at *new low* prices, a complete line of exclusive, patented "Layer-Bilt" "B" batteries. Now *all* of these batteries are of the famous *flat cell* construction that insures longer service life than round cell batteries of the same size and more service hours per dollar. Note these *new low prices:*

No. 585	Medium Size, "LAYER-BILT" "B" Battery	**List $1.25**
No. 586	Heavy Duty, Large Size "LAYER-BILT" "B" Battery	**List 1.75**
No. 486	Heavy Duty, Large Size "LAYER-BILT" "B" Battery	**List 2.00**
No. 386	Heavy Duty, Large Size "SUPER LAYER-BILT" "B" Battery	**List 2.29**

No. 762

Large Size Portable. 45 volts, tap at 22½ volts. Plug-in connection. 4 1/4 x 2 9/16 x 5 7/8 in. 3 lbs.



No. 738

Medium Size Portable. 45 volts, tap at 22½ volts. Screw Terminals. 3⅛ x 2⅜ x 4½ in. 1 lb. 4 oz.

No. 733

Small Size Portable. 45 volts, tap at 22½ volts. Screw Terminals. 3⅛ x 1⅜ x 4½ in. 12 oz.

No. X-180

Midget "Layerbilt" Battery. Smallest 45-volt "B" Battery made. Flexible Wire Terminals. 1¼ x 1¼ x 2 in. 2 oz.

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RADIO BATTERIES

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No. 722

Small Size Portable "A" Battery, 3 volts. Screw Terminals. 2 11/16 x 1 1/2 x 4 1/2 in. 11 oz.

No. 723

Medium Size Portable "A" Battery, 3 volts. Screw Terminals. 2¾ x 2¾ x 4⅜ in. 1 lb. 5 oz.

No. 724

Large Size Portable "A" Battery, 3 volts. Screw Terminals. 4 x 2¾ x 6 in. 2 lbs. 4 oz.

No. 761

General Purpose Battery, 4½ volts. Fahnestock Terminals. 4 1/32 x 1 13/32 x 3 5/8 in. 14 oz.

These are the types of batteries most useful to amateurs and experimenters. For a complete catalog of all types of Eveready Radio Batteries write to

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Proved in thousands of installations

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Ask your dealer for Bulletins GEA-2021A, on rectangular capacitors, and GEA-3018, on cylindrical capacitors, or write Radio Dept., General Electric, Schenectady, New York.

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MICROFARAD RATING	VOLTAGE RATING												
	RECTANGULAR TYPE									CYLINDRICAL TYPE			
	500	600	1000	1500	2000	2500	3000	4000	5000	600	1000	1500	2000
0.01	—	—	$1.06	—	—	—	—	—	—	—	—	—	—
0.05	—	—	1.09	—	—	—	—	—	—	—	—	—	—
0.1	—	—	1.15	—	—	—	—	—	—	—	—	—	—
0.25	—	—	1.18	—	—	—	—	—	—	—	—	—	—
0.5	—	—	1.26	—	—	—	—	$13.52	$14.70	—	—	$1.62	—
1	$1.32	$1.62	1.76	$2.21	$3.09	$8.23	$10.58	15.29	17.64	—	$1.32	1.76	$2.21
2	—	2.06	2.65	3.68	4.70	10.00	13.52	17.64	19.92	$1.32	1.62	2.21	2.50
3	—	—	—	—	—	—	—	—	—	1.62	2.06	—	—
4	—	2.65	4.12	5.29	6.47	14.70	17.64	—	—	1.76	2.21	—	—
5	—	3.18	4.70	6.47	7.64	—	—	—	—	—	—	—	—
10	—	—	6.47	10.00	11.17	—	—	—	—	—	—	—	—
12	—	—	—	—	11.76	—	—	—	—	—	—	—	—
15	—	—	7.06	10.58	—	—	—	—	—	—	—	—	—

TELEVISION CAPACITORS: 4000 volts, 0.05 microfarads, $3.82
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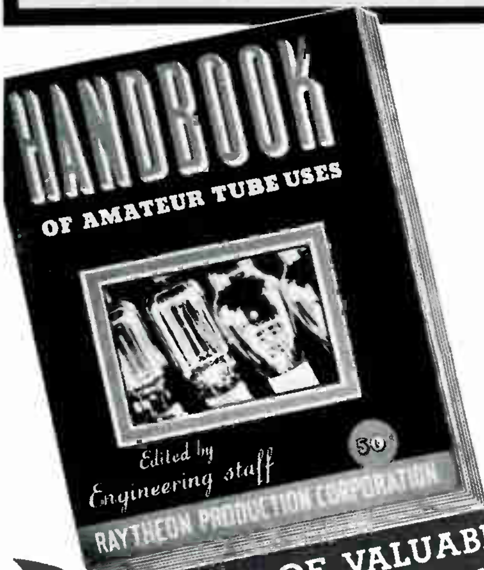

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McGRAW-HILL Radio Books

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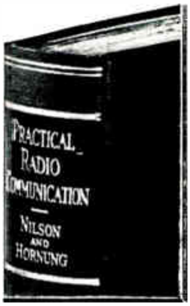

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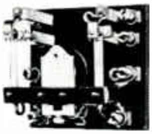
RESISTORS - RHEOSTATS - RELAYS

SPECIFICATIONS and PRICES of RELAYS

REMOTE CONTROL

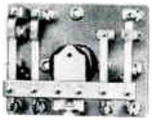


ANTENNA

OVERLOAD

TIME-DELAY

KEYING



BREAK-IN

Description	Cat. No.	CONTACTS				Amps	List Price
		Poles	Throw	Break	Normal Position		
Thermal Time Delay	507-501	Single	Double	Single	.....	4.	$15.00
Remote Control	507-503	Double	Single	Single	Open	4.	8.00
Remote Control	507-504	Double	Single	Single	Open	4.	8.00
Remote Control	507-505	Double	Double	Single	.....	4.	9.00
Remote Control	507-506	Double	Double	Single	.....	4.	9.00
Low Voltage Keying	507-507	Single	Single	Double	Open	6.	7.00
Low Voltage Keying	507-508	Single	Single	Double	Open	6.	7.00
Crystal Oven	507-509	Single	Single	Double	Open	6.	7.00
Remote Control	507-510	Single	Single	Double	Open	6.	7.00
Remote Control	507-511	Double	Double	Single	.....	4.	9.00
Overload	507-512	Single	Single	Double	Closed	6.	8.50
Overload	507-513	Single	Single	Double	Closed	6.	8.50
Underload	507-514	Single	Single	Double	Open	4.	10.00
Underload	507-515	Single	Single	Double	Open	4.	10.00
High Voltage Keying	507-516	Single	Single	Double	Open	10.	7.50
Midget Latch-In	507-517	Single	Double	Double	.....	6.	14.50
Heavy Duty Remote Control	507-518	Single	Single	Double	Open	10.	8.80
Steel Knock-out Box	507-519	.....	.....	.....	.....	...	3.00
Bakelite Cover	507-520	.....	.....	.....	.....	...	.70
Heavy Duty — R. F. Antenna Change Over	507-521	Double	Double	Single	.....	15.	25.00
Heavy Duty — R. F. Antenna Change Over	507-522	Double	Double	Single	.....	15.	25.00
Heavy Duty — R. F. Antenna Change Over	507-523	Double	Double	Single	.....	15.	25.00
Heavy Duty—R. F. Break-In	507-526	Four●	.....	Single	.....	15.	27.50
Heavy Duty—R. F. Break-In	507-527	Four●	.....	Single	.....	15.	27.50
Heavy Duty—R. F. Break-In	507-528	Four●	.....	Single	.....	15.	27.50
Midget—R. F. Antenna Change Over	507-531	Double■	Double	Single	.....	4.	10.00
Midget—R. F. Antenna Change Over	507-532	Double■	Double	Single	.....	4.	10.00
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D. C. Sensitive	507-539	Single	Double	Single	.....	2.	12.50
D. C. Sensitive	507-540	Single	Double	Single	.....	2.	12.50
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ADJUSTOHM RESISTORS

The adjustable band permits connection to include the number of turns desired to obtain the correct resistance. Simple and convenient. Circular 507 lists size for 10 to 200 watts with prices.

FIXED *Wire Wound* RESISTORS

These resistors are made with the highest grade resistance wire, wound on a special refractory tube, conservatively rated. 10 and 20 watts size up to 100,000 ohms. Circular 507.

HEAVY DUTY RESISTORS

Ward Leonard wire wound resistors are known throughout the radio industry for their accuracy, dependability and long life. 25 to 200 watts in various resistance values up to 150,000 ohms. Circular 507.

RING TYPE RHEOSTATS

This compact, power ring type rheostat offers a continuous control that is practically stepless. 1½", 2¼", 3" and 4" diameters, giving 30, 50, 100 and 150 watts capacity. Wide range of resistance values up to 10,000 ohms. See 1937 circular 507.

PLAQUE RESISTORS

Non-inductive, non-capacitive. 2", 4" and 5¾" giving 20, 40 and 100 watts capacity with resistance values up to 10,000 ohms. Ideal for finely balanced circuits. Circular 507.

WARD LEONARD ELECTRIC CO. MT. VERNON, N. Y.

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7 GOOD BUYS FOR AMATEURS

304B TRIODE

Upper frequency limit—300 megacycles. Maximum voltage—1250 volts. Nominal power output, Class C—unmodulated—85 watts.

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Full ratings up to 50 megacycles. Maximum voltage—1000 volts. Nominal power output, Class C—unmodulated—85 watts.

306A PENTODE

Full ratings up to 50 megacycles—reduced ratings up to 70 megacycles. Maximum voltage—300 volts. Maximum power output 8.8 watts.

307A PENTODE

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316A TRIODE

Upper frequency limit—750 megacycles. Maximum voltage—450 volts. Nominal power output at 500 megacycles—7.5 watts.

300A TRIODE

High quality audio. Maximum voltage—450 volts. Maximum output—17.8 watts.

Power Amplifier
242C TRIODE

Maximum voltage—1250 volts. Approximate carrier output, Class B, 100% modulated—50 watts. 100% modulated—Class C Nominal power output—130 watts.

For full information, consult your dealer, or write to

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1939 EDITION

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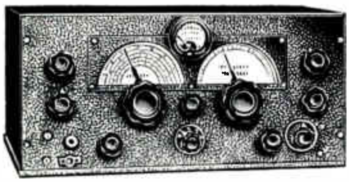
REFINE and IMPROVE

In these two words RADIO MFG. ENGINEERS, INC. have given to the radio communication field the best possible receivers and accessory units which are now being used very universally. In our business of satisfying communication needs there are no yearly models. The basic design of a good receiver — the coils — the frame — the valuable features — are standard.

This does not mean that our laboratory lags behind. The research and development program goes on. Fine suggestions come to us periodically from radio men in the field.

Descriptive literature sent on request

The RME-69

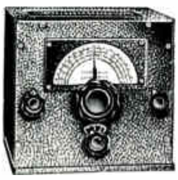


The RME-69, with its great flexibility in adaptations to special needs, is being built as before. With or without manual noise suppressor — in standard or battery model — for special frequency coverage in the low or ultra-high ranges — for relay rack mounting — or any special requirements in your station — look to the RME-69 for complete satisfaction. When searching for a receiver which will perform under all conditions — one which will give you full vision tuning, band spread, variable phasing crystal filter circuit, and most everything you would want and need for satisfactory DX results — The RME-69 is the answer!

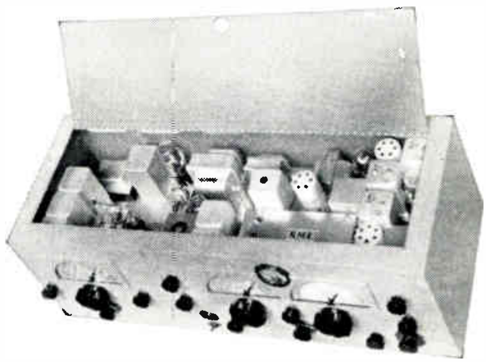
The DB-20 Preselector and R. F. Amplifier

A two-stage — three-circuit, self-powered, R.F. Amplifier unit which may be used ahead of any good superheterodyne receiver and out*perform* your present performance. With antenna changeover switch incorporated as standard, supplied with three tubes, frequency range 550 to 32,000 KC in six bands, A.C. or battery or combination supply optional, this unit has found acceptance in thousands of radio stations.

The 510X Frequency Expander



The latest unit to be introduced is this Expander which, when used with good stable superheterodyne receivers, will permit exceptional results in the range 28 to 70 megacycles. A good image rejector, since the R.F. stage of the receiver is definitely set at 10 MC, a three-band scale (approximately twenty-one inches of scale travel) equipped with antenna changeover switch, self contained power supply, built on cast aluminum frame. This unit will *open up* five meter operation and give the radio amateurs something new to shoot at. Already users are reporting a "Worked all districts on five meters."



The Combination

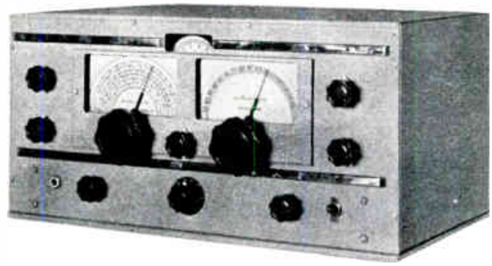
Fine appearance and fine performance is contained in the combination RME-69 receiver and DB-20 preselector. With antenna changeover switch incorporated and obtainable in either conventional black crinkle or gray crinkle cabinet this combination instrument, housed in one cabinet, features everything that will put any amateur radio station out in front.

This combination is also available in relay rack mount. See literature for details.

RADIO MFG. ENGINEERS, Inc.
PEORIA, ILLINOIS, U. S. A.

THE RME-70

A NEW MODEL
WITH NEW FEATURES
AT A LOW PRICE



THIS IS WHAT YOU WILL FIND IN THE RME-70

1. **New illuminated DB-R meter**
2. **Three new iron core IF transformers**
3. **Improved automatic Noise Suppressor**
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5. **Break-in relay control**
6. **Frequency range from 550 to 32,000 Kc**
7. **Extreme selectivity**
8. **Streamlined cabinet design**
9. **Controls designated with lettering**
10. **Total complement ten tubes**
11. **One stage of amplification**
12. **Sturdy construction, detailed engineering and exceptional quality throughout**

The same sturdy construction, the same fidelity to detail in engineering, the same high quality workmanship that has always been characteristic of RME products will be found in this new receiver.

The speaker housing also has been redesigned to match the receiver cabinet design.

Ask us for a comprehensive folder on all of the units.

The RME-70 is a ONE TYPE, ONE MODEL receiver. NO variations are obtainable other than the combination and the gray or black crinkle finish. In order to offer to the radio field an instrument of this type and quality at a lower price it was necessary to standardize on the one unit and eliminate variable adaptations. If any alterations to the RME-receiver are desired you will find your requirements met in the RME-69 series of instruments.

THE DB-20-70

The two stage R.F. amplifier and preselector may be ordered to match the outward appearance of the RME-70. Frequency Range from 550 to 32,000 Kc. Net price, with tubes and change over switch, black or gray finish, $42.60.

THE 510X-70

This frequency expander is available in the front trim to match the RME-70 receiver at no additional cost. Frequency coverage 28 to 70 megacycles. Very effective in image suppression. Net price, with tubes and changeover switch, black or gray finish $45.10.

THE COMBINATION

The RME-70 and DB-20-70 are also built into one cabinet, either black or gray finish. This combination makes one of the finest and most up-to-date units for any amateur radio station. Ask for complete details.

RADIO MANUFACTURING ENGINEERS, Inc.

PEORIA, ILLINOIS, U. S. A.

World Radio History

• WHEN YOU NEED A GOOD IRON

ESICO ESICO ESICO ESICO

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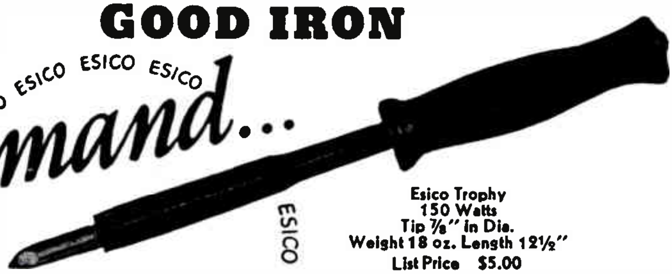


Esico Trophy
150 Watts
Tip 7/8" in Dia.
Weight 18 oz. Length 12½"
List Price $5.00

ESICO ESICO ESICO ESICO ESICO ESICO ESICO

ESICO!

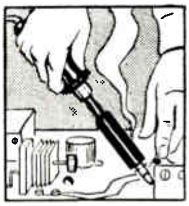
When you need a good iron — an iron that stays clean — an iron that stays hot — an iron that you can depend upon — Demand Esico.

Many years of experience in manufacturing electric soldering irons for large radio and industrial companies have produced ESICO — the iron that is "good" because it is built around three factors — DEPENDABILITY — LONGEVITY — EFFICIENCY.

Esico Midget
65 Watts
Tip 7/16" in Dia.
Weight 7 oz.
Length 11¼"
List Price $1.75

ESICO STAYS CLEAN

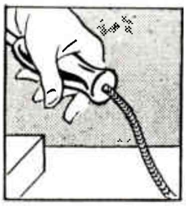
A special copper drop forged solder tip — produced only after many trials and experiments — stays clean exceptionally long after tinning. The importance of a clean tip is known to us all. The quickly oxidizing iron has caused much annoyance and ruined many an iron. Here is your chance to use a "good" iron that you won't have to clean for every job.



ESICO STAYS HOT

The average iron loses a considerable portion of its heat only a short period after it is put into operation. The element and oxidizing causes this difficulty. ESICO has gone a step forward by using NICHROME V in the construction of the electric soldering iron element and reducing this factor to a negligible level. "Good" Esico soldering irons give the full wattage rating during their long life.

Esico Nick Nack
55 Watts
Tip 7/16" in Dia.
Weight 6 oz.
Length 11¾"
List Price $1.10



ESICO DOES NOT FRAY

Electric cords fraying and shorting cause much inconvenience to many amateurs and in some cases result in physical injury. A special patented method of firmly anchoring a heavily asbestos lined, number 14 electric cord, to the iron proper, entirely eliminates this difficulty.

Esico Junior
85 Watts
Tip 7/16" in Dia.
Weight 9 oz.
Length 12¼"
List Price $2.75

Many thousands of hams the country over admit the superiority of ESICO. Why not join this increasing army of loyal and well satisfied Esico users?

All Esico electric soldering irons are unconditionally guaranteed. A "good" quality iron plus absolute protection assures you of complete satisfaction.

Electric Soldering Iron Co., Inc.
Deep River, Connecticut

ESICO
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World Radio History

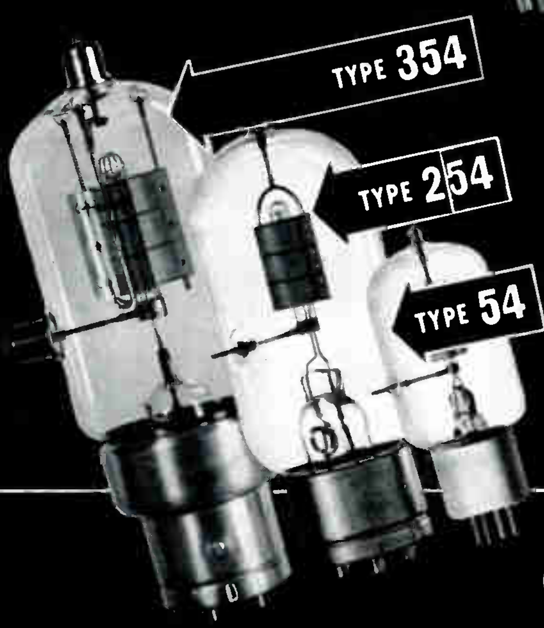
New Savings $ with GAMMATRON $ $ $

TYPE 24

Gammatron's newest low priced triode built to meet the requirements of the low power ham. Yet the high standards of Gammatron quality are retained. Improved design provides exceptional ultra high frequency performance.

PRICE $3.50

Power output, watts	87.5
Plate dissipation, watts	25
Max. plate volts	1500
Max. plate M. A.	75
Amp. factor	25
Excitation, watts	3.8
Filament volts	6.3
Filament amps.	3.0



The long life 150 watt tantalum plate tube. Made in five amplification factors. Maximum power output 700 watts. Price. $24.50

The easy to neutralize 100 watt tantalum plate tube. Maximum power output 450 watts. $12.50

The easy to drive 50 watt tantalum plate tube. Maximum power output 210 watts. Price. $6.75

HEINTZ AND KAUFMAN LTD
SOUTH SAN FRANCISCO CALIFORNIA U. S. A.

WALTER H. CANDLER
Maker of Champions Will Train You Personally to Qualify for that Bigger, Better Job.

★

LEARN or SPEED UP YOUR CODE at Home

With the NEW CANDLER SYSTEM

TRAINS YOU TO MEET NEW CODE SPEED REQUIREMENTS

Obtain Your Amateur or Commercial License in ½ Usual Time With

The New CANDLER SYSTEM Training

You Can Learn Code RIGHT, from the beginning *as you will be using it on the air*, or obtain your commercial license and qualify for a good job by taking CANDLER TRAINING in your own home, as McElroy, Jean Hudson and many others have done and are doing. It is surprisingly easy and inexpensive.

It takes more than merely the sending and receiving of code to become a skilled radio-telegraph operator. The New CANDLER SYSTEM teaches you quickly the technique of Fast, Accurate telegraphing.

CANDLER Trained McElroy, Champion Class A, Speed 69 wpm.

CHAMPION McELROY says: "Practice alone, of any kind, will not develop skill and speed. It takes a thorough knowledge of the fundamentals and Mind Training, taught exclusively by THE CANDLER SYSTEM."

LEARN AT HOME

To Read Code at High Speeds Like You Read Print

If you've practiced and practiced with any kind of practice set, but can't get over the "hump" that seems to be your limit — don't be discouraged. Thousands of skilled operators have had the same experience. Some thought they were dumb; others thought they weren't "gifted." But you should see those fellows today! They can send beautiful code and copy fast press 4 to 8 words behind without conscious effort or strain. Those fellows have *Automatic Sound Consciousness* — and they got it through CANDLER Training!

L. R. McDONALD, W8CW
Winner A.R.R.L. Code Contest Detroit Convention Sept. 6, 1937 by copying 60 wpm without error.

"Practice alone of any kind will not develop a fast op. Candler makes available to all ops the Mental Training formerly acquired by only a few, and then by accident."
L. R. McDonald, W8CW

No Expensive Practice Sets Needed for Candler Training

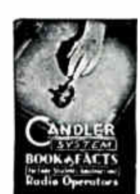
Learning to Send and Receive Code Rapidly and skilfully is a Mental Process that requires Mind Training such as only CANDLER can give you. Practice of any kind without this Specialized Training is like trying to learn electricity without a knowledge of *Ohm's Law*. CANDLER shows you the easy, interesting way to Speed, Skill, and that Amateur or Commercial License in half the usual time.

CHAMPION JEAN, W3BAK
Two months after beginning Candler training, Jean could copy 30 wpm on her "mill" easily.

FREE

The New BOOK of FACTS for Code Students, Amateurs and Radio Operators Will Be Sent to You Without Cost or Obligation.

Contains inside advice and tips from the champions and world's fastest Amateur and Commercial ops. They tell you how to quickly develop Skill and Speed. *Contains* information on License Requirements and a list of QUESTIONS, many of which will be asked you by the R. I., when you take your exam.



CANDLER SYSTEM
Box 331, Dept. HB-39
ASHEVILLE, N. C., U.S.A.

World Radio History

RACKS
PANELS

Par-Metal

CHASSIS
CABINETS

In presenting our new line of Rack and Panel Equipment our desire has been not only to make it complete but also to follow the current trend toward streamlining in design.

We now have ready several new types of racks, cabinets and amplifier chassis to meet the demand for new equipment with modern, distinctive lines. To effect a more harmonious color combination than is possible with the conventional black finish, many units are offered, without any additional cost, in slate gray enamel which blends perfectly with red, black, or chrome trim dials, instruments, etc.

NEW DE LUXE STREAMLINED UNITS


De Luxe Type "C" Single Unit


De Luxe Speaker Unit


De Luxe Type "C" Enclosed Relay Rack

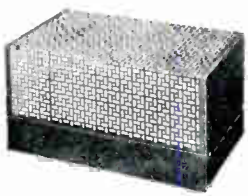

De Luxe Type "C" Double Unit


De Luxe Amplifier Foundation Chassis

REGULAR STANDARD RACKS & ACCESSORIES


Type "A" Channel Relay Rack


Combination Bracket and Panel


Standard Amplifier Foundation Chassis


Type "A" Enclosed Relay Rack

Our new units are completely described in our catalog No. 39 which will be mailed upon request. Write for your copy today.

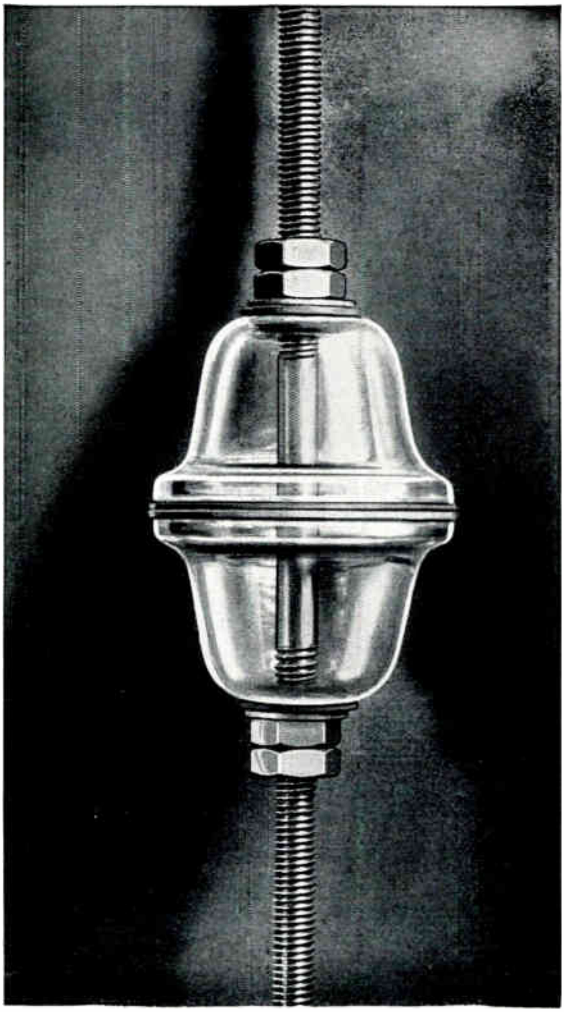
PAR-METAL PRODUCTS CORPORATION

3525 41st Street *Dept. Q-39* **Long Island City, N. Y.**

World Radio History

PYREX *Radio Insulators*

BRAND



The Perfect Lead-in Insulator—PYREX No. 67104

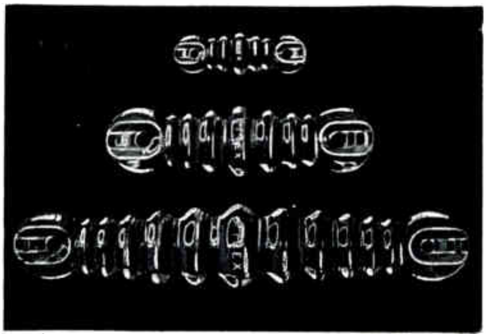
For Amateur Use

PERFORMANCE, which alone has won for PYREX Radio Insulators their present day supremacy, is the direct result of the inherent properties of the glass composition from which they are made.

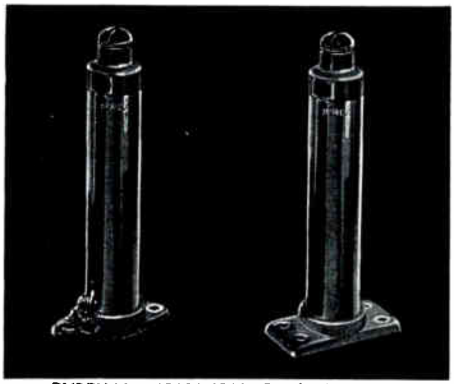
The high volume and surface resistance and low power loss of PYREX brand glass result in clearer signals and better distance, particularly under adverse conditions.

The perfection of surface of PYREX Radio Insulators is an important factor in preserving their continuous efficiency. Except in heavy storms, rain does not form a continuous film on the surface, and as atmospheric dust particles find no pores or cracks for permanent lodgment, a mild rainfall washes away anything which may have settled on the insulator surface.

A folder describing PYREX Brand Radio Insulators will be sent to you on request.



PYREX Nos. 67007-67017-67021 Antenna Insulators for Improved Transmission



PYREX Nos. 67106-67108 Stand-off Insulators for High Power Transmitters

"PYREX" is a registered trade-mark and indicates manufacture by

CORNING GLASS WORKS, CORNING, N. Y.

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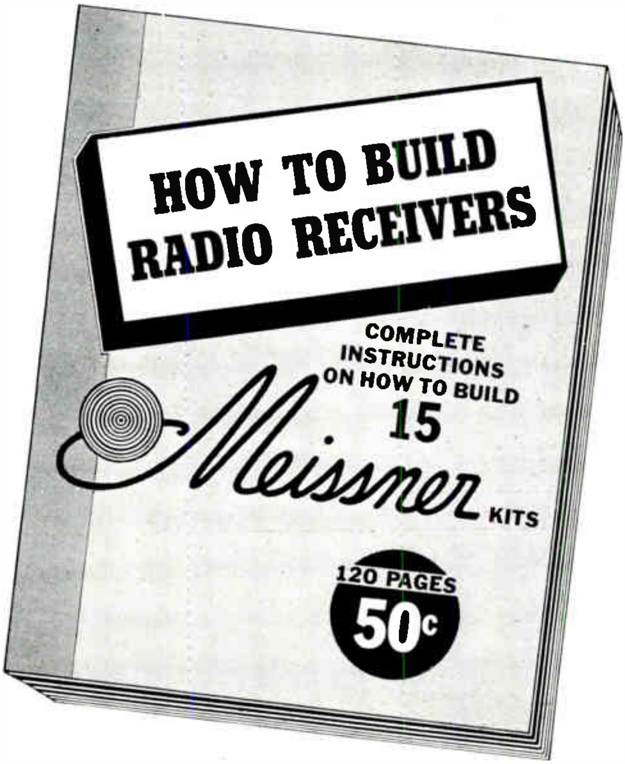
NEW!

120-PAGE COMPLETE INSTRUCTION BOOK

Detailed wiring instructions! Diagrams! Schematics! Pictorial Diagrams! Alignment Data! And operating instructions for all Meissner units!



A NEW book — Page after page of invaluable information, both theory and technical data. With graphs and charts; contains pictorial diagrams, schematic diagrams, alignment data, constructional data and operating instructions for 15 of the new Meissner receiver kits; also adapters and converters.

AT YOUR PARTS JOBBERS

NET PRICE 50¢

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Meissner MT. CARMEL, ILLINOIS

"A FAMOUS NAME FOR TWO DECADES"

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EASY WAY TO LEARN RADIO CODE

To speed up the learning of the code use a Machine we send to you. Always ready — no delay trying to tune in on Short Wave — no schedules to watch for — no weather interference. Beats having another send to you, as you concentrate fully on the study.

MACHINES FOR SALE OR RENT

THE "STANDARD" INSTRUCTOGRAPH

The Instructograph is a scientifically constructed machine that sends telegraphic characters perfectly at any desired speed.

By so doing it literally takes the place of an operator-instructor, and enables anyone to learn either the Morse or Continental codes without any further assistance.

The "Standard," as illustrated, includes the full set of ten tapes and book of instructions. Priced $20.25, delivered to any point in the United States or possessions. $1.00 additional to points in Foreign Countries.

THE "JUNIOR"

The "Junior" Model of the Instructograph, similar in appearance to the "Standard" Machine, only a little smaller, with five tapes and the book of instructions IS NOT RENTED, but may be purchased for $12.00, delivered to any point in the United States or possessions, and $13.00 to points in Foreign Countries.

The "Junior" operates just as efficiently as the larger machine, and the difference being mainly in the size, weight and number of tapes supplied. However, additional tapes may be purchased at a reduced rate. Oscillator equipment may be installed in the "Junior" also.

BOTH MACHINES ARE SOLD ON EASY MONTHLY PAYMENTS IF DESIRED

Full Oscillator equipment — Audio transformer, and tube socket wired and installed in the machine, "99" type of radio tube, key and connecting cord and Trimm head phones. Priced $6.50.

RENTALS (In United States only)

No. 1. Instructograph, 10 tapes and book of instructions: First month $3.00, each additional month, $2.25.

No. 2. Instructograph, 10 tapes and book of instructions, with transformer and tube socket wired and installed in machine: First month, $3.25, and each additional month, $2.50.

No. 3. Instructograph, 10 tapes, book of instructions, transformer and tube socket installed in the machine, key and connecting cord, and head phones: First month $3.50, and each additional month, $2.75.

THE INSTRUCTOGRAPH
accomplishes these purposes:

FIRST — It teaches you to receive telegraph symbols, words and messages.

SECOND — It teaches you to send smoothly and accurately.

THIRD — It increases your speed of sending and receiving after you have learned the code.

We pay return transportation charges on all rentals, and pay it both ways if rented for three months or more, and full three months' rental accompanies the order. A deposit of $10.00, in addition to the rental, is required or satisfactory references asked.

Postal card will bring full particulars immediately

THE INSTRUCTOGRAPH CO.

912 LAKESIDE PLACE *(Dept. H. B. 5)* **CHICAGO, ILLINOIS**

World Radio History

FOUNDATION TUNERS DESIGNED EXCLUSIVELY FOR THE AMATEUR

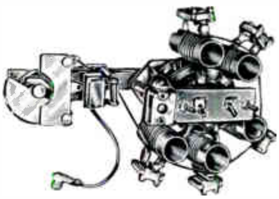
Here are the band-switching Tuners you have been waiting for! They cover the 10- 20- 40- 80- and 160- meter amateur bands and are so versatile that each Tuner fills many needs in any shack.

▶ WHAT THEY ARE ◀

The Exciter Tuners — BL-5G and BL-5P

The BL-5G — Five high-Q cathode-tapped coils with band switching arrangement, designed for the grid circuit of a stable electron coupled oscillator. Each coil shunted by a large, stable Silver Cap fixed condenser whose capacity is constant over a wide range of temperature and humidity. High ratio of capacitance to inductance permits remarkable frequency stability. Coil frequencies allow second harmonic operation of the plate circuit on the 10- 20- 40- 80- and 160-meter bands. Tuning accomplished by means of a 100 mmf. variable condenser common to all bands. Unit completely wired and assembled at the laboratory.

The BL-5P — Five high-Q coils together with band-switching arrangement and tuning condenser, designed for plate circuit operation in a crystal or electron coupled oscillator. Covers the 10- 20- 40- 80- and 160-meter bands. High L/C ratio for maximum output. Unit completely wired and assembled at the laboratory.



The BL-5H — This Tuner consists of 5 high-Q coils, 5 trimmer band-setting condensers, series antenna condenser, main tuning condenser, and grid resistor-condenser combination. The coils are rigidly mounted on a band-switching arrangement. Trimmer condensers especially designed for stability. Coils cover the 10- 20- 40- 80- and 160-meter bands. Each band spread over a large portion of the tuning scale.

▶ WHAT THEY DO ◀

The BL-5G and BL-5P — Use these two high quality units to build the all-band Exciter you have always dreamed about. The high C grid coils and high L plate coils provide an ideal combination. Bed rock stability makes possible accurate and permanent calibrations. Complete constructional details given in July, 1938 issue of *QST*. Giving 35 watts output, the Exciter is a transmitter in itself — a driver for a 200-watt final.

The BL-5H — This little Tuner is the most versatile unit ever offered to the amateur fraternity. Designed primarily as the basis of a simple regenerative receiver, it has found even greater popularity as the basis of an efficient and simple regenerative preselector. Many other uses will suggest themselves to the amateur. Use it as a frequency monitor, a wave trap, a Ham band signal generator.

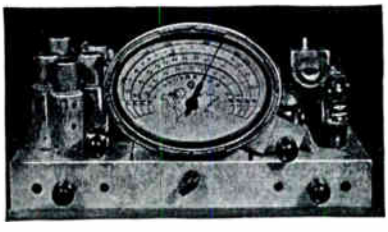
▶ WHAT THEY COST ◀

	Amateur Price
5-H Tuner	$7.85
5-P Tuner	6.65
5-G Tuner	8.80

	Amateur Price
Etched and Engraved 7″ x 10″ panel	$1.40
1⅜″ knob with 1⅜″ pointer and two 1¼″ pointer knobs (Price for all 3)	.60

Your Parts Distributor Has These Tuners in Stock

FOR THE DISCRIMINATING EXPERIMENTER



FOR the set builder, the experimenter, the man who wants the thrill of building a better radio than he can buy, we present the Browning 83. This new development of the Browning Laboratories is not just another kit receiver. It presents features not elsewhere obtainable. Using a basic superheterodyne circuit, it concentrates not on frills but on providing noise-free reception and high audio fidelity — continuous frequency coverage from .54 to 22 mc. Its signal-to-noise ratio is especially high, its sensitivity below a microvolt on all bands. It is designed for the experimenter, and with this end in view, the chassis has been laid out to allow individual experimentation. Full-sized pictorial wiring diagrams together with complete instructions make construction easy, even for the inexperienced. Can be aligned and tracked without the aid of a signal generator.

Complete BROWNING 83 KIT (Includes everything necessary to build the Browning 83 except tubes, speaker, and cabinet) **$44.75**

BROWNING LABORATORIES, Inc., Winchester, Massachusetts

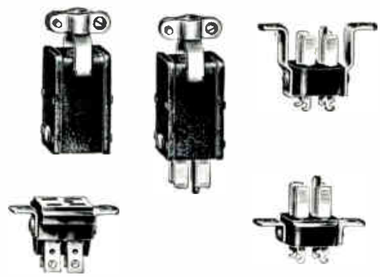
***Export Department:* 461 Fourth Avenue, New York**

World Radio History

JONES

PLUGS, SOCKETS AND TERMINAL PANELS

HEAVY DUTY SERIES



Five numbers of over 200 in the Heavy Duty Series fulfilling practically all plug and socket requirements in Public Address, Radio and kindred fields.

Rugged construction that will withstand hard usage.

Socket Contacts — Knife switch type. Phosphor bronze. Tin plated.
Plug Contacts — Hard brass. Tin plated. 1/4" x 1/16" cross section.
Insulation — Moulded bakelite.
Caps — Steel. Black crackle enamel, baked.

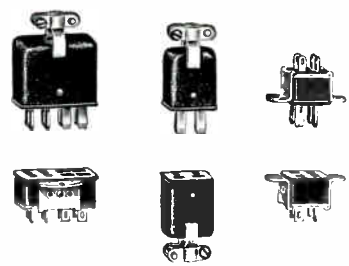
Made in 2, 4, 6, 8, 10 and 12 contacts

The best all around plug and socket at popular prices

"300" SERIES

Six numbers of over 100 in the 300 Series. A new line of HIGH GRADE small plugs and sockets, adaptable to thousands of uses. This series has already been purchased in large quantities by nationally known manufacturers of Radio and P.A. equipment.

Priced low, but should not be confused with plugs and sockets manufactured with the express purpose of selling below competition.



All plugs and sockets polarized. Made in 2 contacts to 33 contacts. Phosphor bronze "knife switch" type female contacts. Brass, tin plated male contacts, bar type 5/32" x 3/64" cross section. Moulded bakelite insulation. Drawn metal caps. Formed fibre linings. Simple assembly. Inexpensive.

TERMINAL PANELS

MANUFACTURERS! NOTICE!

For years we have been serving manufacturers on requirements for special terminal panels to blue print. Our line of terminals has been developed by customer needs and range from small sizes (2–56 screws), to large sizes (10–32 screws). Prompt quotation will be supplied upon receipt of blue print or sketch.

REQUEST YOUR CATALOG

Jobbers, No. J-38 • Manufacturers, No. M-38 • Radio Amateurs, A-38

HOWARD B. JONES

2300 Wabansia Avenue • Chicago, Illinois

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Radio Telegraph Apparatus by World's Champion

T. R. McELROY, 175 Congress St., Boston, Mass.

Exclusive European representative: C. Webb Ltd., 14 Soho St., London

"I've designed and built my semi-automatic and hand radio-telegraph keys in accordance with principles of balance and ease of operation that I've learned in 25 years as an active radio, cable and telegraph operator. Nearly anywhere in the world wherever dots and dashes are used, operators move more traffic with less effort with MAC brand keys."

DeLuxe MAC KEY
$9.50

Carefully selected and tested springs partially take the place of wrist and fingers. Fast, rhythmical Morse with little effort. Heavy one piece casting with beautiful and permanent marble finish. ¼" adjustment screws, 3/16" contacts; bakelite insulation throughout. Pigtails, dot stabilizer, circuit closer, case hardened bearings.

STANDARD MODEL, $7.50. Same key but some design and finish economies to lower cost.

JUNIOR MODEL, $4.95. Same main lever. Stamped steel base.

DeLuxe STREAM KEY
$2.25

The prettiest telegraph key I've ever seen! Heavy chrome plate, 3/16" contacts, superbly balanced main lever. My twenty-five years experience as an operator has gone into the design of the finest hand key human skill can build. Its action will positively delight any operator!

PROFESSIONAL, $1.80. All Brass
COMMERCIAL, $1.50. Chrome & Black
AMATEUR, $1.20. Cadmium & Black

These three keys on conventional type straight key base.

AC/DC AUDIO OSCILLATOR
$5.95

Molded bakelite case. Separate outputs for phones and modulation. Knob control tone selection. 600, 800, 1000 cycles. Complete with two 6C5G and one ballast tube. Ideal for operators and engineers.

OPERATOR'S PRACTICE SET
$2.95

Same prettily designed and balanced lever as all my keys. Mounted on heavy cast base. MAC HUMMER, mechanical oscillator 1000 cycles. Uses 6 volts or more. Apparatus that will remain prized long after the beginner's stage has been left behind.

"I've employed recent developments in the field of electronics to produce simply designed, ruggedly built, and low cost, completely automatic transmitting and receiving equipment. Trouble-free photo-electric cell circuit supplants intricate and costly mechanical principles. High speed ink recording direct from receiver output by application of newly discovered, economical means of signal rectification and positive pen action resultant from use of cast NIPERMAG magnets and special bobbins."

MAC AUTO
$29.75

Uses regulation inked slip. Light from exciter lamp onto photo-cell interrupted by inked dots and dashes. Amplified to give positive relay action. Key transmitter or local oscillator. Unequalled for training operators. Limitless supply tape available thru Recorder. Transmits perfectly up to 100 wpm.

MAC RECORDER

$29.75

Connects to output of communication receiver and records up to 100 wpm perfectly. Built-in transformer and rectifier. Complete in one unit. Merely throw switch to DC input and record your own sending. Anything recorded may be run through Mac Auto at any desired speed.

PRACTICE REELS
$1.00

25 different reels of practice slip available, 2000 words per reel.

TAPE PULLER

$12.00

For either AUTO or RECORDER. Speeds from 5 wpm to 100 wpm.

World Radio History

For RUGGED DEPENDABILITY

THOUSANDS of amateurs look daily to the Hoyt meters on their instrument panels for accurate, reliable information. They know that these meters are the result of thirty-four years of electrical manufacturing experience, and that Hoyt instruments are widely and favorably known throughout the radio and automotive fields.

Properly designed and soundly engineered these meters are built by the skilled fingers of New England Craftsmen. You can buy with assurance, and place full confidence in these rugged, time-tested dependable Hoyt meters.

Type 597 shown at the top, is the New Square Meter which measures 3″ across the face. It is a rugged D.C. instrument with a long scale. Accuracy is 2%; sensitivity 50 MV in the 0/1 MA range. A matching companion A.C. meter, Type 598, with pneumatically damped movement, is available in the same size.

At the right is the R.F. Antenna Meter (hot-wire type) No. 586. Used for measuring transmitter output, this instrument is unaffected by frequency changes. It is supplied in three ranges and three case styles.

Next down, is Type 582, a D.C. jewel-bearing, moving-coil instrument, measuring 3½″ across the bakelite case. The accuracy is 2%. At the bottom of the page is shown Type 584, an A.C. repulsion movement meter with jewelled bearings. The case is the same size as the 582 and both instruments have insulated zero adjusters.

All these attractive meters are priced to suit the amateurs pocket book. Ask your jobber for these instruments or send for our handy reference catalog on the complete Hoyt line.

BURTON-ROGERS CO.
SALES DIVISION OF THE HOYT
ELECTRICAL INSTRUMENT WORKS
857 BOYLSTON ST.
BOSTON MASS.

HOYT METERS

World Radio History

BIRNBACH PRODUCTS for the AMATEUR

50 and 10 WATT SOCKETS

Designed especially for U.H.F. work.
No. 434 — 50 watt socket. List, each $1.25
No. 435 — 10 watt socket. List, each .... .85

GIANT INSULATED PLUG

No. 392 with insulated handle. Fits into recess leaving *no* metal to contact hand. 3" overall. Red or black. List, each 50c

GIANT INSULATED JACK

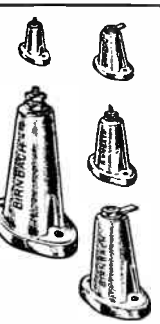
No. 393 leaves no exposed metal when mounted on panel. 1⅜" long, red or black. Complete with nut, insulating washer for ½" mtg. hole. List, each 40c

CONE INSULATORS

In a complete range of heights for condensers, coils, etc., threaded taps. White glaze.

No.	Heights	List
430	⅝"	10c
431	1"	15c
431J	1"	20c
432	1½"	20c
432J	1½"	25c
433	2¾"	25c
433J	2¾"	50c

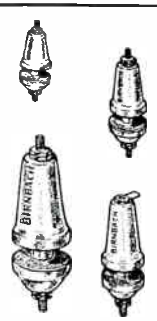
BIRNBACH STANDOFF INSULATORS



Come in fine, properly graduated heights to cover every need. Highly vitrified, low absorption porcelain used throughout. White only.

Cat. No.	Height	List Price
405	⅝"	$.065
966	1"	.075
966J	1"	.10
866	1½"	.12
866J	1½"	.15
866SJ	1½"	.35
4275	2¾"	.30
4275J	2¾"	.55
4450	4½"	.50
4450J	4½"	.75

FEEDTHRU STANDOFF INSULATORS



An original Birnbach development. Two pieces. Designed and proportioned for maximum strength. Brass nickel plated hardware supplied. White.

Cat. No.	Height	List Price
458	⅝"	$.12
478	1"	.20
478J	1"	.25
4125	1¼"	.25
4125J	1¼"	.30
4175	2¾"	.50
4175J	2¾"	.75
4234	2¾"	.55

AIRPLANE (EGG) INSULATOR

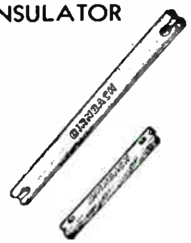
No. 473 — 2" List price ea. 7c
No. 474 — 1½" List price ea. 5½c

X'MTR LEAD-IN INSULATORS

Made of highly vitrified glazed porcelain. Feature low absorption.

Cat. No.		List Price
4235	10" rod	$ .90
4236	15" rod	1.00
4237	10" rod with bushings	1.20
4238	15" rod with bushings	1.50
4240	Bushings 1" long, ¾" Dia.	.05
4241	Bushing ½" long, ¾" Dia.	.05

BIRNBACH ANTENNA INSULATOR



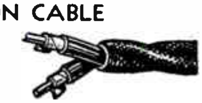
Unusually strong. Long leakage path.

Cat. No.	Length	List Pr. Ea.
470	7"	$.50
471	12"	.70
472	20"	1.50

FEEDER SPREADERS

Round edges to prevent chafing.
462 — 2" long. List 12c
464 — 4" long. List 15c
469 — 6" long. List 20c

E01 TRANSMISSION CABLE



Genuine Paper Wrap Mica Finish

Can be used any length to 1000 ft. Handles any power to 1 KW. Surge impedance of 72 ohms.
No. 956 — 100 ft. spool. List price $10.50
250, 500, or 1000 ft. lengths also available.

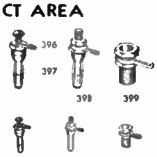
COPPERWELD ENAMEL ANTENNA WIRE

Steel core, copper covered, heavily enameled, low R.F. resistance. Fine for X'mitting doublet and directional antennae.
No. 10 Gauge — 100 ft. List price $2.60
No. 12 Gauge — 100 ft. List price 1.80
No. 14 Gauge — 100 ft. List price 1.25

Special lengths to order

BIRNBACH JACKS AND PLUGS

FEATURE LARGE CONTACT AREA



Cat. No.	Description	List Price
394.	Giant Jack, ⅜" Mtg. Hole 1 5/16" long	25c
395.	Giant Jack, ⅜" Mtg. Hole 15/16" long	25c
396.	Giant Plug, 10/32 threaded hole	25c
397.	Giant Plug, ¼–20 threaded hole	25c
398.	Giant Plug, ¼–28 threaded shank	25c
399.	Giant Jack, ½" mounting hole	25c
400.	Plug, 6/32 threaded shank ½" long	6c
401.	Plug, 6/32 threaded hole	7c
403.	Jack, ¼ threaded mounting hole	6c

BIRNBACH WIRE

The Birnbach wire department is geared to meet your every requirement. Anything and everything in wire and cable: Stranded bare, stranded tinned, stranded enamel, solid bare, solid tinned, solid enamel, stranded colored rubber, colored hookup, test lead wire, leadin, ground, magnet, antenna, hookup and slipback wire, mike, battery, S.J. cable.

GET OUR CATALOG

Hundreds of other Birnbach products are listed. Have a copy handy so you can consult it before ordering from your jobber.

BIRNBACH RADIO CO. INC., 145 HUDSON ST. BIRCO N.Y.C.

World Radio History

MASTER THE CODE WITH MASTER TELEPLEX

ALL ELECTRICALLY OPERATED
Just plug it in

THIS TAPE ➞ was made on MASTER TELEPLEX by "Bug" sending

YOU CAN'T GO WRONG WHEN YOU CAN SEE WHAT YOU ARE DOING!

THERE IS ONLY ONE WAY TO LEARN TO RECEIVE THE CODE SIGNALS AND THAT IS BY LISTENING TO THE SIGNALS. THERE IS ONLY ONE WAY TO LEARN TO SEND THE SIGNALS PROPERLY AND THAT IS BY BEING ABLE TO SEE AND HEAR YOUR OWN SIGNALS.

WITH MASTER TELEPLEX YOU LEARN THE CODE IN THE NATURAL, EASY, FASCINATING WAY. THERE IS NO GUESSWORK BECAUSE YOU ACTUALLY SEE AND HEAR WHAT YOU ARE DOING!

Learning to send PROPERLY is more difficult than learning to receive. Most people think sending is easy. Well, just ask the fellow who tries to receive it!

How do you make the letter "C"? Of course not like the third one shown below. But you might be surprised! Actually; most professional operators are astounded to see their sending recorded on MASTER TELEPLEX.

MASTER TELEPLEX will show you exactly how you make the letter "C" and all the rest of the characters. And it will show you how to make them correctly!

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The Rigs You Can Depend On!

More and more operators are realizing that only in a Gross transmitter can they obtain appearance, quality, performance and value. Really high power phones at amazingly low prices. Truly the "more watts per dollar" slogan takes on a new significance.

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NEW!! GROSS CB-250
RADIOPHONE TRANSMITTER

R.F. Line Up — 42 oscillator, 6L6G buffer, two Taylor TZ-40's amplifier. *Speech Amplifier* — 6C5, 6N7, 6N7, two 42's. *Modulator* — Two TZ-40's, separate power supply using one 80 and one 5Z3. *Power Supply* — Two 866 Jrs, one 83. *Antenna Unit* — Self contained antenna tuning unit. *Frequency Coverage* — 1.7, 3.5, 7, 14, 30 mc. *Power* — Radiophone and CW 250 watts input. *Cabinet* — Floor model, extremely compact size, finished in rich gray wrinkle lacquer.

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Profit by getting our prices before buying your Transmitter

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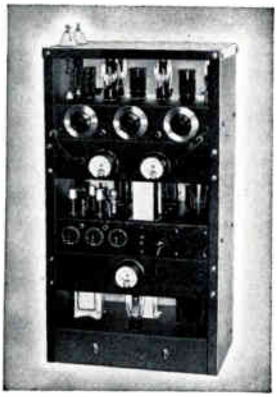
Gross presents another fine transmitter having real power at an amazingly low price.



CB-55
MODERATELY PRICED

Radiophone Transmitter

FB. FOR 30. MC.

Input — 95 watts. Uses 2–T20 tubes in R.F. and 6L6's in modulator. Coils available for 30, 14, 7, 3.5, and 1.7 mc.

Descriptive Bulletin on Request

Input — 150 watts Phone and C.W.

Coils available for 30, 14, 7, 3.5, and 1.7 mc.

Class B modulation

All the very latest type tubes used throughout

Completely self-contained from mike jack to antenna tuning unit

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Descriptive Bulletin on Request

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A-8	*Amps. 300. Per cell...*	7.00
A-10	*Amps. 375. Per cell...*	8.00
A-12	*Amps. 450. Per cell...*	10.00
B-4	*Amps. 90. Per cell...*	3.50
M-8	*Amps. 11. Per cell...*	1.00
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J-3	*Amps. 37. Per cell...*	3.00

For 32 Volt System — Less 10%
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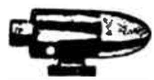
Complete with Trays and Connectors

DYNAMOTORS



Navy Aircraft Dynamotor. G.E. 24/1000 volts, 1 ampere, extended shaft giving 24 volts for filament and 1000 volts for plate. Value $250.00. Special price.............$50.00

Army AC generator, self excited 900 cycle, 200 watt 110 volt. 15 lb. "Westinghouse." Portable. Every lab. can use one. New $25.00.
Used....................$15.00

U. S. N. double current generator, 450 volt at 250 mills and 12 volts at 3.75 amp. Complete with filter. May be used as dynamotor, $25.00

GENERATORS

110 volt a.c. 400 cycle, self-excited 250 watts	$25.00
120 volt a.c. 600 cycle, self-excited 250 watts	25.00
110 volt a.c. 500 cycle, self-excited 250 watts	25.00
1500 volt d.c. 660 mills, 1 kw. Esco 1750 r.p.m.	45.00
240 volt a.c. 500 cycle, self-excited 2500 r.p.m. 250 watt equipped with hand drive	25.00
600 volt d.c. 2 kw.	45.00
220 volt a.c. 500 cycle 1 kw.	45.00
220 volt a.c. 500 cycle 2 kw.	60.00

MOTOR GENERATORS

120 volt d.c., 110 or 220 volt a.c., 500 cycle, 250 watt	$40.00 up
120 volt d.c., 110 or 220 volt a.c., 500 cycle, 500 watt	$40.00 *to* $100.00
120 volt d.c., 110 or 220 volt a.c., 500 cycle, 1 kw.	75.00 *to* 125.00
120 volt d.c., 110 or 220 volt a.c., 500 cycle, 2 kw.	50.00 *to* 200.00
120 volt d.c., 110 or 220 volt a.c., 500 cycle, 5 kw.	95.00 *to* 350.00
120 volt d.c./20 volt d.c. 2 kw.	60.00
120 volt d.c./400 volt d.c. 2 kw.	45.00
120 volt d.c./600 volt d.c. 2 kw.	65.00

CONVERTERS

120 volt d.c., 120 volt a.c., 60 cycle, 2 kw.	$85.00
32 volt d.c., 110 volt a.c., 400 mills	15.00
32 volt d.c., 110 volt a.c., 800 mills	20.00
"Dayton" Input 110 a.c., 60 cycle. Output 450 d.c. at 80 mills and 7 d.c. at 1.75 amps. 1750 r.p.m. has extended shaft	15.00

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Said to have cost in excess of $130.00. Now..............$12.50

Formerly used on large calibre guns. Makes an excellent finder. Has many other uses. Consists of an optical system of 7 lenses, main telescope tube, erector draw tube and eyepiece draw tube. Also excellent scope for spotting game or targets. Object Lens 2"; Variable, magnifies from 3 to 10 power; Exit pupil 0.2" to 0.09"; Eye Lens 15/16". All bronze and brass. Cross Hairs, Angular field 3°30′ to 12°; Erect image. Weight 6 lbs. Limited amount. Each..$12.50

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Ward Leonard Vitrohm Rheostats. Variable 500 ohm, .2 to 1.5 amp., 35 taps....................................$5.00
Ward Leonard Vitrohm Rheostats. Variable 6 ohm, 15 to 5 amp. battery charging type...............................$3.50

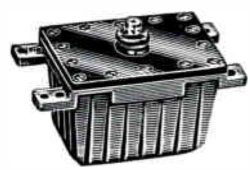
United States Government

NEW FIRE EXTINGUISHER

Carbon tetrachloride (pyrene liquid); pressure type; ideal for laboratories, etc., trucks, etc., boats, gas stations.
(10 times more pressure than hand extinguishers.) Just turn handle. No pumping necessary.
(Original cost $40.00)
1 qt. (100 lbs. pressure)............$9.85
2 qts. (200 lbs. pressure)..........$14.95

Dynamotor, 32/350 volt, ball bearing, 80 mills.
Special price.....................$9.00
Per pair..........................15.00

CONDENSERS



Mica Condensers, .004 mfd., 12,500 V. operating:

Dubilier, new	$6.00
Dubilier, used	4.00
Wireless Spec., new	5.00
Wireless Spec., used	2.50
8500 Volt, .0004 mfd.	4.00
8500 Volt, .004 mfd.	4.00

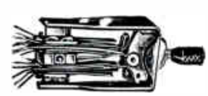
Murdock Condensers:
.002 mfd., 5000 Volt....$1.00
.002 mfd., 12,000 Volt... 2.50

Wireless Spec. copper glass leyden jar, 10,000 working voltage, .002 mfd.......... 2.00

Dubilier Condenser. CD-1494 mica .0006 mfds., 25,000 volts. Price...............$10.00

Western Electric type 21AA Condensers. 1000 V. a.c. test. 1 mfd. Use in series parallel for high capacity and voltage. Each..................$.75

Western Electric type 21AB Condensers. 1000 V. a.c. test. Three capacities, .125, .25 and .5 mfd. Each............$.75



Anti-Capacity Switches, Western Electric 14 terminals, platinum contacts, both sides locking, value $3.50 each. Special $.95

12 terminal, one side momentary, other side locking...$.95

Lightning switch, navy, ceiling type, heavy brass. Handle 5 kw. Beautiful piece of equipment. Special..........$4.50

KEYS

Army Transmitting key. ¼" Silver contacts. With blinker light. Special..........$1.50

Aircraft key. Silver contacts. Beautiful instrument....$1.50

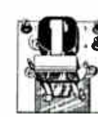
U. S. Army Telegraph Practice sets. Key and 4 ohm sounder mounted on baseboard. $2.50

WE Microphone with breast plate, light weight type, carbon button — a very excellent and sensitive microphone....$1.95

RELAYS

West. Elect. low voltage relay. 2 upper and 3 lower plat. point screws; 3 contact arms. Price.................$2.50

Relays. 5 kw. 110 or 220 V. d.c. ⅝" silver contacts. Price.................$7.50



AC Relay, single pole, double throw, silver contacts, will handle 30 amps. 110 or 220 volt. $3.00

WE Army Field Telephone Set, Magneto ringing, Battery talking. Also buzzer phone. Complete, sending key, microphone, headphones............$7.50

Drop and Jack combination. (Plug resets drop) 350 ohms 6 to 24 volts. Good switchboard item. Price, each.......$1.50

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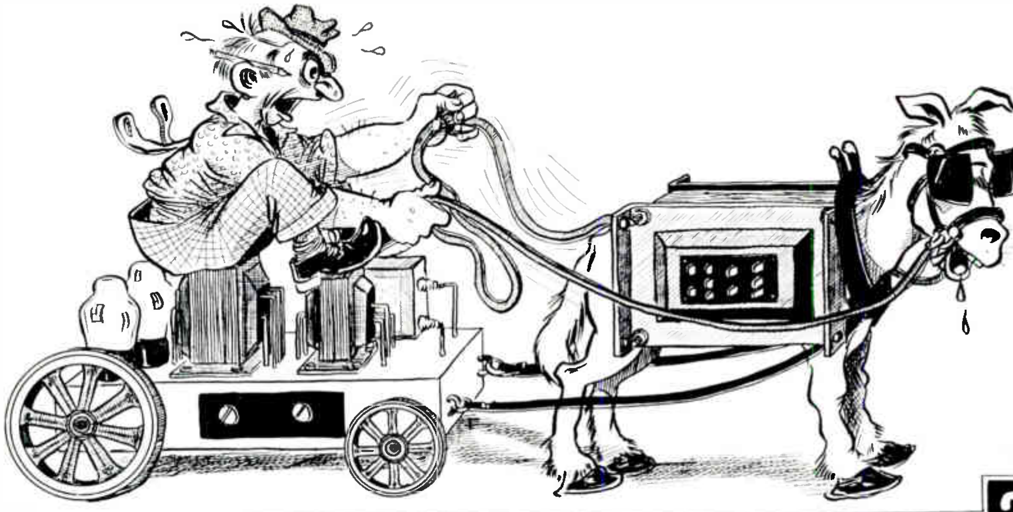

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represent the last word in modern transformer design . . . thoroughly dehydrated and impregnated under special **36-hour vacuum-varnish treatment** . . . **hermetically sealed** against atmospheric changes with non-hygroscopic humidity-proof compound in **one attractive style steel casing** for that uniform, commercial-looking layout, and also provide facilities for **universal mounting** in either upright or inverted positions . . . and last, but not least, the highest grade materials, workmanship and advanced transformer engineering skill incorporated throughout . . . all of which means better all-around performance in any radio assembly.

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DON'T BE MISLED!

to accept substitutes for genuine KENYON T-line transformers. Look for the KENYON Diamond-K trade mark and "T" line type number. A complete line for every amateur transmitter application, including television equipment. Ask for the Kenyon T-line catalog.

If your local jobber-dealer cannot supply you with Kenyon T-line components send us his name together with your order enclosing your remittance at regular amateur discounts (40% off list prices) and we will ship your order direct, prepaid anywhere in the U. S. A.

KENYON TRANSFORMER COMPANY, INC.

840 BARRY STREET • • NEW YORK, N. Y.

Export Department 25 Warren St., New York, N. Y.

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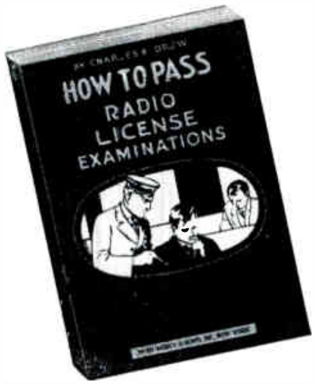

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Questions and answers for the amateur who is preparing for commercial exams, for the radiotelegraph operator, the radiotelephone operator, and all prospective commercial radio licensees.

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201 pages; 6½ by 9⅝
73 illustrations
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HOW TO PASS
RADIO LICENSE EXAMINATIONS

By Charles E. Drew, I.R.E., A.I.E.E.

This book is more than just a new edition of a famous work. It has been completely rewritten. It will serve as an excellent guide to all radiomen, whether interested in broadcasting, marine, aeronautical, or any other field of radio transmission and reception. The concise presentation of the essential questions and answers which the operator must know makes it easy to follow. Important phases of the subject are given thorough treatment, so that the man who understands the content of this book will be well qualified to pass the examination for his commercial license.

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Rectifier tubes for supplying high-voltage for tube operation

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The procedure for changing operating power and operating on a new transmitting frequency

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Radio laws and regulations

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Light Weight, with plug at microphone, (an "American" feature)
Permitting Quick Cable Adjustment

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A Most POPULAR *Pickup*

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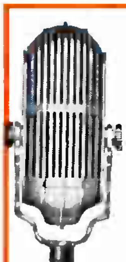

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Pickup from FRONT only — High Output
Good Response

D9T. 10,000 ohms, 25' cable. List. $37.50
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Available on order in 200 or 500 ohms. List. . . . $37.50

Bulletin No. 29 contains complete technical information

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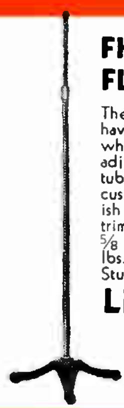
AMERICAN CARBON MICROPHONES

MODEL EL4 DOUBLE-BUTTON MICROPHONE

EL4
LIST
$7.50

Cast Grille. Chrome finish. Dependable performance. Excellent value. Complete with ⅝ x 27 mounting yoke and screw eyes for suspension.



FH3 AND FL3 FLOOR STANDS

The FH-3 and FL-3 Floor Stands have a positive action, friction lock which assures reliable, noiseless adjustments; insulated, heavy steel tubing; and three-contact rubber cushioned, "Floor Grip" Base Finish baked Satin Black with chrome trim. Adjustable to full six feet. ⅝ x 27 thread FH-3 Net Wt 15 lbs., FL-3, Net Wt 8 lbs., FH-3, Studio Model, Code: FUHET

List. $15.50

FL-3, Lighter Model, Code: FLEXR.
List Price $10.50

MODEL DB2

This double button mike is built to withstand rough usage. No rubbing noises are transmitted from the case to the microphone. Switch in handle.

Output constant between upper and lower limits of speaking voice. Chrome finish. 12' cord. 200 ohms resistance per button.

DB2
LIST
$15.00

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"Microphones of Quality"

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Bliley

TYPE VF1

Enjoy clear channels with a variable frequency crystal unit. The crystal frequency is continuously variable up to 6kc. with the 80-meter unit or 12kc. with the 40-meter unit. When multiplying, the variation is proportionally increased. The specially ground crystals have a drift of less than 4 cycles/mc./°C. and an activity only somewhat less than high activity fixed-frequency crystals.

Price—40-meter band, minimum frequency ±15kc. of specified	$7.50
Price—40-meter band, minimum frequency ±5kc. of specified	$10.00
Price—80-meter band, minimum frequency ±5kc. of specified	$7.50
Price—80-meter band, minimum frequency at exact integral specified kc.	$10.00

TYPE LD2

The outstanding amateur crystal unit for the 80 and 160-meter bands. It contains a powerful, highly active crystal with a frequency drift of less than 4 cycles/mc./°C. Correctly designed and precision ground, this time-proven unit will give accurate dependable crystal control.

Price—±5kc. of specified frequency*	$4.80
Price—at exact integral specified frequency	$5.90

TYPE BC3

The Type BC3 crystal unit is a popular, economically priced mounted crystal with unusual activity and power output. It has a frequency drift of only 23 cycles/mc./°C. Now available for the 160-meter as well as for the 40 and 80-meter bands. An exceptional value.

Price—40, 80-meters, ±5kc. of specified frequency*	$3.35
—at exact integral specified frequency	$4.95
Price—160-meters, ±10kc. of specified frequency	$3.35

TYPE CF1

No modern communications receiver is complete without a crystal filter. The Bliley CF1 Crystal Filter Unit, with its high Q and freedom from spurious responses, assures maximum selectivity and minimum signal loss.

Price—456kc., 465kc. or 500kc., I. F.	$5.50
—1600kc., I. F.	$9.50

All prices shown are net in U. S. A.
*Or choice from dealer's stock

The Bliley Electric Company also manufacturers crystals, holders and ovens for operation at any frequency between 20kc. and 30mc. Bliley broadcast frequency crystals and ovens are approved by F. C. C.

BLILEY ELECTRIC CO.,

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CRYSTALS

TYPE B5

A superior crystal unit for the 20 and 40-meter bands. The correctly proportioned crystal, mounted in its individually designed holder, is distinctive in performance. Frequency drift is less than 4 cycles/mc./°C.

Price—7.0 to 7.3mc., ±5kc. of specified frequency*	$4.80
—at exact integral specified frequency .	$5.90
Price—14.0 to 14.4mc., ±15kc. of specified frequency	$7.50
—±5kc. of specified frequency . .	$12.00
Price—14.4 to 15.0mc., ±30kc. of specified frequency	$7.50
—±5kc. of specified frequency . .	$17.50

TYPE HF2

Bliley pioneered high frequency crystals with the HF2 20-meter unit. Now, with the addition of the HF2 10-meter unit, the many advantages of simplified crystal control are extended to the 5-meter band. Frequency drift is 20 cycles/mc./°C. for the 20-meter unit and 43 cycles/mc./°C. for the 10-meter unit.

Price—14.0 to 14.4mc., ±15kc. of specified frequency*	$5.75
—±5kc. of specified frequency . .	$10.00
Price—14.4 to 15.0mc., ±30kc. of specified frequency*	$5.75
—±5kc. of specified frequency . .	$15.00
Price—28.0 to 30.0mc., ±50kc. of specified frequency	$5.75

TYPE SMC 100

The Type SMC100, dual-frequency crystal unit, offers a means for constructing a simple, flexible, inexpensive frequency standard. It is ideal for checking receivers and signal generators. Calibration is ±.01% at 100kc. and ±.05% at 1,000kc.

Price	$7.75

TYPE SOC 100

A precision mounted 100kc. bar for accurate calibration of frequency meters, test oscillators, radio receivers or for performing general frequency measurements. Temperature coefficient is less than 3 cycles/mc./°C. The oscillator tank coil is included in the mounting.

Price—Type SOC100	$15.50
Price—Type SOC100X mounted 100kc. X-cut bar (no tank coil included) . .	$9.50

All Bliley Crystal Units described on these pages, with the exception of the Type SMC100, fit standard 5-prong tube sockets.

Engineering Bulletin E-6, FREQUENCY CONTROL WITH QUARTZ CRYSTALS, should be read by every amateur and engineer. Price, 10¢ (Canada 15¢). Descriptive catalogs of Bliley Crystals are available at no charge.

ERIE, PENNSYLVANIA

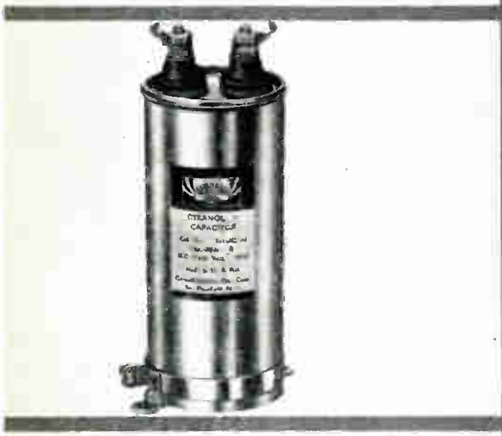
World Radio History

CORNELL

DYKANOL TRANSMITTING CAPACITORS — TYPE TJU

A notable record of performance of these hermetically sealed, proof Dykanol capacitors is attested by the fact that they rarely in service when operated even at 10% higher voltage than rating. complete technical data and listing see Catalog No. 161.

Cat. No.	Capacity Mfd.	Working Voltage, d.c.	
TJU-6020	2	600 v	$
TJU-6040	4	"	
TJU-10020	2	1000 v	
TJU-10040	4	"	
TJU-15020	2	1500 v	
TJU-15040	4	"	
TJU-20020	2	2000 v	
TJU-20040	4	"	
TJU-30020	2	3000 v	1
TJU-30040	4		2



CYLINDRICAL CASE DYKANOL TRANSMITTING CAPACITOR
TYPE TQ

Type TQ are genuine Dykanol, fireproof transmitting filter cap tors that can be mounted vertically or inverted by means of mounting ring supplied. Equipped with neat porcelain termi Real Values — never before offered to the trade.

Cat. No.	Capacity Mfd.	Working Voltage, d.c.	
TQ-6020	2	600 v	$
TQ-6040	4	"	
TQ-10010	1	1,000 v	
TQ-10020	2	"	
TQ-10040	4	"	
TQ-15010	1	1,500 v	
TQ-15020	2	"	
TQ-20010	1	2,000 v	
TQ-20020	2		

DYKANOL FILTER UNITS — TYPE TLA

These fireproof units are encased in cylindrical aluminum tainers, are not only classical in appearance but also in performa They solve the need for a compact high voltage filter capacitor to with high fidelity P. A. amplifiers, power supplies for short portable transmitters and transceivers. Type TLA will withs transient voltages as well as high peak voltage surges and is desi to operate for continuous, full load duty.

Cat. No.	Capacity Mfd.	Working Voltage, d.c.
TLA-6020	2	600 v
TLA-6040	4	600 v
TLA-10020	2	1000 v

CORNELL-DUBILIER ELECTRIC CORPORATI

X-MITTING C

World Radio History

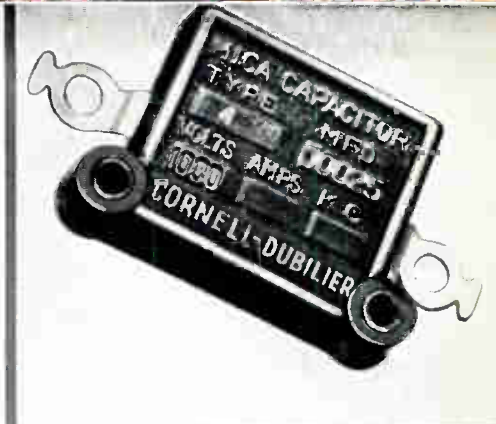
DUBILIER

MICA RECEIVING-TRANSMITTING CAPACITORS — TYPE 4

he evolution of the original small "micadon" capacitor has resulted the perfection of Types 4 and 9 mica units. Effectively used for r.f. /pass, high voltage D.C. blocking, low power tank capacitors, ıdders, coupling functions, audio and video purposes.

ype 4 uses short solder-lug terminals and has insulated mounting ɔles for panel mounting.

ıt. No.	Capacity Mfd.	Test Voltage, d.c.	List Price	Cat. No.	Capacity Mfd.	Test Voltage, d.c.	List Price
6Q5	.00005	1000 v	$ .35	4-12D2	.002	2500 v	$ .95
6T1	.0001	"	.35	4-12D5	.005	"	1.50
6D1	.001	"	.40	4-12S1	.01	"	2.35
6D2	.002	"	.45	4-25Q5	.00005	5000 v	.70
6D6	.006	"	.65	4-25T25	.00025	"	.90
6S1	.01	"	.80	4-25T5	.0005	"	1.25
6S2	.02	"	1.20	4-25D1	.001	"	1.50
12Q5	.00005	2500 v	.60	4-25D2	.002	"	2.25
12D1	.001	"	.75	4-25D5	.005	"	3.50



MICA RECEIVING-TRANSMITTING CAPACITORS — TYPE 9

he terminal studs on Type 9 are moulded into case.

ıt. No.	Capacity Mfd.	Test Voltage, d.c.	List Price	Cat. No.	Capacity Mfd.	Test Voltage, d.c.	List Price
6Q5	.00005	1000 v	$ .40	9-12T5	.0005	2500 v	$ .70
6T25	.00025	"	.40	9-12D1	.001	"	.90
6D1	.001	"	.50	9-12D2	.002	"	1.35
6D2	.002	"	.50	9-12S1	.01	"	2.80
6D5	.005	"	.70	9-25Q5	.00005	5000 v	.90
6D6	.006	"	.85	9-25T25	.00025	"	1.05
6S1	.01	"	1.15	9-25D1	.001	"	1.50
6S5	.05	"	3.85	9-25D2	.002	"	2.25
12Q5	.00005	2500 v	.70	9-25D5	.005	"	3.40
12T1	.0001	"	.70	9-25S1	.01	"	4.10
12T25	.00025	"	.70				

MICA TRANSMITTING CAPACITORS — TYPE 86

y selecting the very best grade of India ruby mica, the Type 86 ıpacitors have a very low r.f. resistance and power-factor, but ex-remely high D.C. resistance and negligible power losses. The patented esign has eliminated corona and reduces internal heating, so that ne Q quality characteristic is exceptionally high.

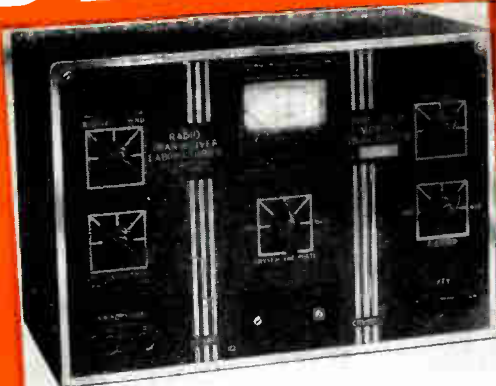
			Max. Current in Amps.					
ıt. No.	Capacity Mfd.	Max. D.C. Voltage	30mc 10M	1500kc 20M	7500kc 40M	3750kc 80M	1875kc 160M	List Price
IA-86	.0001	12,500	5	5	4	3	2	$3.57
5A-86	.00025	12,500	5	7	8	6	4	3.75
A-86	.0005	12,500	5	8	9	8	7	4.25
C-86	.0005	7,000	5	7	8	6	4	3.75
IA-86	.001	12,500	5	9	10	11	12	5.00
IC-86	.001	7,000	5	8	9	10	8	4.25
5A-86	.0015	12,500	6	9	10	11	12	5.50
A-86	.002	12,500	6	9	12	13	15	6.50
C-86	.002	7,000	6	8	9	10	10	5.25
B-86	.005	10,000	7	10	13	14	15	9.50
C-86	.01	7,000	7	10	13	15	15	9.50

11 HAMILTON BLVD., SO. PLAINFIELD, N. J.

APACITORS

World Radio History

DEPENDABILITY...



★ **TYPE HFM TRANSMITTER:** ● The Transmitter of the Future ● Six Bands 1715 — 60,000 K.C. on two crystals ● All Frequencies Crystal Controlled ● Instantly Changeable Mobile or Portable ● Final Tube Input 21 to 36 Watts. **Net to Amateurs**...... **$57.60**

★ **"COMPACT 6" TRANSMITTER-RECEIVER:** ● A Six Tube 2-volt version of the TR-8 ● Crystal or M.O.P.A. Transmitter ● Batteries self contained ● Final tube input 4 Watts.
Net to Amateurs........................ **$38.50**

★ **TYPE TR-8 TRANSMITTER-RECEIVER:** ● The proven dependable 5 meter TR-7 revised for new regulations ● Reliable tuned R.F. super-regenerative four tube receiver ● Crystal Control or M.O.P.A. Transmitter ● 21 to 36 Watts input to final.
Net to Amateurs........................ **$62.70**

★ **TYPES PTR and PTRX:** ● Pack Transmitter-Receiver for Broadcasting Stations ● Audio Fidelity ± 1db. 30–20,000 cycles ● Type PTR M.O.P.A. Type PTRX crystal control ● Final input power 4 Watts. **Net to Broadcasting Stations**.... **$150.00**

★ **TYPE R510 RECEIVER:** ● The receiver of the TR-8 unit in a smaller cabinet ● Excellent for Fixed or Mobile reception ● Plug-in coils 5–10 meters.
Net to Amateurs........................ **$28.00**

★ **FIELD STRENGTH METER:** ● Tuning an Antenna is largely guesswork without a field intensity meter ● Exceptional sensitivity using a 1 B 4 and 22½ volt integral battery ● Band switching 1715 — 60,000 Kc. **Net to Amateurs**............. **$18.50**

WRITE FOR BULLETINS

RADIO TRANSCEIVER LABORATORIES

8627 115 STREET   RICHMOND HILL, NEW YORK CITY

CABLE ADDRESS: "RATRALAB", NEW YORK

World Radio History

ELECTRICAL MEASURING INSTRUMENTS

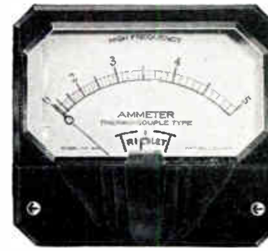
TRIPLETT

A NEW CONCEPTION OF QUALITY

Model 327

Model 321

Model 529



Model 446

Today's Most Modern Instruments . . . 18 styles . . . round, square and fan cases . . . 2", 3", 4", 5", 7" and twin models . . . Front and rear illumination . . . Triplett's complete line includes voltmeters, ammeters, milliammeters, millivoltmeters, microammeters, thermo ammeters, decibel meters and instrument relays.

New methods and extremely accurate processes representing years of instrument building experience are embodied in Triplett designs. First considerations are for dependable accuracy, simplicity, and the best application of the fewest number of parts. Long research has resulted in the development of a super magnet (the heart of the instrument) by means of which it has been possible to eliminate extra pole pieces. This achievement has brought from prominent laboratories graphs that prove Triplett magnets give more uniform scale characteristics. Magnet air gaps are absolutely uniform because they are made without tolerance after hardening has been completed.

Similar painstaking methods apply to aging of all materials after processing; to relieve strains and assure proper adjustments. All instruments are double checked in separate departments. Extreme care also is taken in selecting pivots and jewels and applying them in exact alignment. Infinite care is observed thruout the entire process of manufacture to assure the ultimate in instrument value.

MODEL 1295 MODULATION MONITOR

Actual modulation percentage of radio transmitters is shown on the direct reading dial of Model 1295. Ranges 40 to 120 per cent. This unit eliminates the uncertainty of depending on the ear, variation of antenna ammeter or the loop and light in determining carrier shift and percentage of modulation.

Net Price in U. S. A. $24.83

Vacuum Tube Voltmeters and a complete line of radio test equipment also are available. Write for free instrument and tester catalogs.

Model 666
Volt-Ohm-Milliammeter

Handy . . . For 1000 Uses

Model 666 A. C.-D. C. Pocket Volt-Ohm-Milliammeter is of convenient pocket size . . . A. C.-D. C. Volts 0-10-50-250-500-1000 at 1000 ohms per volt; 0-1-10-50-250 D. C. Milliamperes; Low Ohms, ½ to 300; High Ohms to 250,000 with provisions for higher resistance measurements by using external batteries.

Net Price in U. S. A. $15.00

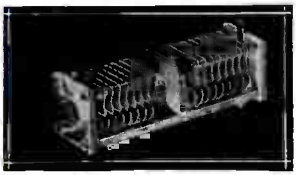
THE TRIPLETT ELECTRICAL INSTRUMENT COMPANY

888 HARMON DRIVE **BLUFFTON, OHIO, U. S. A.**

World Radio History

CARDWELLS *for every purpose*

"TRIM-AIR" MIDGET CONDENSERS



ET-30-AD

Complete line of single units with New Dual Trim-Air series to match. Universally used for high frequency portable equipment, exciter units and low power transmitters. Detachable shafts on singles leaves screw driver slot and lock provides permanent adjustment for fixed tune. Singles require 1 5/16" x 1 13/32" panel mount space and duals 1 45/64" x 1 13/32" condenser open. All Duals double bearing, shaft extended at rear for coupling and have removable intersection shield except "ganged neutralizer" types. All Trim-Airs have Isolantite insulation, ¼" nickel plated brass shaft; aluminum plates. All Trim-Air Accessories fit both single and dual units.

★ *SINGLE "TRIM-AIRS"*

Type	Max. Cap.	Min. Cap.	Nr. Plates	Air Gap	Depth Back Panel	List Price	Dealers Price
ZU-75-AS	75	2.7	15	.020"	1 5/16"	$1.70	$1.02
ZU-100-AS	100	3	19	.020"	1 7/16"	1.75	1.05
ZU-140-AS*	140	5	27	.020"	1 7/8"	3.15	1.89
ZR-10-AS	10	1.2	3	.030"	15/16"	1.25	.75
ZR-15-AS	15	1.5	5	.030"	15/16"	1.25	.75
ZR-25-AS	25	2	7	.030"	1"	1.40	.84
ZR-35-AS	35	2.5	11	.030"	1 5/16"	1.50	.90
ZR-50-AS	50	2.8	13	.030"	1 5/16"	1.60	.96
ZV-5-TS	5	1.8	3	.061"	15/16"	1.25	.75
ZT-15-AS	15	3	9	.070"	1 7/16"	1.55	.93
ZT-30-AS	30	4	17	.070"	2 1/8"	1.85	1.11
ZS-4-SS	4	1.5	5	.140"	1 5/16"	1.85	1.11

* Double bearing; two end plates.
† Supplied with 2 segment stator for 5 meter circuits. Extra plate also supplied; easily installed; makes it 3 plates as listed.

★ *DUAL "TRIM-AIRS"*

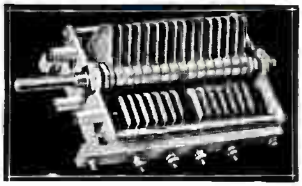
Type	Max. Cap.	Min. Cap.	Nr. Plates	Air Gap	Depth Back Panel	List Price	Dealers Price
EU-75-AD	75	2.7	15	.020"	3 5/8"	$3.30	$1.98
EU-100-AD	100	3	19	.020"	3 5/8"	3.40	2.04
EU-140-AD	140	5	27	.020"	4 9/32"	6.00	3.60
ER-10-AD	10	1.2	3	.030"	2 25/32"	2.60	1.56
ER-15-AD	15	1.5	5	.030"	2 25/32"	2.60	1.56
ER-25-AD	25	2	7	.030"	2 25/32"	2.70	1.62
ER-35-AD	35	2.5	11	.030"	3 5/8"	2.90	1.74
ER-50-AD	50	2.8	13	.030"	3 5/8"	3.10	1.86
ET-15-AD	15	3	9	.070"	3 5/8"	3.00	1.80
ET-30-AD	30	4	17	.070"	5 3/32"	3.60	2.16
ET-30-ADI*	With insulated coupling				5 21/32"	4.10	2.46
ES-4-SDI*	4	1.5	5	.140"	3 5/8"	4.10	2.46
ES-7-SDI*	7	4.0	7	.140"	4 3/8"	4.50	2.70

* Ganged neutralizers with insulated coupling.

Cardwell Trim-Air Condenser Accessories may be purchased separately as follows: Mounting Bracket, with two screws and nuts, 10c list. Dealers' Price 6c. Mounting Posts, (one pair required per condenser) with screws and locking washers — per pair, 13c list. Dealers' Price 8c. Extra Extension Shafts with setting nut, 7c list. Dealers' Price 4c.

MIDWAY FEATHERWEIGHT CONDENSERS

For low and medium power transmitters and receivers, where light weight and small space are factors. Ideal for portable and aircraft equipment. Panel mounting space only 2⅛" x 3" condenser open. ¼" steel shaft; aluminum frame; brass bearings; plates buffed, rounded on all airgaps .070" or over. Supplied with aluminum mounting feet. G. E. Mycalex insulation.



MT-70-GD

★ *SINGLE MIDWAYS*

ALSO FOR LOW POWER TRANSMITTERS

Type	Max. Cap.	Min. Cap.	Nr. Plates	Air Gap	Depth Back Panel	List Price	Dealers Price
MR-25-BS	25	5	3	.030"	2 17/32"	$2.70	$1.62
MR-50-BS	50	6	5	.030"	2 17/32"	2.80	1.68
MR-70-BS	70	7	7	.030"	2 17/32"	2.95	1.77
MR-105-BS	105	8	11	.030"	2 17/32"	3.05	1.83
MR-150-BS	150	10	15	.030"	2 17/32"	3.15	1.89
MR-260-BS	260	11	25	.030"	3 17/32"	3.30	1.98
MR-365-BS	365	14	35	.030"	3 17/32"	3.80	2.28
MO-165-BS	165	15	25	.050"	3 17/32"	3.30	1.98
MT-20-GS	20	5	5	.070"	2 17/32"	3.25	1.95
MT-35-GS	35	6	7	.070"	2 17/32"	3.50	2.10
MT-50-GS	50	8	11	.070"	2 17/32"	3.90	2.34
MT-70-GS	70	10	15	.070"	3 17/32"	4.45	2.67
MT-100-GS	100	12	21	.070"	3 17/32"	4.90	2.94
MT-150-GS	150	16	31	.070"	4 15/32"	6.00	3.60
MG-35-NS	35	12	15	.171"	4 15/32"	6.00	3.60

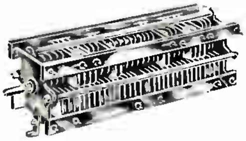
★ *DUAL MIDWAY CONDENSERS*

Type	Max. Cap.	Min. Cap.	Nr. Plates	Air Gap	Depth Back Panel	List Price	Dealers Price
MR-25-BD	25	5	3	.030"	2 17/32"	$4.35	$2.61
MR-50-BD	50	6	5	.030"	3 17/32"	4.70	2.82
MR-70-BD	70	7	7	.030"	3 17/32"	4.90	2.94
MR-100-BD	100	8	11	.030"	3 17/32"	5.10	3.06
MR-150-BD	150	9	15	.030"	3 17/32"	5.30	3.18
MR-260-BD	260	11	25	.030"	4 15/32"	5.50	3.30
MO-180-BD	180	15	29	.050"	6 5/32"	8.00	4.80
MT-20-GD	20	6	5	.070"	3 17/32"	5.55	3.33
MT-35-GD	35	7	7	.070"	3 17/32"	6.00	3.60
MT-50-GD	50	9	11	.070"	3 17/32"	6.35	3.81
MT-70-GD	70	10	15	.070"	4 15/32"	7.00	4.20
MT-100-GD	100	13	21	.070"	5/32"	8.00	4.80

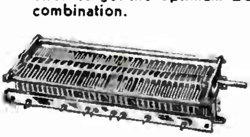
NOTE — Capacities and number plates are per section.

MULTI-BAND CONDENSERS

Notice how popular air wound coils such as Coto and B & W readily adapt themselves to these effective capacity ranges for push-pull balanced circuits, and flexibility of ranges for you fellows who "roll your own" tank coils in an effort to get the optimum LC combination.



FEX



XE-160-70-XQ

EFFECTIVE BALANCED CAPACITY RANGES AVAILABLE BY PROPER CONNECTIONS TO COIL

Type	Cap. Ranges	List Price	Dealers Price
XE-160-70-XQ	9– 34 mmfd 13.5– 83 " 19–114 "	$22.00	$13.20
FEX	5.8– 18.5 mmfd 7–35 " 10–50 " 19–120 "	$25.00	$15.00

World Radio History

"X" TYPE TRANSMITTING

Standard of Comparison for Years. Heavy aluminum rounded plates; frames and tie rods nickled brass; ball thrust type rotor bearing; phosphor bronze rotor contact; nickled brass bushings; steel shaft supports rotor plates and spacers. "G.E." Mycalex insulation. Frame measures 3⅜" x 4". Supplied with mounting feet. Shafts ¼".

XD-160-XD

★ "X" TYPE STANDARD SINGLES

Type	Max. Cap.	Min. Cap.	Nr. Plates	Air Gap	Depth Back Panel	List Price	Dealers Price
XT-220-PS	220	20	21	.070"	4"	$4.50	$2.70
XT-440-PS	440	40	43	.070"	5 13/16"	7.70	4.62
XP-90-KS	90	16	11	.084"	2 7/8"	4.50	2.70
XP-165-KS	165	22	19	.084"	4"	6. 0	.90
XP-290-KS	290	35	33	.084"	5 13/16"	9.50	5.70
XP-330-KS	330	37	37	.084"	6 3/8"	10.80	6.48
XE-240-KS	240	30	33	.100"	6 3/8"	10.80	6.48
XG-25-KS	25	8	5	.171"	2 13/16"	3.50	2.10
XG-50-KS	50	15	11	.171"	3 15/16"	6.50	3.90
XG-110-KS	110	26	23	.171"	6 7/16"	9.70	5.82
XC-18-XS	19	8	5	.200"	2 7/8"	5.50	3.30
XC-40-XS	40	15	11	.200"	4"	7.50	4.50
XC-65-XS	65	20	17	.200"	5 13/16"	9.50	5.70
XC-100-XS	100	28	25	.200"	7 7/16"	11.50	6.90

★ "X" TYPE STANDARD DUALS

Type	Per Section			Air Gap	Depth Back Panel	List Price	Dealers Price
	Max. Cap.	Min. Cap.	Nr. Plates				
XR-500-PD	500	18	21	.030"	4"	$6.50	$3.90
XT-80-PD	80	11	9	.070"	4"	5.50	3.30
XT-210-PD	210	22	21	.070"	5 13/16"	8.70	5.22
XP-90-KD	95	15	11	.084"	4 1/2"	7.50	4.50
XP-165-KD	165	23	19	.084"	6 1/2"	11.00	6.60
XP-325-KD	325	38	37	.084"	11 1/16"	22.00	13.20
XE-240-KD	240	32	33	.100"	11 1/16"	21.00	12.60
XG-50-KD	50	14	11	.171"	6 7/16"	10.70	6.42
XG-110-KD	110	27	23	.171"	11 1/16"	18.00	10.80
XC-40-XD	40	14	11	.200"	7 7/16"	13.00	7.80
XC-75-XD	75	21	19	.200"	11 1/16"	17.00	10.20
XD-160-XD	160	28	27	.125"	11 1/16"	19.00	11.40

H.F. NEUTRALIZING CONDENSERS

High frequency neutralizers for low capacity tubes. Mycalex insulation; heavy buffed plates with rounded edges. 180 degree rotation permits calibration and reset.

NA-16-NS

Type	Max. Cap.	Min. Cap.	Nr. Plates	Air Gap	Depth Back Panel	List Price	Dealers Price
NA-4-NS	4	2.5	2	adj.	1 3/8"	$3.60	$2.16
NA-6-NS	6	4	3	.218"	1 3/16"	3.60	2.16
NA-10-NS	11	6	6	.218"	2 1/8"	4.50	2.70
NA-16-NS	16	7	8	.218"	2 9/16"	5.00	3.00
NA-12-ND*	12	6	7	.218"	5 25/32"	15.00	9.00

* Ganged neutralizer with insulated coupling; Information given is per section.

PLUG-IN FIXED CONDENSERS

Type "J" Plug-in Fixed Air Condensers for boosting a tank circuit designed for 20 and 40 meters to 80 and 160. Just plug-in proper "J" unit into Jack Base and load tank to proper "C", for the lower frequencies.

Type	Capacity mmfds.	Air Gap	Length	List	Dealers Price
JCO-50-OS	50	.250"	5 3/8"	$5.50	$3.30
JCO-25-OS	25	.250"	3 3/4"	4.00	2.40
JD-80-OS	80	.125"	4"	5.50	3.30
JD-50-OS	50	.125"	3 3/16"	4.00	2.40
JD-25-OS	25	.125"	2 1/2"	2.80	1.68
JR-750-OS	750	.030"	4"	8.80	5.28

All "J" types are 2¼ inches square.

Type JB — Jack Base for "J" fixed units. Alsimag 196 — 2⅜" x 2⅜" x ¼". Complete with mtg. posts, screws and nuts, list $1.00. Dealer's Price $.60.

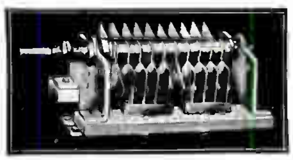
DISC TYPE NEUTRALIZERS

Type ADN, capacity range .5–4 mmf.
List $3.00
Dealers' Price 1.80
Type BDN, for high power.
Capacity 2–12 mmf. List $5.00
Dealers' Price 3.00

Alsimag No. 196 insulation throughout. Satin finish aluminum — fine screw adjustment, no wabble. Knurled thumb nut for easy locking — nickle silver bearing.

ULTRA HIGH FREQUENCY DUALS

FOR 5 AND 10 METER TRANSMITTERS AND DIATHERMY MACHINES



Widely used for ultra H.F. power oscillators and amplifiers; 5 and 2½ meter radio transmitters, and 6 meter diathermy sets. No closed metallic loops — lowest losses. Isolantite Insulation.

NP-35-ND

Type	Per Section			Air Gap	Insulation	Depth Back Panel	List Price	Dealers Price
	Mx. Cap.	Min. Cap.	Nr. Plts.					
NP-35-ND	35	5	9	.081"	Isolantite	1 1/8"	$6.00	$3.60
NP-35-DD	Same as above except unbuffed						$5.35	$3.21

CARDWELL FLEXIBLE COUPLINGS

TYPE "A"

Type A — Fits all ¼" shafts. Has isolantite insulation with new type nickel plated phosphor bronze springs and reversed brass hubs. Minimum space required. Maximum flexibility with no back lash. A real improvement over existing types. Overall diameter 1½". Overall width outside hub-to-hub ⅝". Packed in standard cartons of one dozen.

List price . . . . $ .60 each
Dealers' Price . . . . .36 each

Type B is the same as type A except that the hubs are reversed to give maximum flashover. Price same as "A."

TYPE "E"

A heavy duty unit for high power variable air condensers or other rotary R.F. units.

Insulation — No. 196 Alsimag disc 1½" diameter, ¼" thick. Special steel cup set screws, heavy N.P. brass hubs, permanently staked into thick nickle plated phosphor bronze springs. Removable bushings to fit ¼" shafts. Hubs fit ⅝" shafts with bushings removed.

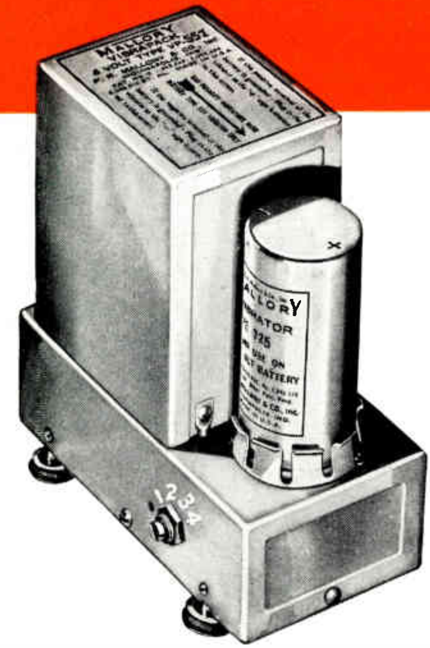
List Price $1.50
Dealers' Price 90

Type "ENF" — Lo-Flex rigid insulated coupling. ¼" shafts only — 10,000 V., 1½" iso. disc. List $1.00
Dealers' Price 60

THE ALLEN D. CARDWELL MFG. CORP.
83 PROSPECT STREET • BROOKLYN, NEW YORK

World Radio History

P. R. MALLORY & CO., Inc.
MALLORY YAXLEY



The technical data sheet "Perfect Portable Power" gives complete operating and installation instructions. Get your copy—your Mallory-Yaxley Distributor has it.

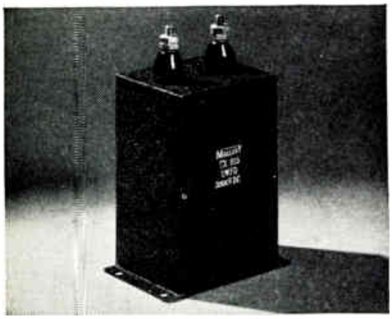
The MALLORY VIBRAPACK
provides Perfect Portable Power for Transmitters, Receivers, P. A. Systems

Economical, dependable plate voltage can be obtained from a 6 volt storage battery through the use of this *perfected* vibrator type power supply. Flexible—efficient—easy to use, and available in Self Rectifying and Tube Rectifying types. In addition, Vibrapack VP-G556 is available for airplane, bus and boat service requiring operation with a 12 volt storage battery.

Cat. No.	*Type*	*Nominal Output Voltage*	*List Price*
VP 551	Self Rectifying	125-150-175-200	$15.00
VP 552	Self Rectifying	225-250-275-300	18.50
VP 553*	Tube Rectifying	125-150-175-200	16.50
VP 554*	Tube Rectifying	225-250-275-300	20.00
VP-G556	Self Rectifying	225-250-275-300	20.00

* Tube Rectifier types required only for applications where B — cannot be at ground Potential.

Mallory Vibrapacks are equipped with complete, built-in noise suppression equipment, but do not include high voltage filter.



New Low Prices
on Transmitting Condensers

Now Mallory Transmitting Condensers are within the reach of every amateur. Made with a new type impregnating material, unlike wax or the customary oil impregnating compounds, it operates satisfactorily at temperatures that would be destructive to other types. Its high dielectric constant and insulation resistance make possible the relatively small size of these transmitting units. Available in rectangular types as shown, or round can types.

Capacity	SIZE *(Thickness)*	*(Width)*	*(Height)*	*(Width between mounting holes)*	*Catalog No.*	*List Price*
			"600 Volts DC"			
1 mfd.	1 1/4	1 15/16	2 1/8	2 3/8	TX-801	$2.75
2 mfd.	1 1/4	1 15/16	2 5/8	2 3/8	TX-802	3.50
4 mfd.	1 1/4	1 15/16	4 9/16	2 3/8	TX-803	4.50
			"1000 Volts DC"			
1 mfd.	1 1/4	1 15/16	2 1/8	2 3/8	TX-804	3.00
2 mfd.	1 1/4	1 15/16	3 1/2	2 3/8	TX-805	4.00
4 mfd.	1 3/4	2 1/2	4 9/16	2 15/16	TX-806	5.00
			"1500 Volts DC"			
1 mfd.	1 1/4	1 15/16	3 1/2	2 3/8	TX-807	3.50
2 mfd.	1 7/16	2 3/16	4 9/16	2 5/8	TX-808	5.00
4 mfd.	2	2 3/4	4 9/16	3 3/16	TX-809	7.00

Capacity	SIZE *(Thickness)*	*(Width)*	*(Height)*	*(Width between mounting holes)*	*Catalog No.*	*List Price*
			"2000 Volts DC"			
1 mfd.	1 1/4	1 15/16	4 9/16	2 3/8	TX-810	$ 4.50
2 mfd.	1 3/4	2 1/2	4 9/16	2 15/16	TX-811	5.50
			"2500 Volts DC"			
1 mfd.	1 7/16	2 3/16	4 9/16	2 5/8	TX-812	8.00
2 mfd.	2	2 3/4	4 9/16	3 3/16	TX-813	13.00
			"3000 Volts DC"			
1 mfd.	1 3/4	2 1/2	4 9/16	2 15/16	TX-814	12.00
2 mfd.	2 5/8	3	4 9/16	3 7/16	TX-815	15.00

MALLORY Heavy Duty and High Surge Condensers

Mallory Heavy Duty and High Surge Dry Electrolytic Condensers are ideal for use in power supply systems for the low powered oscillator and buffer-doubler stages of an amateur transmitter. They are more compact and less expensive than equivalent paper-dielectric units.

Mallory Heavy Duty Condensers are rated at 500 working volts DC, and are for use only where the momentary surge does not exceed 585 volts. Conservatively rated at 600 working volts, Mallory High Surge Condensers have been satisfactorily used in power supplies having momentary surges as high as 800 volts.

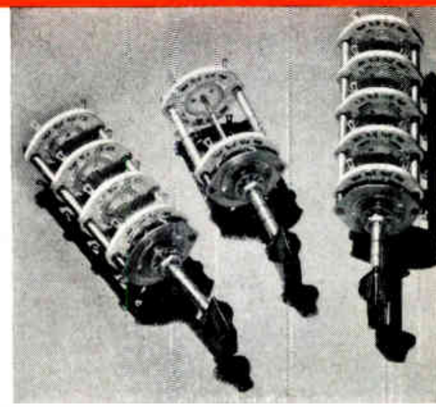
P. R. MALLORY & CO. Inc.
MALLORY

P. R. MALLORY & CO., Inc.

World Radio History

Amateur Radio Products

for Transmitter Band Switching New HamBand Switches with Ceramic Insulation



Convenient terminal arrangements, wide spacing of current carrying parts, heavy silver-plating on contacts, and low-loss magnesium silicate ceramic insulation especially designed for high frequency applications . . . make band switching a reality for every amateur . . . changes from one band to another can be made with practically the same facility as with a modern communications receiver. Mallory-Yaxley 160C HamBand Switches are rated for use in transmitter plate circuits using up to 1000 Volts DC with power up to 100 watts inclusive. Your Mallory-Yaxley distributor can give you complete information.

OTHER APPLICATIONS—Hundreds of other applications are practical with the Mallory-Yaxley HamBand Switches, including transmitter meter switching, inductance tapping for loading coils, antenna matching networks, etc. The Switch Engineers of P. R. Mallory & Company welcome the opportunity of helping you with your switch problems. Address your inquiries to the Application Research Department, Wholesale Division.

YAXLEY "HAMSWITCH" No. 151-L

Provides simple method of using single meter to measure currents or voltages up to and including five circuits of an Amateur Transmitter. Less expensive, more compact and convenient than the conventional cord, plug and jack system.
Five complete circuits may be used in many combinations such as oscillator plate current, buffer plate current, final grid current, final plate current and plate voltage.
High insulating qualities and low loss construction permit a conservative rating of 1000 volts RMS AC or 1500 volts DC. Employs efficient silver to silver wiping contacts and has adjustable stop which permits use of fewer positions, if desired. Has 2-inch notched shaft and bar knob.
Yaxley "Hamswitch" complete with Yaxley Bar Type Knob—No. 151-L List Price $1.80

MALLORY Grid Bias Cells

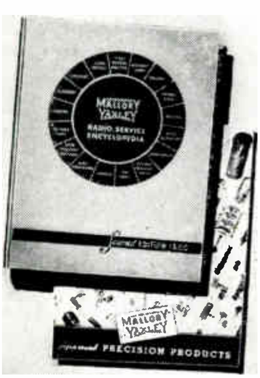
Phone amateurs will appreciate the many advantages to be obtained by using Mallory Bias Cells for the high gain stages of microphone pre-amplifiers. The advantages are:

1. Simplified construction—fewer parts required.
2. Better frequency response at lower cost.
3. Lower hum level.
4. Greater stability.

An interesting technical data sheet on Mallory Bias Cells will be forwarded on request.

Second (1938) Edition RADIO SERVICE ENCYCLOPEDIA

Bigger and Better than ever!



You'll join the thousands of other service men throughout the country in acclaiming the Second Edition "MYE" as the greatest help a service man or radio enthusiast ever had. Covers every phase of automatic tuning . . . every system. Nearly twice the information given in the 1st Edition. Be sure to have your distributor reserve a copy for you.

LIST PRICE $3.00

Other MALLORY-YAXLEY *Products for* AMATEURS

Dry Electrolytic Condensers	Vitreous Resistors
Wet Electrolytic Condensers	Truvolt Resistors
Tip Jacks and Plugs	Precision Resistors
Phone Plugs	Rheostats
Jacks and Jack Switches	Potentiometers
Dial and Panel Lights	Volume Controls
Radio Convenience Outlets	T & L Pads
Knobs—Nuts—Washers	Rotary Switches
Dry Disc Rectifiers	Push Button Switches
Auto Radio Vibrators	Cable Connectors

The items listed are only a few of the hundreds of the Mallory-Yaxley Precision Radio Products used by radio amateurs. Get your copy of the new Mallory-Yaxley general parts catalog from your distributor, or send your request on your Q S L card to the address below.

YAXLEY

INDIANAPOLIS, INDIANA

Cable Address—PELMALLO

World Radio History

Be Right with OHMITE

NEW — *Vacuum Type* DUMMY ANTENNA

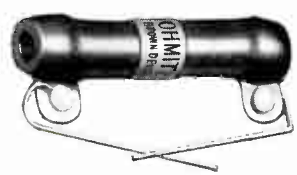
RESISTOR ★ MODEL D-100

Now — a simple, accurate way to check the R. F. power and output of your transmitter, tune up for peak operating efficiency and avoid creating interference during tuning-up and adjustment. ★ Built like a vacuum-tube, with four-prong base. Mounts in standard tube socket. ★ Power easily determined from R. F. ammeter reading. ★ 73 ohm value—to match concentric and twisted pair lines. Available also in higher resistances. ★ 100 watt rating. Easily grouped for increased power capacity or other required resistances. ★ Unique non-inductive, non-capacitive design.

List Price . . . $5.50
PATENTS PENDING

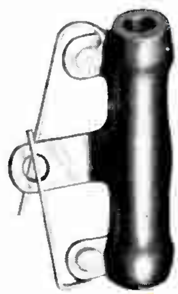
GET the extra-dependability of these sturdy time-proved Ohmite Resistance Units in Your rig. Their long record of faithful, trouble-free service in countless installations — their ability to stand up under shock and vibration, heat and humidity—their world-wide adoption as standard equipment by discriminating designers and manufacturers of amateur and commercial transmitters and receivers — have proved their complete reliability and economy.

★ *Ohmite Vitreous Enamel is unexcelled as a protective and bonding covering for power rheostats and resistors.*



CENTER-TAPPED RESISTORS

Especially designed for use across tube filaments to provide an electrical center for the grid and plate returns. Center tap accurate to plus or minus 1%. Available in Wirewatt (1 watt) and Brown Devil (10 watt) units, in resistances from 10 to 200 ohms.



POPULAR BROWN DEVILS

There's good reason for the world-wide popularity of Ohmite "Brown Devil" Resistors. They're tough, extra-sturdy units — built right, sealed tight and permanently protected by Ohmite Vitreous Enamel. 10 and 20 watt sizes, in resistances from 1 to 100,000 ohms.

R. F. PLATE CHOKES

High frequency solenoid chokes designed to avoid either fundamental or harmonic resonance in the amateur bands. Single-layer wound on low power factor steatite cores with non-magnetic mounting brackets. Moisture-proof. Built to carry A THOUSAND MA. 4 stock sizes for 5 to 160 meter bands. Details in Bulletin 106.

R. F. POWER LINE CHOKES

Just the thing to keep R. F. currents from going out over the power line, lessen interference with BCL receivers. Also to prevent high frequency and R. F. interference from coming in to the receiver. 3 stock sizes, rated at 5, 10, and 20 amperes. Consists of two chokes wound on a single core. Details in Bulletin 105.

SEND FOR YOUR FREE COPY OF NEW CATALOG 17

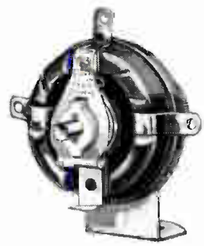
World Radio History

RHEOSTATS ★ RESISTORS ★ SWITCHES ★ CHOKES

Vitreous-Enameled RHEOSTATS

These are the rheostats used by amateurs and broadcast stations alike to keep power tube filaments at rated value all the time—increase tube life—get peak efficiency. Time-proved Ohmite all-porcelain vitreous-enameled construction and metal-graphite contact assure permanently smooth, safe, exact control. Available in 25, 50, 75, 100, 150, 225, 300, 500, and 1,000 watt sizes, for all tubes and transmitters. (Underwriters' Laboratories Listed).

OHMITE BAND-SWITCH



A flick-of-the-wrist on the knob of this popular Ohmite Band-Change-Switch gives you instant, easy change from one frequency to another, with really low-loss efficiency. Band changing may be provided in all stages of the transmitter, and "ganged" for complete front-of-panel control. Can be used in rigs up to 1 K.W. rating.

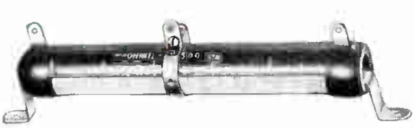
Ask Your Jobber for the Ohmite parts you need, or Write today for Catalog 17.

FIXED RESISTORS

These are the same dependable Ohmite vitreous-enameled resistors that are almost universally used by eminent designers and manufacturers of amateur and commercial transmitters and receivers. Available in 25, 50, 100, 160, and 200 watt stock sizes, in resistances from 5 to 250,000 ohms.

NEW—Hermetically Sealed PRECISION RESISTORS

Now—Perfect protection against humidity, salt air and other severe atmospheric conditions. These new precision units are pie-wound and enclosed in strong evacuated glass tubes with the terminals emerging through vacuum-type glass seals. Ideal for laboratory and test equipment as well as all other applications, particularly in industrial, coastal, marine and tropical locations. Non-inductive winding. Resistance 0.1 ohm to 2.5 megohms. 1 watt rating—1% accurate (or closer tolerances when required.) Provided with soldering lugs and wire terminals or with tube base. Write for further information.



ADJUSTABLE DIVIDOHMS

Mighty handy resistors to have around when you need a change of resistor value or a replacement in a hurry. You can quickly adjust the Dividohms to the exact resistance you want and put on one or more taps wherever needed. Patented percentage of resistance scale. 7 ratings from 10 to 200 watts. Resistances up to 100,000 ohms.

OHMITE

OHMITE MANUFACTURING CO.
4822 FLOURNOY STREET
CHICAGO, U.S.A. • *Cable "Ohmiteco"*

World Radio History

THE NAME "JOHNSON"

ON A PIECE OF TRANSMITTING EQUIPMENT IS

Your Guarantee

OF A DEPENDABLE RIG!

Never in the history of the company has the name "JOHNSON" been associated with an inferior piece of transmitting equipment.

For years Communications and Broadcast engineers have come to Johnson with tough transmitting problems. You are cordially invited to take advantage of the same FREE service.

JOHNSON ENGINEERS

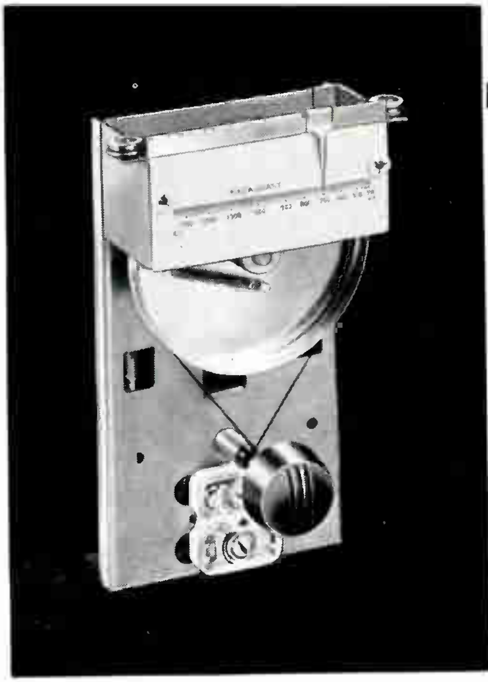
Are experienced in the design of all types of transmitters for operation on low, broadcast, high and ultra-high frequencies, and will be glad to make recommendations concerning the application of transmitter components. Write the laboratory — attention Chief Engineer.

Your Parts Jobber sells Johnson Antennas, Insulators, Variable Condensers, Inductors, Sockets, Coupling Units, etc. The latest Johnson literature may be obtained from your jobber or by writing to Johnson direct for Catalog 965 M.

E. F. JOHNSON CO.
WASECA, MINNESOTA
MANUFACTURERS OF RADIO TRANSMITTING EQUIPMENT

EXPORT: 25 WARREN ST., NEW YORK, N. Y.

World Radio History



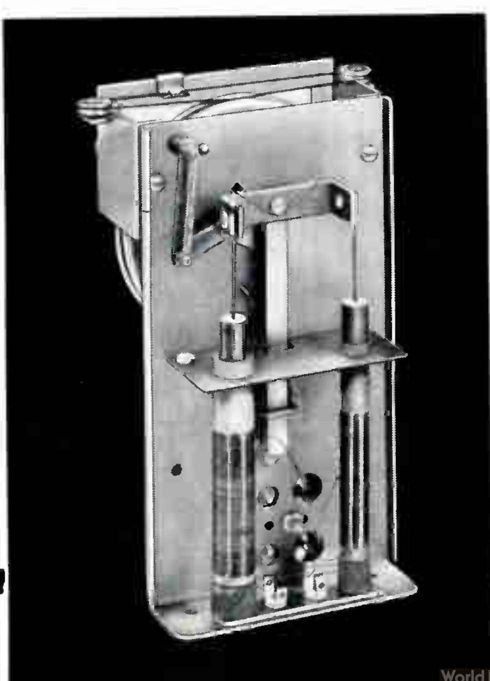
Front view shows dial scale and drive assembly. Note trimmer has only two adjustments.

Remarkable

NEW ALADDIN

ELIMINATES GANG TUNING CONDENSERS!

Rear view shows Permeability Tuning action utilizing newly designed Aladdin Polyiron core and coil combination instead of gang condensers.



PERFECT TRACKING WITH SINGLE POINT ALIGNMENT

Again, Aladdin Engineers contribute another important development to radio . . . the NEW ALADDIN POLYIRON PERMEABILITY TUNER. This remarkable assembly ELIMINATES gang tuning condensers! It takes the place of a 2-gang condenser, an antenna coil, and an oscillator coil, and combines the function of all three into one compact, simple movement. It assures perfect tracking with single point adjustment. Uniform antenna gain. Excellent image rejection. More freedom from microphonics. Simplifies assembly and wiring. Covers Broadcast band 1720 to 540 kc. Tuning ratio 6 to 1. We invite you to investigate all the startling details of this amazing engineering achievement. Write to

ALADDIN RADIO INDUSTRIES, INC.

466h W. Superior Street, Chicago, Ill.

Licensee of Johnson Laboratories, Inc.

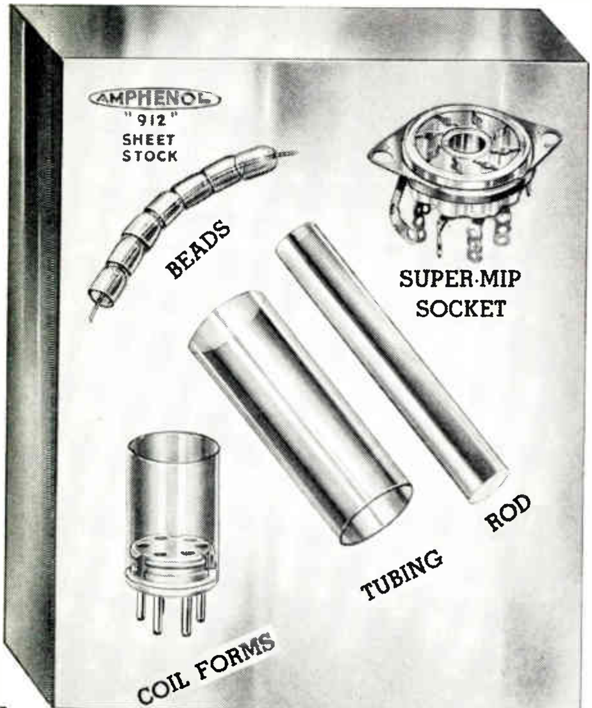
These devices manufactured under one or more of the following U. S. Letters Patent: 1,887,380, 1,940,228, 1,978,568, 1,978,599, 1,978,600, 1,982,689, 1,982,690, 1,997,453, 2,002,500, 2,005,203, 2,018,626, 2,028,534, 2,032,580, 2,035,439, 2,037,883, 2,038,281, 2,051,012, 2,059,393, 2,082,587, 2,082,589, 2,082,590, 2,082,595, 2,104,792, 2,094,189, 2,095,420, 2,106,226, 2,106,229, 2,106,253, 2,113,603, 2,122,874, 2,131,976, 2,111,373, 2,111,490. Other patents pending.

Aladdin
TRADE MARK

Reg. U. S. Pat. Off.

World Radio History

The Radio Sensation of 1939



AMPHENOL "912"

Ultra-Low-Loss

INSULATING MATERIAL

A transparent polystyrene-base material, developed because the amateur and radio manufacturer needed an ultra-low-loss insulator. Loss factor at one megacycle is only .00053 (zero for all practical purposes.)

SHEET — ROD — TUBING

A tensile strength of 5000 pounds per square inch, yet Amphenol "912" machines easily. Actually possible to whittle into shape with a knife. No danger of splitting when drilling or turning on a lathe.

Complete variety of various size tubes, rods and sheet stock so that you can quickly build your own insulators, terminal strips, trimming condensers, special coils, etc. Cement parts together with Liquid Amphenol "912" listed below.

LIQUID AMPHENOL "912"

(Coil Dope — Insulating Cement)

Liquid Amphenol "912" is simply the solid of Amphenol "912" reduced to liquid form. Used as a coil dope, it protects windings from humidity without effecting the electrical characteristics of the coil. Applied to windings on Amphenol "912" coil forms and tubing, actually imbeds windings into the solid.

Unequalled for sealing the pores of fibre, paper and other moisture absorptive materials. When used as a cement for Amphenol "912" sheet stock, rod or tubing, it fuses parts together, instead of merely gluing them. Exceptionally rapid drying; permits handling in three minutes.

PLUG-IN COIL FORMS

Standard Tube Base Prongs

No holes for windings because it is so simple to drill holes exactly where you want them. No ribs to hold windings away from coil form, because the insulating quality of Amphenol "912" is practically the same as air.

INSULATING BEADS

New "spaghetti type" insulators for all high frequency leads. Strings on any size wire up to No. 12 to form a non-hygroscopic fish spine. Ball and socket design permits bending and flexing on a one inch radius. Diameter of bead 5/16", overall length 7/16".

Cat. No. 73—Insulating Beads—List $2.50 for 250

Also available—Other size beads up to 1" in dia.

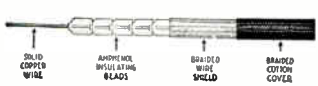
Comparison between Amphenol "912" and other good insulators.

	Best Steatite	Low-Loss Bakelite	AMPHENOL "912"
Power Factor	.04	.34	.0002
Dielectric Constant	5.8	4.1	2.60
Loss Factor	**.23**	**1.39**	**.00053**
Dielectric Strength per mil.	200.	400.	500.
Tensile Strength lbs. per sq. inch	8500.	5000.	5000.

All above tests made at 1,000,000 cycles.

AMPHENOL CO-AXIAL CABLE

(Shielded Concentric Transmission Line)



For carrying high frequencies inches or miles without radiation or pick-up, with a minimum amount of loss. Construction of No. 14 solid copper wire, strung with Amphenol Insulating Beads, shielded with a woven tinned copper shell, finally covered with two moisture proof cotton braids. Ideal for microphone, photo-cell and other high frequency leads and transmission lines. Unequalled as an antenna lead-in.

If copper tubing lead-in is already installed, replace ceramic spacers with Amphenol Insulating Beads. Use two beads for each spacer, cementing them directly on the wire with Liquid Amphenol "912."

Cat. No. 72—Co-Axial Cable—List 60c per foot.

FREE: SAMPLE and CATALOG

Send your QSL card or name and address on a penny post card and we will forward immediately our latest bulletins and a sample of the Insulating Beads.

Please mention name of your usual jobber.

AMERICAN PHENOLIC CORPORATION

1252 Van Buren Street — Chicago, U. S. A.

Manufacturers of Bakelite, Steatite and Amphenol "912" Radio Parts

• Microphone Connectors • Tube Sockets • Cable Connectors

World Radio History

Standard of Quality — SPRAGUE "600" LINE — Throughout the World

SPRAGUE

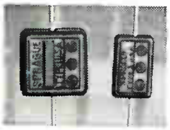
SILVERED MICA CONDENSERS

An Inexpensive Air Condenser Substitute

These tiny condensers (approximate average size 1-1/16" x 9/16") have a minimum Q of 1500, temperature coefficient too small to measure and a high stability on humidity better than that of most air condensers. Inductance is unusually low due to their small size. Use them wherever the call is for an air condenser of equivalent voltage rating.

FIXED MICA CONDENSERS

Voltage Ratings Guaranteed



The superior performance of Sprague Micas is largely due to their remarkably high resistance to moisture. Power Factor is extremely low and stable. Voltage ratings fully guaranteed. Equipped with heavy, flexible wire leads.

FIXED MICA UNITS

INTERMEDIATE CAPACITIES AVAILABLE

Cat. No.	Cap. Mfd.	Work. Volt.	List Price
1FM-45	.00005	600	$.15
1FM-31	.0001	600	.15
1FM-32	.0002	600	.20
1FM-325	.00025	600	.20
1FM-35	.0005	600	.20
1FM-21	.001	600	.25
1FM-215	.0015	600	.30
1FM-22	.002	600	.35
1FM-23	.003	600	.40
1FM-24	.004	600	.45
1FM-25	.005	600	.55
1FM-26	.006	600	.60
2FM-44	.00004	300	.15
2FM-45	.00005	300	.15
2FM-475	.000075	300	.15
2FM-31	.0001	300	.15
2FM-315	.00015	300	.20
2FM-32	.0002	300	.20
2FM-325	.00025	300	.20
2FM-35	.0005	300	.20

SILVERED MICA UNITS

Test Voltage 1000 volts D.C. — Tolerance 2½%, D.C. Working Voltage 700

Cat. No.	Cap. Mmfd.	Cap. Mfd.	List Price
SM-55	5	.000005	$ .30
SM-41	10	.00001	.30
SM-415	15	.000015	.30
SM-42	20	.00002	.30
SM-425	25	.000025	.30
SM-45	50	.00005	.30
SM-31	100	.0001	.40
SM-32	200	.0002	.40
SM-33	300	.0003	.40
SM-34	400	.0004	.60
SM-35	500	.0005	.60
SM-36	600	.0006	.70
SM-37	700	.0007	.70
SM-38	800	.0008	.70
SM-39	900	.0009	.70
SM-21	1000	.001	.70
SM-22	2000	.002	1.00
SM-23	3000	.003	1.50
SM-24	4000	.004	1.75
SM-25	5000	.005	2.00

1% Tolerance 30% increase in List Price

SAVE TIME — SAVE SPACE — SAVE MONEY!

THE NEW "UNIVERSAL" DRY ELECTROLYTIC REPLACEMENTS

Just the thing for thousands of service replacement jobs where you've got to have real condenser reliability in the smallest possible size at a rock-bottom price. The dry electrolytic development of the year that is sweeping the market! Made by exclusive Sprague etched-foil process. No "blow-outs" — not a "firecracker" in a carload. Available in all standard capacities including Dual Combinations.

Actual size of an 8 mfd. 450 V. A om is only ¾" x 1⅝". List price only 60c. Others equally low.

SPRAGUE ATOMS —

Mightiest Midgets of All

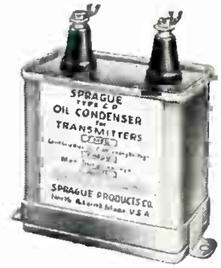
ATTENTION!

Write for our complete catalog listing Sprague Condensers for every application.

SPRACOL!

THE NEW SPRAGUE TYPE CR TRANSMITTING CONDENSERS *with the Universal mounting feature*

You've been asking for Xmitting Condensers with flanges for mounting in any position. Here they are . . . backed with all the features that have made Sprague Condensers the standard of quality wherever Radio is used plus SPRACOL — the famous Sprague filler oil of the same type used to impregnate the giant transatlantic cables. All units rated to conform to tube and circuit design. They'll stand the gaff!



Oil condensers spell highest quality — and SPRACOL leads the way!

ROUND TYPE OT XMITTERS

New Low Prices

All Sprague Transmitting Condensers are oil impregnated and oil-filled with SPRACOL, the finest, most durable oil ever developed for the purpose. Spracol is identical to the oil used to impregnate the giant transoceanic cables. Nuf said! See below for Type OT Price List.

← TYPE OT

TYPE PC →

You'll find this newly developed Sprague Type PC Inverted Screw Can Round Condenser unexcelled for **P. A. and TRANSMITTER WORK—also for TELEVISION and HIGH GAIN AMPLIFIERS.**

SPRAGUE TYPE CR

OIL IMPREGNATED — OIL FILLED
Fully Sealed — Compact —
"ALL MOUNT" Feature

Cat. No.	Cap. Mfd.	Voltage	List Price
CR-16	1	600	$ 2.75
CR-26	2	600	3.50
CR-46	4	600	4.50
CR-11	1	1000	3.00
CR-21	2	1000	4.00
CR-41	4	1000	5.00
CR-115	1	1500	3.50
CR-215	2	1500	5.00
CR-415	4	1500	7.00
CR-12	1	2000	4.50
CR-22	2	2000	5.50
CR-42	4	2000	9.00
CR-125	1	2500	8.00
CR-225	2	2500	13.00
CR-13	1	3000	12.00
CR-23	2	3000	15.00

TYPE OT

Round Cat. No.	Capacity	D.C. Working Voltage	Surge Voltage	List Price
OT-27	2 Mfd.	700v	1000v	$2.25
OT-11	1 Mfd.	1000v	1500v	2.25
OT-21	2 Mfd.	1000v	1500v	2.75
OT-41	4 Mfd.	1000v	1500v	3.75
OT-115	1 Mfd.	1500v	2000v	3.00
OT-215	2 Mfd.	1500v	2000v	3.75
OT-12	1 Mfd.	2000v	3000v	3.75
OT-22	2 Mfd.	2000v	3000v	4.25
OT-13	1 Mfd.	3000v	3500v	7.50
OT-515	0.5 Mfd.	1500v	2000v	2.75

TYPE PC

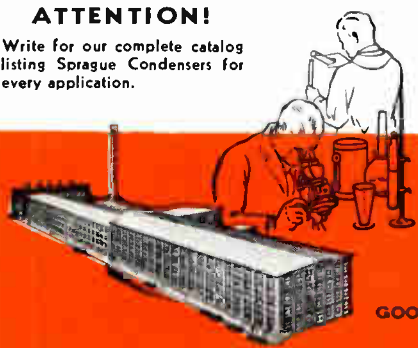
	Mfd.	Voltage	List Price
PC-26	2	600	$2.25
PC-46	4	600	3.00
PC-11	1	1,000	2.25
PC-21	2	1,000	2.75

Low Cost Xmitting Condensers

Just the Thing for Beginners

For those who want fully reliable and decidedly economical high voltage condensers rated up to 1,000 volts, we suggest the famous Sprague Type UC Cased Paper Condensers. Type UC-11, 1 mfd. 1,000 d.c. volts lists at only $1.50 — others propor ionately low. Write for catalog or see your Sprague jobber.

SPRAGUE PRODUCTS CO., North Adams, Mass.



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GOOD CONDENSERS • EXPERTLY ENGINEERED • COMPETENTLY PRODUCED

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COMPONENTS that stand the Gaff!

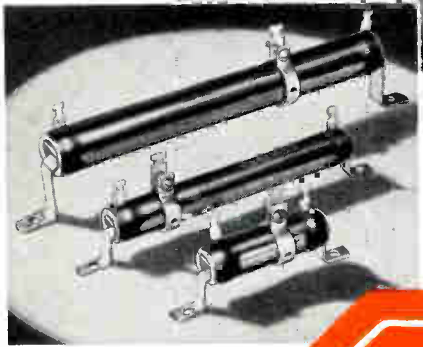
● Millions of radio sets are now equipped with AEROVOX condensers. Millions of electric refrigerators use AEROVOX motor-starting capacitors. Countless other equipment depends on AEROVOX condensers and resistors, to stand the gaff of service, unexpected abuse, exceptionally long life. If that's the sort of service you expect from your "rig", simply insist on AEROVOX condensers — and resistors, too.

CONDENSERS

● All types — paper, oil, mica, electrolytic, etc. All voltages, capacities, combinations. You can find precisely what you require in the AEROVOX line. This all-inclusiveness, plus established dependability, accounts for the selection of AEROVOX *throughout* in leading transmitter kits and assemblies.

RESISTORS

● And to round out that dependability, there are essential wire-wound and carbon AEROVOX resistors. Fixed and adjustable wire-wound vitreous-enamel units. Bakelite-molded and lacquered-carbon resistors. Listed in our latest catalog.



● Be sure to look at the AEROVOX HYVOL X-mitting condensers, at your local suppliers. Sturdy welded-steel container. In both oil-filled and wax-filled types. High-tension pillar terminals. Attractive prices. Just compare!

Ask for CATALOG . . .

● Your local AEROVOX supplier has your copy of the latest catalog covering our line of condensers and resistors. Ask for it. Or write us direct for catalog and sample copy of the monthly AEROVOX RESEARCH WORKER.

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SHURE MICROPHONES

Built for Better Communications

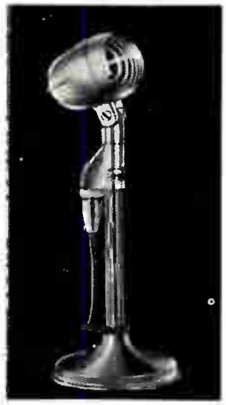
Heard 'Round the World

FIRST with the special "high efficiency" speech characteristic for voice-communications — and FIRST again with "Super-Level" performance and other important advanced developments — there's good reason for the outstanding popularity of Shure Microphones in amateur and commercial installations in more than 55 countries in all climates 'round the world.

MILITARY-TYPE HAND MICROPHONE

Fits naturally, firmly in the palm of the hand. Takes minimum space in portable equipment. Sturdy cast-aluminum case, with Satin-finished grille. Optional locking press-to-talk switch. Removable suspension hook and 7 ft. shielded cable. Crystal and Carbon types in general-purpose and "anti-noise" close-talking models.

List Prices..**$15** to **$31.50**



NEW SHURE ROCKET COMMUNICATIONS-TYPE

You'll enjoy the performance and beauty of this new ROCKET Deluxe communications-type crystal microphone. It gives you ultra-modern streamlined design — plus the famous Shure "high efficiency" speech characteristic that doubles power on important intelligibility speech frequencies — gives clear, crisp speech that cuts through noise and static. Tilting head, finished in rich Satin Chrome. New built-in Cable Connector. 7 ft. shielded cable. Desk Stand in Iridescent Gray.

Model 706S. List Price **$27.50**

Model 706SH. Same without Desk Stand. List Price **$25**

NEW UNIPLEX UNI-DIRECTIONAL

There's nothing like this new "Uniplex" Uni-Directional Crystal Microphone! Sensitive at the front, dead at the rear — it stops unwanted sounds, really solves feedback, background noise, reverberation problems. Speed-line design, in rich Satin Chrome finish. Equipped with new built-in Cable Connector and 25 ft. of special noise-free Super-Shielded cable.

Model 730A "UNIPLEX". List Price **$29.50**

70SW SUPER-LEVEL COMMUNICATIONS-TYPE

First to give you the "high-efficiency" speech characteristic that cuts through noise and static with double power on important intelligibility speech frequencies — the world-favorite 70SW now gives you the highest output level ever available in a crystal microphone! Used in countless amateur and commercial stations everywhere. Output level 46 db below 1 volt per bar. Satin Chrome head, with built-in Cable Connector. 7 ft. shielded cable. Desk Stand in Iridescent Gray.

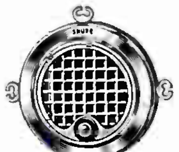
Model 70SW. List Price........**$25**

Model 70SWH. Same without Desk Stand. List Price............**$22.50**

"ULTRA" Wide-Range Crystal Microphones

These world-famous microphones give you life-like "Ultra" Wide-Range response from 30 to 10,000 cycles. Complete with built-in Cable Connector and 25 ft. cable with microphone plug attached. Model 700D "Swivel," 701D "Skyscraper" (illustrated), 702D "Spherical."

List Price.............**$25**



SHURE MODEL 3B TWO-BUTTON CARBON

Full-size, two-button microphone with Shure quality performance at low cost, for amateur transmitters, inter-communication systems and Public Address installations. Rigid cast frames and built-in protective grille. Rich new Satin Chrome finish. Diameter 3". Has four Shure "Quickway" Hooks for spring suspension.

Model 3B. List Price **$5.50**

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A Superior Key For Superior Work

STANDARD OF THE WORLD FOR CLARITY · SPEED · SENDING EASE

Only the Genuine Vibroplex has "THE BUG" Trade Mark

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VIBROPLEX

SEMI-AUTOMATIC KEY

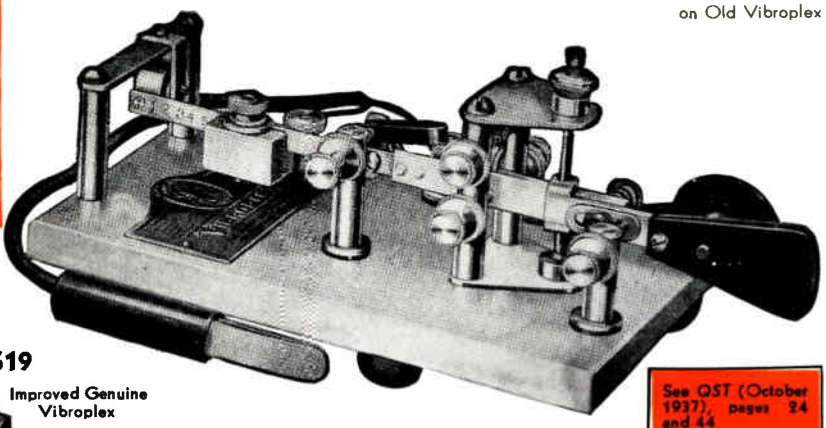
Liberal Allowance on Old Vibroplex

MAKES SENDING EASIER
CUTS EFFORT IN HALF

GREAT NEW Vibroplex No. 6

ILLUSTRATED

Improved flat pendulum. New Design frame. Instantly adjustable dot contact spring. Bridged damper frame. Circuit breaker parallel with pendulum. In high favor with scores of operators for its ease of operation and high quality signal.



Black Base . . . . . **$17** Nickel-Plated . . **$19**

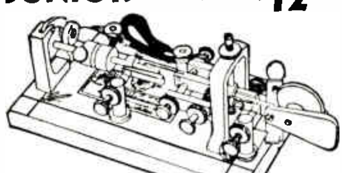
See QST (October 1937), pages 24 and 44

Improved Genuine Vibroplex

A smooth, easy-working semi-automatic key that has won fame on land, sea and air for clarity, speed and sending ease.

Black Base . . . . . . **$17** Nickel-Plated . . . **$19**

JUNIOR ONLY $12.50



Slightly smaller and more compact, but in all other details the same as the large model illustrated. All standard features and improvements. A low priced key with world famous Vibroplex quality. COMPLETE WITH CORD AND WEDGE

Carrying Case $3.00

Handsome black morocco. Reinforced corners. Flexible leather handle. Keeps bug free from dust, dirt and moisture. With patent lock and key, $3.00

Approved by Over 100,000 Operators

Experienced operators — over 100,000 of them, have put their stamp of approval on the Vibroplex Semi-Automatic Key for clarity, speed and sending ease. They have learned from actual experience that the Vibroplex really does make sending a lot easier and better for every one, and that it develops a higher degree of sending ability than the average operator attains in a life time.

Press Lever — Vibroplex Does the Rest

If you can send on the regulation key — you can send better, faster and with half the effort with a Vibroplex. Its simplicity, mechanical perfection, machine speed and sending ease enables any operator with a little practice, to send with the skill of an expert. You will have no difficulty in learning to use the Vibroplex. Many have mastered it in a day or so. You simply press lever — the Vibroplex does the rest. Take the advice of experienced operators and get a Vibroplex. Demand the Genuine. Only the Genuine has "THE BUG" trade mark. Accept no substitute. Look for this trade mark on the bug you buy. You will always be glad you did. Money order or registered mail. Write for FREE illustrated catalog.

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SOLAR TRANSMITTING CAPACITORS

TRANSOIL TRANSMITTING CAPACITORS
OIL IMPREGNATED—OIL FILLED

TYPE XL

TYPE XD

TYPE XC

TYPE XT

TYPE XT—TUBULAR
Oil Impregnated—Metal Case

Cat. No.	Cap. Mfd.	Operating Volts D.C.	Size Inches	List Price
XT-0005	.0005	1600	½x1½	$ .60
XT-001	.001	1600	½x1½	.60
XT-002	.002	1600	½x1½	.60
XT-003	.003	1600	½x1½	.60
XT-004	.004	1600	9/16x1½	.60
XT-005	.005	1600	9/16x1¾	.60
XT-007	.007	1600	⅝x1¾	.60
XT-01	.01	1600	⅝x2⅛	.60
XT-02	.02	1600	¾x2⅛	.65
XT-05	.05	1600	15/16x2⅛	.80
XT-1	.1	1600	1 3/16x2¼	.90
XT-101	.01	1000	9/16x1¾	.50
XT-102	.02	1000	⅝x1¾	.55
XT-105	.05	1000	15/16x2⅛	.65
XT-11	.1	1000	15/16x2⅛	.80

TYPE XD—DRAWN SHELL CAN
Oil Impregnated—Oil Filled

XD-61	.1	600	1 15/16x1 x ¾	1.45
XD-625	.25	600	1 15/16x1 x ¾	1.70
XD-65	.5	600	2 x1¾x1	1.95
XD-11	.1	1000	1 15/16x1 x ¾	1.80
XD-125	.25	1000	2 x1¾x1	2.20

TYPE XC—ROUND INVERTED AL. CAN
Oil Impregnated—Oil Filled

XC-61	1	600	1½x3	2.00
XC-62	2	600	1½x3	2.25
XC-64	4	600	1½x4⅝	3.00
XC-11	1	1000	1½x3	2.25
XC-12	2	1000	1½x4⅝	2.75
XC-155	.5	1500	1½x3	2.75
XC-151	1	1500	1½x4⅝	3.00

TYPE XL—RECTANGULAR CANS
Oil Impregnated—Oil Filled

Cat. No.	Cap. Mfd.	Size Inches	List Price
600 D.C. Oper. Volts—440 R.M.S. Rect. A.C.			
XL-6-1	1	2⅛x1¾x1	$2.75
XL-6-2	2	2⅞x1¾x1	3.50
XL-6-4	4	3⅝x2½x1 3/16	4.50
1000 D.C. Oper. Volts—660 R.M.S. Rect. A.C.			
XL-10-05	.5	2⅛x1¾x1	2.15
XL-10-1	1	2⅜x1¾x1	3.00
XL-10-2	2	4 x1¾x1	4.00
XL-10-4	4	4¾x2½x1 3/16	5.00
1500 D.C. Oper. Volts—1000 R.M.S. Rect. A.C.			
XL-15-1	1	4 x1¾x1	3.50
XL-15-2	2	4¾x2½x1 3/16	5.00
XL-15-4	4	4¾x3¾x1½	7.00
2000 D.C. Oper. Volts—1500 R.M.S. Rect. A.C.			
XL-20-01	.1	2⅛x1¾x1	3.25
XL-20-025	.25	2⅛x1¾x1	3.75
XL-20-05	.5	2⅞x1¾x1	4.00
XL-20-1	1	3⅝x2½x1 3/16	4.50
XL-20-2	2	4¾x3¾x1½	5.50
XL-20-4	4	4¾x3¾x2¼	9.00
2500 D.C. Oper. Volts—1800 R.M.S. Rect. A.C.			
XL-25-1	1	4¾x3¾x1¼	8.00
XL-25-2	2	4¾x3¾x2¼	13.00
3000 D.C. Oper. Volts—2200 R.M.S. Rect. A.C.			
XL-30-01	.1	2⅞x1¾x1	8.00
XL-30-025	.25	3⅝x2½x1 3/16	8.50
XL-30-05	.5	4¾x3¾x1½	9.00
XL-30-1	1	4¾x3¾x2¼	15.00
XL-30-2	2	4¾x3¾x3 3/16	22.00
4000 D.C. Oper. Volts—2800 R.M.S. Rect. A.C.			
XL-40-01	.1	3⅝x2½x1 3/16	13.00
XL-40-025	.25	4¾x3¾x1½	15.00
XL-40-05	.5	4¾x3¾x2¼	18.00
5000 D.C. Oper. Volts—3500 R.M.S. Rect. A.C.			
XL-50-01	.1	4¾x2½x1 3/16	17.00
XL-50-025	.25	4¾x3¾x1½	18.00
XL-50-05	.5	4¾x3¾x2¼	20.00

SOLAREX TRANSMITTING CAPACITORS
OIL IMPREGNATED WAX FILLED

TYPE X—RECTANGULAR CANS

Cat. No.	Cap. Mfd.	D.C. Oper. Volts	D.C. Volts Flash Test	Size Inches	List Price
X-101	1	1000	2000	3 x2 7/16x1½	$1.85
X-102	2	1000	2000	4⅝x2 7/16x1½	2.50
X-104	4	1000	2000	4⅝x3 3/16x2 3/16	3.35
X-151	1	1500	3000	4⅝x2 7/16x1½	2.40
X-152	2	1500	3000	4⅝x3 3/16x2 3/16	3.35
X-154	4	1500	3000	4⅝x3 9/16x2 9/16	5.40
X-201	1	2000	4000	4⅝x3 3/16x2 3/16	2.90
X-202	2	2000	4000	4⅝x3 9/16x2 9/16	4.10
X-204	4	2000	4000	6 x3 9/16x2 9/16	7.75
X-301	1	3000	6000	6 x3 9/16x2 9/16	4.15
X-302	2	3000	6000	6 x4¼x2⅝	8.25

TYPE XB MICA TRANSMITTING CAPACITORS
MOLDED IN LOW-LOSS BAKELITE—WITH WIRE LEADS

Size 1 13/16x¼x⅜ inches except those marked * are 2x1x5/16 inches.

2000 D.C. V.O. 4000 Volts Test

Cat. No.	Cap. Mfd.	List Price
XB-2-31	.0001	$ .70
XB-2-325	.00025	.75
XB-2-35	.0005	.80
XB-2-21	.001	.95
XB-2-22	.002	1.25
XB-2-24	.004*	1.50
XB-2-25	.005*	1.75
XB-2-11	.01*	2.50
XB-2-115	.015*	3.00

3000 D.C. V.O. 6000 Volts Test

Cat. No.	Cap. Mfd.	List Price
XB-3-31	.0001	$1.00
XB-3-325	00025	1.05
XB-3-35	.0005	1.25
XB-3-21	.001	1.50
XB-3-215	.0015	1.90
XB-3-22	.002*	2.00
XB-3-24	.004*	2.50
XB-3-25	.005*	2.75
XB-3-28	.008*	3.00

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AMPEREX

GRAPHITE ANODE TRANSMITTING TUBES

Even cursory inspection will show how AMPEREX tubes differ from the mere adaptations of conventional tube types. . . . Exclusive engineering developments and radical design refinements are incorporated in the structure of these tubes and reflected in their superior performance.

So universal has been the recognition of the merits and efficiency of these tubes that a large percentage of all diathermy ultra short wave generators are equipped with AMPEREX tubes and thousands more are in operation in almost every country in the world . . . in broadcast, communication, amateur and industrial apparatus where they have replaced more costly or less efficient tubes.

ZB-120

Low Distortion zero-bias class B amplifier and modulator, high efficiency R.F. frequency multiplying power amplifier, conventional R.F. power amplifier.

The ZB-120 is an exclusive AMPEREX development. In common with other tubes of original AMPEREX design it is a low voltage high current type and possesses a high ratio of transconductance to interelectrode capacitance. Although it approaches nearer the ideal in a zero-bias class B tube it is also a highly efficient performer in many other classes of service.

GENERAL CHARACTERISTICS

Filament: Voltage	10–10.5 volts A.C. or D.C.
Current	2 amperes
Amplification Factor	90
Grid to Plate Transconductance @ 120 ma.	5000 micromhos
Direct Interelectrode Capacitances:	
Grid to Plate	5.2 uuf
Grid to Filament	5.3 uuf
Plate to Filament	3.2 uuf

Net Price **$10.00**

HF-100

An ultra-high, normal R.F. power amplifier and oscillator and class B audio amplifier or modulator.

The HF-100 is one of a distinctive group of low voltage high current tubes, an original development of the AMPEREX ENGINEERING LABORATORIES. It is in addition characterized by an extraordinary high ratio of transconductance to interelectrode capacitance, a characteristic which is responsible for its outstanding efficiency in ultra-high frequency circuits.

GENERAL CHARACTERISTICS

Filament: Voltage	10–10.5
Current	2 amperes
Amplification Factor	23
Grid to Plate Transconductance @ 100 ma.	4200
Direct Interelectrode Capacitances:	
Grid to Plate	4.5 uuf
Grid to Filament	3.5 uuf
Plate to Filament	1.4 uuf

$12.50 Net Price

HF-200

High and normal R.F. power amplifier, oscillator, class B modulator.

The HF-200 is another of the highly proficient ultra-high frequency generators of original AMPEREX design and development. The outstanding features of low voltage, high current and a high ratio of transconductance to interelectrode capacitance are also properties of this tube.

GENERAL CHARACTERISTICS

Filament: Voltage	10–11 volts
Current	3.4 amperes
Amplification Factor	18
Grid to Plate Transconductance @ Plate Current of 150 ma.	5000 micromhos
Direct Interelectrode Capacitances:	
Grid to Plate	5.8 uuf
Grid to Filament	5.2 uuf
Plate to Filament	1.2 uuf

Net Price **$24.50**

HF-300

R.F. power amplifier, oscillator, class B modulator.

The HF-300 has found favor with many broadcasters and transmitter designers as a substitute for the 204A. A study of the operational data will disclose its superiority, in many classes of service, to the latter tube. It also, like the HF-100 and HF-200, is an efficient ultra-high frequency generator and possesses the characteristic common to AMPEREX designed tubes, of a high ratio of transconductance to interelectrode capacitance.

GENERAL CHARACTERISTICS

Filament Voltage	11–12 volts
Current	4 amperes
Amplification Factor	23
Grid to Plate Transconductance @ 150 ma.	5600 micromhos
Direct Interelectrode Capacitances (App.):	
Grid to Plate	6.5 uuf
Grid to Filament	6.0 uuf
Plate to Filament	1.4 uuf

$35.00 Net Price

AMPEREX ELECTRONIC PRODUCTS, Inc.

79 WASHINGTON STREET BROOKLYN, NEW YORK

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The American Radio Relay League, Inc.

West Hartford, Connecticut

World Radio History

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For twenty-two years (and thereby the oldest American radio magazine) *QST* has been the "bible" of Amateur Radio. It faithfully and adequately reports each month the rapid development which makes Amateur Radio so intriguing. Edited in the sole interests of the members of The American Radio Relay League, who are its owners, *QST* treats of equipment and practices and construction and design, and the romance which is part of Amateur Radio, in a direct and analytical style which has made *QST* famous all over the world. It is essential to the well-being of any radio amateur. *QST* goes to every member of The American Radio Relay League and membership costs $2.50 per year in the United States and Possessions, and Canada. All other countries $3.00 per year. Elsewhere in this book will be found an application blank for A.R.R.L. membership.

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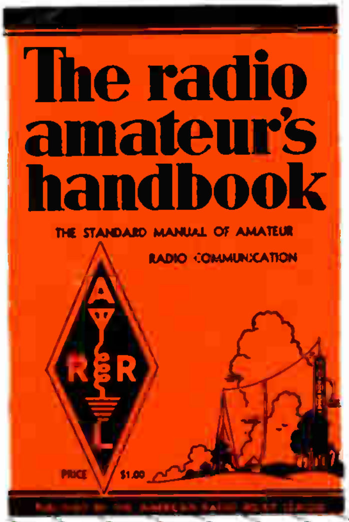

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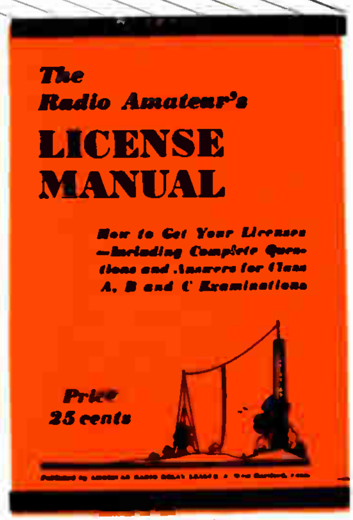
Before you can operate an amateur transmitter, you must have a government license and an officially assigned call. These cost nothing — but you must be able to pass the examination. The License Manual tells how to do that — tells what you must do and how to do it. It makes a simple and comparatively easy task of what otherwise might seem difficult. In addition to a large amount of general information, it contains 198 typical questions and answers such as are asked in the government examinations. If you know the answers to the questions in this book, you can pass the examination without trouble.

Price 25¢ postpaid



Universally recognized as the standard elementary guide for the prospective amateur, HOW TO BECOME A RADIO AMATEUR describes, in clear understandable language, apparatus incorporating features hitherto confined to more advanced stations. Although completely modernized, the station can still be built at a minimum of expense, and the designs have been made flexible so that parts out of the junk box readily can be substituted. While easy to build, the performance of the equipment is such that any amateur can own and operate it with satisfaction and pleasure. Complete operating instructions and references to sources of detailed information on licensing procedure are given, as well as a highly absorbing narrative account of just what amateur radio is and does.

Price 25¢

An introduction into Amateur Radio-telephony. Written for the man who has a class C or class B license. A companion book to "How to Become a Radio Amateur." Contains simple description of the process of modulation and principles of good design for 'phone. Description of inexpensive low power transmitter and modulator, with complete operating instructions plus some antenna dope of particular interest in 160- and 10-meter operation. It tells what a new or inexperienced ham should know before attempting to use 'phone.

Price 25¢

Amateurs are noted for their ingenuity in overcoming by clever means the minor and major obstacles they meet in their pursuit of their chosen hobby. An amateur must be resourceful and a good tinkerer. He must be able to make a small amount of money do a great deal for him. He must frequently be able to utilize the contents of the junk box rather than buy new equipment. Hints and Kinks is a compilation of hundreds of good ideas which amateurs have found helpful. It will return its cost many times in money savings — and it will save hours of time.

Price 50¢

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LIGHTNING

by th

Aware of the practical bent of the average amateur and knowing of his limited time, th League, under license of the designer, W. P. Koechel, has made available several calcu lators to obviate the tedious and sometimes difficult mathematical work involved in th design and construction of radio equipment. The various lightning calculators are ingeniou devices for rapid, certain and simple solution of the various mathematical problems whic arise in all kinds of radio and allied work. They make it possible to read direct answe without struggling with formulas and computations. They are tremendous time-savers fo

RADIO CALCULATOR

Type A

This calculator is useful for the problems that confront the amateur every time he builds a new rig or rebuilds an old one or winds a coil or designs a circuit. It has two scales for physical dimensions of coils from one-half inch to five and one-half inches in diameter and from one-quarter to ten inches in length; a frequency scale from 400 kilocycles through 150 megacycles; a wavelength scale from two to 600 meters; a capacity scale from 3 to 1,000 micro-microfarads; two inductance scales with a range of from one microhenry through 1,500; a turns-per-inch scale to cover enameled or single silk covered wire from 12 to 35 gauge, double silk or cotton covered from 0 to 36 and double cotton covered from 2 to 36. Using these scales in the simple manner outlined in the instructions on the back of the calculator, it is possible to solve problems involving frequency in kilocycles, wavelength in meters, inductance in microhenrys and capacity in microfarads, for practically all problems that the amateur will have in designing — from high-powered transmitters down to simple receivers. Gives the direct reading answers for these problems with accuracy well within the tolerances of practical construction.

$1.00
POSTPAID

OHM'S LAW CALCULATOR

Type B

This calculator has six scales:

A power scale from microwatts through 10 kilowatts.

A resistance scale from 0.1 ohms through 10 megohms.

A current scale from microamperes through 100 amperes.

A voltage scale from microvolts through 100 kilovolts.

A supplementary wire scale from 0 to 40 B. & S.

A decibel scale, plus and minus 40 db.

With this concentrated collection of tables, calculations may be made involving voltage, current, and resistance, and can be made with a single setting of a dial. The power or voltage or current or resistance in any circuit can be found easily if any two are known. The resistance in ohms per thousand feet of copper wire is shown to the limit of the B. & S. wire gauge scale. The power ratio of any two power values expressed in decibels can readily be obtained from the calculator, and instructions are also given for finding the answers when the value is greater than 40 db, the limit of the scale. All answers will be accurate within the tolerances of commercial equipment.

$1.00
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CALCULATORS

A.R.R.L.

amateurs, engineers, servicemen and experimenters. Their accuracy is more than adequate or the solution of practical problems, and is well within the limits of measurement by ordinary means. Each calculator has on its reverse side detailed instructions for its use; the greatest mathematical ability required is that of dividing or multiplying simple numbers. All calculators are printed in several colors and are wrapped in cellophane. You will find lightning calculators the most useful gadgets you ever owned.

Wire Data Calculator

Type C

Makes instantly available information on electrical conductors which would require hours of work and access to many textbooks. It has scales for dia. in mills, Stubbs and B&S wire gauges, current carrying capacity in milliamps, turns-per-inch and turns-per-centimeter for all kinds of insulated and bare wire, and a current-carrying-capacity scale for weather-proof and rubber-insulated wire. It gives turns per sq. in., ft. per lb., ohms per mi., ohms per km., ohms per 1000′, volts lost per 1000′ per amp., current carrying capacity at 1500 cm. per amp., lbs. per 1000′, lbs. per mi., approximate tensile strength, ft. and meters per ohm, circular mills, equivalent in sq. wire. Nichrome, manganin, nickel, brass, aluminum, copper and silver wires are covered by these scales.

50¢ POSTPAID

Decibel Calculator

Type D

With a scale each for input and output level in current or voltage or power, and a transmission loss or gain scale for either voltage or power ratio plus and minus 120 or 60 db., this calculator may be used in determining decibel gain or loss in four types of problems. When input and output voltages are known, when input and output currents are known, when input and output power are known, or when input voltage to receiver and output level are known. The decibel calculator gives an instant and clear picture of what a decibel is — its relation to power and voltage. Anyone having to do with amplifiers, transmission lines, directional antennas, etc., will appreciate this calculator.

50¢ POSTPAID

Parallel Resistance Series Capacity Calculator

Type E

Solves easily an always confusing problem — the total effective resistance of two or more resistors in parallel, or the total effective capacity of two or more condensers in series. Direct reading answers for condensers or resistors of any size. A simple calculator but very useful.

50¢ POSTPAID

Resistance Calculator

Type F

This calculator makes an ohm-meter of your voltmeter. With it, it is possible to measure the resistance of a resistor or circuit by using any voltmeter with a known voltage source of from 1 to 300 volts, such as a "B" battery. Has a range from 1 ohm to 1 megohm.

50¢ POSTPAID

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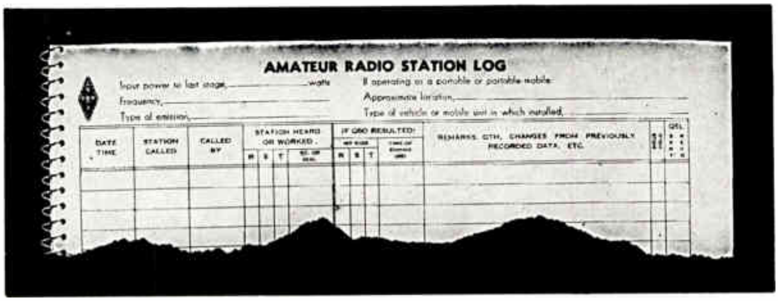
STATION OPERATING SUPPLIES

Designed by A.R.R.L. Communications Department



THE LOG BOOK

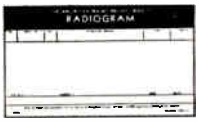
As can be seen in the illustration, the log page provides space for all facts pertaining to transmission and reception, and is equally as useful for portable or mobile operation as it is for fixed. The 38 log pages with an equal number of blank pages for notes, six pages of general log information (prefixes, etc.) and a sheet of graph paper are spiral bound, permitting the book to be folded back flat at any page, requiring only the page size of $8\frac{1}{2}$ x 11 on the operating table. In addition, a number sheet for traffic handlers is included with each book. The LOG BOOK sells for 35c per book or 3 books for $1.

OFFICIAL RADIOGRAM PADS

The radiogram blank is now an entirely new form, designed by the Communications Department to comply with the new order of transmission. All blocks for fill-in are properly spaced for use in typewriter. It has a strikingly-new heading that you will like. Radiogram blanks, $8\frac{1}{2}$ x $7\frac{1}{4}$, lithographed in green ink, and padded 100 blanks to the pad, are now priced at 25c per pad, postpaid.

and MESSAGE DELIVERY CARDS

Radiogram delivery cards embody the same design as the radiogram blank and are available in two forms — on stamped government postcard, 2c each; unstamped, 1c each.



World Radio History

MEMBERSHIP SUPPLIES

Available only to A.R.R.L. members

Insignia of the Radio Amateur

In the January, 1920 issue of *QST* there appeared an editorial requesting suggestions for the design of an A.R.R.L. emblem — a device whereby every amateur could know his brother amateur when they met, an insignia he could wear proudly wherever he went. There was need for such a device. The post-war boom of amateur radio brought thousands of new amateurs on the air, many of whom were neighbors but did not know each other. In the July, 1920 issue the design was announced — the familiar diamond that greets you everywhere in Ham Radio — adopted by the Board of Directors at its annual meeting. It met with universal acceptance and use. For years it has been the unchallenged emblem of amateur radio, found wherever amateurs gathered, a symbol of the traditional greatness of that which we call Amateur Spirit — treasured, revered, idealized.

Do You Wear the A.R.R.L. Pin?

THE LEAGUE EMBLEM, with both gold border and lettering, and with black enamel background, is available in either pin (with safety clasp) or screw-back button type.

In addition, there are special colors for Communications Department appointees.

- Red enameled background for the SCM.
- Blue enameled background for the ORS or OPS.

(Red available in pin type only. Blue may be had in either pin or button style.)

THE EMBLEM CUT: A mounted printing electrotype, 5/8" high, for use by members on amateur printed matter, letterheads, cards, etc.

ALL EMBLEMS PRICED THE SAME

50c

POSTPAID

STATIONERY

Members' stationery is standard 8½ x 11 bond paper which every member should be proud to use for his radio correspondence. Lithographed on 8½ x 11 heavy bond paper.

100 Sheets, 50c | *250 Sheets, $1.00*

500 Sheets, $1.75

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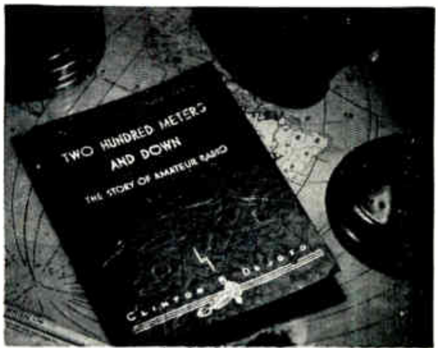
World Radio History

TWO HUNDRED METERS AND DOWN

The Story of Amateur Radio
by CLINTON B. DeSOTO



A detailed, concise presentation in full book length of all the elements that have served to develop the most unique institution of its kind in the history of the world. A book of history but not a history-book, TWO HUNDRED METERS AND DOWN: The Story of Amateur Radio tells in spirited, dramatic fashion the entire chain of significant events in the development of the art.

Part I — From the dawn of the art to the time of the World War. P[illegible] — Spark to C.W.; the progress and recognition accord[illegible] amateur radio. Part III — From the first trans-oceanic communication through development of the short waves. Readjustment and regulation of amateur radio. Its part in expeditions and emergencies. Concluding with an evaluation of the arguments for the future of amateur radio.

Most of today's amateurs have no more than fragmentary knowledge of the beginnings of their art. This book is an invaluable record that every amateur ought to own, to learn thereby the fascinating tale of our earlier days.

Approximately 200 pages, 90,000 words, with durable imitation leather red paper cover

$1.00 postpaid

Deluxe edition bound in blue cloth

$2.00

A.R.R.L. Amateur Radio MAP of the World

A map entirely new in conception and design, contains every bit of information useful to the radio amateur. A special type of projection made by Rand, McNally to A.R.R.L. specifications. It gives great circle distance measurements in miles or kilometers within an accuracy of 2%. Shows all principal cities of the world; local time zones and Greenwich; WAC divisions; 230 countries, indexed; 180 prefixes, districts and subdivisions, where used; and U. S. examining points. Large enough to be usable, printed in six colors on heavy map paper, 30 x 40 inches.

Price $1.25 postpaid

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