The radio amateur's handbook

THE STANDARD MANUAL OF AMATEUR RADIO COMMUNICATION

PRICE $1.00

PUBLISHED BY THE AMERICAN RADIO RELAY LEAGUE

The Radio Amateur's Handbook

THE STANDARD MANUAL OF AMATEUR RADIO COMMUNICATION
BY THE HEADQUARTERS STAFF OF THE AMERICAN RADIO RELAY LEAGUE

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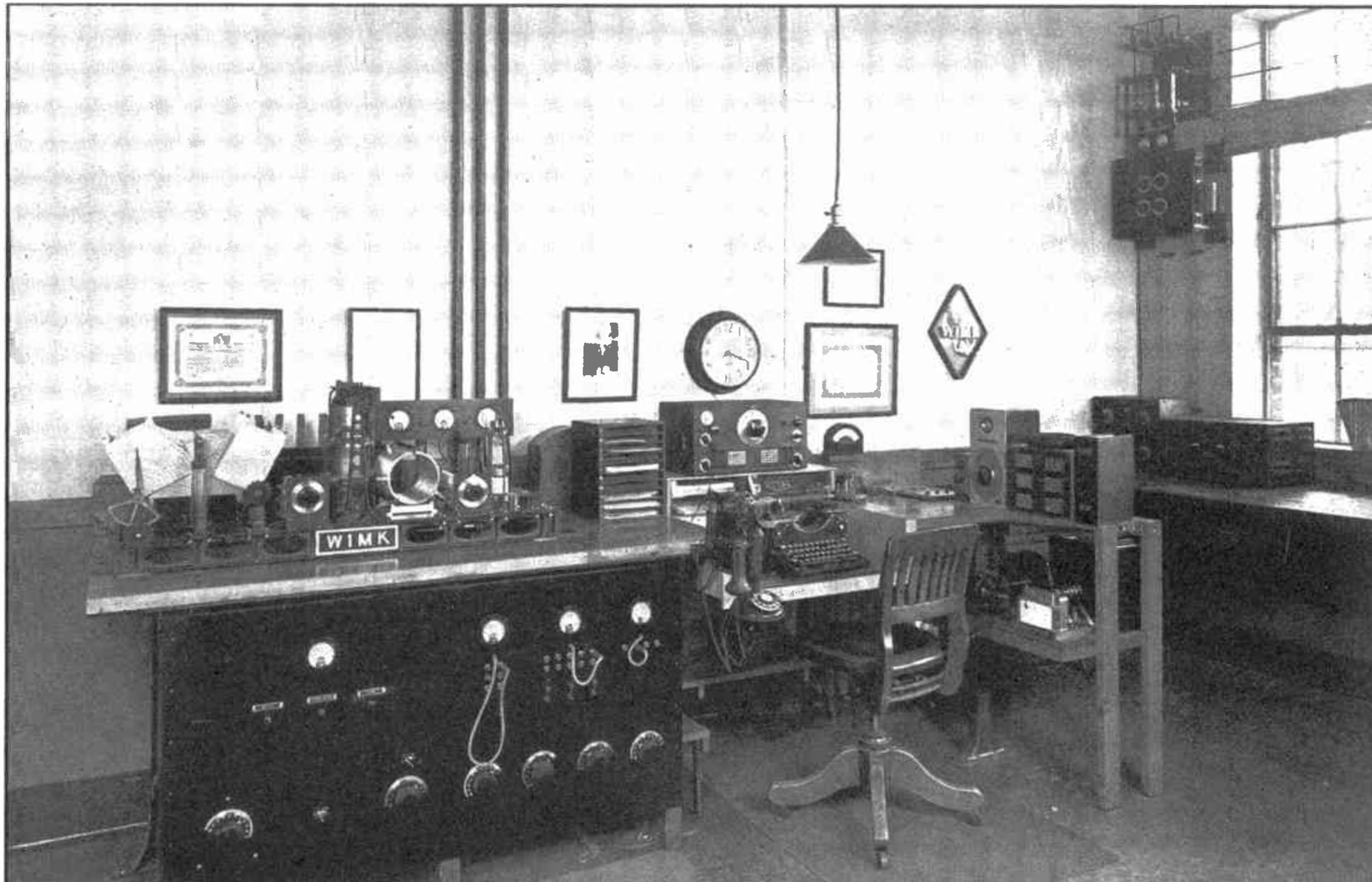


W1MK, HEADQUARTERS STATION OF THE A.R.R.L. AT HARTFORD, CONNECTICUT

Full details of the equipment are given on the last page of Chapter Twenty-one

FOREWORD

In presenting the 1936 edition of THE RADIO AMATEUR'S HANDBOOK the publishers again express the hope that it will be found as helpful as the previous editions and enjoy as whole-hearted a reception at the hands of the amateur fraternity.

The *Handbook* is intended both as a reference work for member-operators of the American Radio Relay League and other skilled amateurs and as a source of information to those wishing to participate in amateur radio activities but having little or no idea how to get started. The choice and sequence of material have been planned with particular thought to the needs of the practising amateur but each topic has been so treated as to cover amateur practice all the way from the most simple to the most comprehensive. Designed to be a practical rather than a theoretical work, theoretical discussions have been made as simple and fundamental as possible and the chief effort directed at practical means for securing results — which, after all, is the principal aim of the amateur in radio.

The *Handbook* had its rather modest beginnings in 1925 when Mr. F. E. Handy, for many years the League's communications manager, commenced work on a small manual of amateur operating procedure in which it was deemed desirable to include a certain amount of "technical" information, since an amateur's results are so greatly influenced by the disposition and adjustment of his apparatus. When Mr. Handy completed his manuscript he had written a considerable-sized book of great value. It was published in 1926 and enjoyed an instant success. Produced in the familiar format of the League's magazine, *QST*, it was possible to distribute for a very modest charge a work which in volume of subject matter and profusity of illustration surpassed most available texts selling for several times its price. Mr. Handy revised several successive editions as reprinting became necessary. With the fourth edition, in 1928, he was joined in this duty by the undersigned, who was directing the technical development program which the A.R.R.L. was then conducting for the special purpose of developing new apparatus and new methods which would meet the difficulties imposed upon amateur radio by the provisions of the new international radio treaty which was to take effect in 1929. Three editions appeared 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 technical material. Now in the headquarters establishment of the League at West Hartford there are many technically-skilled amateurs, each a specialist in his field. It was therefore but natural that with the preparation of the seventh edition in 1930 the technical chapters of the *Handbook* should be given into their hands. Since that time the publication has been a family affair, the joint product of the headquarters staff.

To a total of twenty printings the fame of the *Handbook* has echoed around the world. More than three hundred thousand copies have been distributed at this writing. Its success has been really 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 on the globe. But amateur radio moves with amazing rapidity and the best practices of yesterday are quickly superseded by the developments of to-day. The very success of the book as a publication brings a new responsibility to us, the publishers — the *Handbook* must be kept up to date.

Because the present year has seen further revolutionary changes in amateur practice it has been necessary again to undertake a comprehensive revision for this edition. We are happy at the same time to be able greatly to expand the size of the book. Most of the chapters have been entirely rewritten. All of them have been thoroughly modernized. Several new chapters have been added and in the technical chapters a separation has been made between the discussions of principles and of construction which we hope will be helpful to the reader. The edition represents the collaboration of many members of the A.R.R.L. staff. The first two chapters are from the pen of Mr. A. L. Budlong, the assistant secretary of the League. The several chapters on fundamentals, on receivers and on radio-telephony are by Mr. James J. Lamb, the technical editor of *QST*, Mr. C. B. DeSoto collaborating on the receiver construction chapter. Mr. George Grammer, the assistant technical editor, has prepared the chapters on vacuum tubes, on transmitters and keying, and on instruments and measurements. The power supply chapter has been revised by Mr. Donald H. Mix, of the technical information service. Mr. Clark C. Rodimon, managing editor of *QST*, contributes the chapter on assembling the station. Mr. Handy, our communications manager, has prepared the important chapters on the A.R.R.L. Communications Department, on operating a station and on message handling. The chapters on ultra-high-frequency apparatus are by the undersigned, and several of us have had a hand in the antenna chapter.

By no means the least useful feature of this edition is the quite extensive catalog advertising that accompanies it. It is not generally regarded as in good taste to make any editorial reference to the 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 his *matériel*. Both are necessary ingredients of the complete standard manual of amateur high-frequency communication.

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

ROSS A. HULL
EDITOR

West Hartford, October, 1935.

The Radio Amateur's Handbook

CONTENTS

THE AMATEUR'S CODE

I

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.

II

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

III

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

IV

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.

V

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.

VI

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

CHAPTER ONE

The Story of Amateur Radio

HOW IT STARTED; THE PART PLAYED BY THE A.R.R.L.

Amateur radio represents, to upwards of fifty thousand people, the most satisfying, most exciting of all hobbies. Forty thousand of these enthusiasts are located in the United States, for it is this country which gave birth to the movement and which, since the beginning, has represented its stronghold.

When radio broadcasting was first introduced to the public a few 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 uppermost in the minds of many listeners; yet the thrill of "dx" is still a major factor in the minds of hundreds of thousands of people, as witness the present growing 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 home-made) 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 to foreign contacts; neither high power nor expensive equipment is required.

HIRAM PERCY MAXIM
Founder–President of the American Radio Relay League

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 our 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 or 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?

It started shortly after 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 likes to style himself even today. But amateur radio as we think of it was born when the first private citizen saw in the new marvel a means for personal communication with others and set about learning enough of the new art to build a home-made station, hoping that at least one of his friends would do the same so he could have someone to talk to. 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 before and the second after the World War.

Pre-war amateur radio bore little resemblance to the art as we know it today, 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 trans-continental 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 some 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 short-wave development.

Conceived and formed by the famous inventor and amateur, 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.

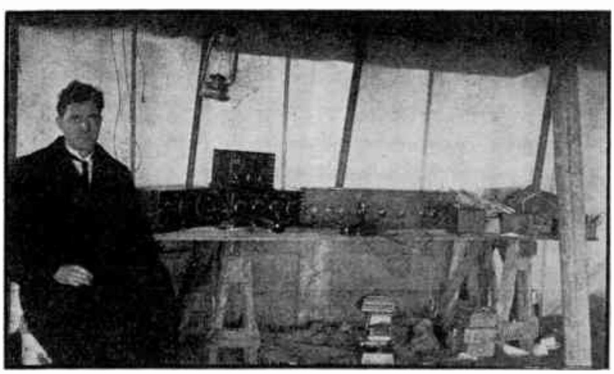
● Few amateurs today realize that the war not only marked the close of the first phase of amateur development but came very near marking its end for all time. The fate of amateur radio was in the balance in the days immediately following declaration of the Armistice, in 1918. The government, having had 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 old 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 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 head-long 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 trans-Atlantic 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 objec-

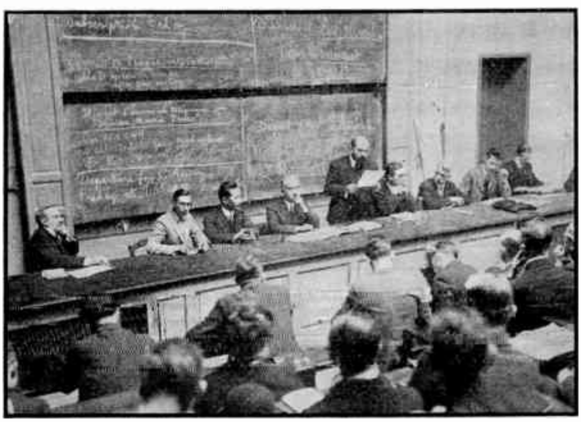


IN GODLEY'S TENT, ON THE SHORES OF SCOTLAND tive: two-way communication across the Atlantic by amateur radio! It *must* be possible — but somehow we couldn't quite make it. Further increases in power were out of the question; many amateurs already were using the legal maximum of one kilowatt. Better 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 1932 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, and Reinartz, 1XAM, 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.



THE FIRST INTERNATIONAL AMATEUR CONGRESS, 1925

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 on 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 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 in enabling an east-coast amateur to communicate with another on the west coast, direct, at high noon. The dream of amateur radio — daylight DX!

● 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. Nearly two thousand such certificates have been issued. Representatives of the A.R.R.L. went to Paris several years ago and deliberated with the amateur representatives of twenty-two other nations. On April 17, 1925, this conference formed the International Amateur Radio Union — a union of national amateur societies. We have discovered that the amateur as a type is the same the world over.

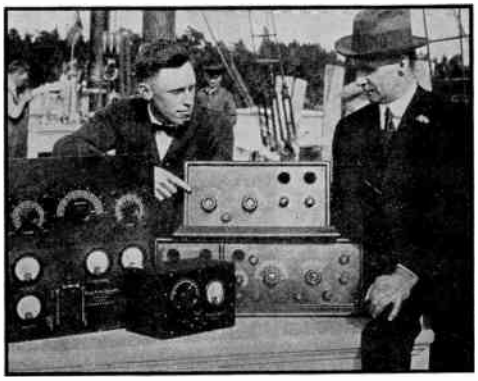
Nor has experimental development been lost sight of in the enthusiasm incident to international amateur communication. The experimentally-minded amateur is constantly at work conducting tests in new frequency bands, devising improved apparatus for amateur receiving and transmitting, learning how to operate 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; many 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.

Most of the technical developments in amateur radio have come from the amateur ranks. Many of these developments represent valuable contributions to the art. 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. It is interesting to know that these articles were read as widely in professional circles as by amateurs with the result that dozens of broadcast stations besieged the League for information on how this method of modulation could be adapted to their own installations. 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 1933 came another great contribution to transmitter practice in the form of the tri-tet crystal oscillator, simplifying the high-frequency crystal controlled transmitter by reducing the number of stages necessary and improving transmitter reliability, stability and efficiency. 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. And 1935 saw the development of the super-infragenerator (S.I.G.) receiver by the League's technical staff, giving to ultra-high-frequency communication a method of reception comparable with that available from superheterodynes on lower frequencies.

● 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."



DON MIX, COMMANDER MACMILLAN, AND WNP, 1923

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 nearly one hundred storm and flood emergencies in this country. The most noteworthy were the Florida Hurricane of 1926, the Mississippi and New England floods of 1927, and the California dam break and second Florida hurricane in 1928. During 1931 there were the New Zealand and Nicaraguan earthquakes, and in 1932 the floods at Caliente, California and in the upper Guadelupe valley of Texas. Outstanding in 1933 was the southern California earthquake.

In 1934 the Montrose (Cal.) and Washita Valley (Okla.) floods resulted in notable amateur coöperation, and in 1935 the Florida hurricane disaster saw some of the best-organized amateur participation in the history of emergency work. In these and many others (see any yearly *QST* index under "Emergencies and Relief Work"), amateur radio played a major rôle in the rescue work, and amateurs earned world-wide commendation for their 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 more than a hundred voyages and expeditions have been assisted. To-day practically no exploring trip starts from this country to remote parts of the world without making arrangements to keep in contact through the medium of amateur radio.

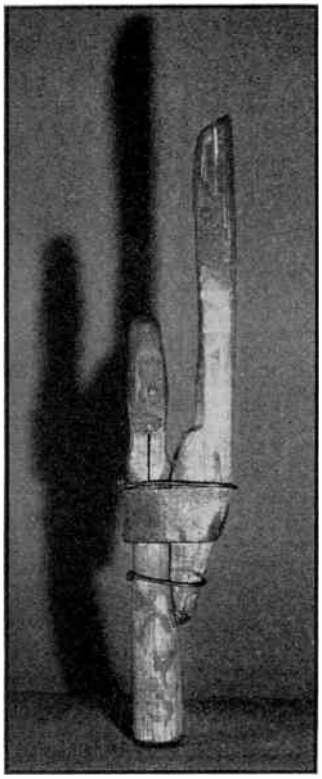
Emergency relief, expeditionary contact, and countless instances of other forms of public service, rendered as they always have been and always will be, without hope or expectation of material reward, have made amateur radio one of the integral parts of our complex national life.

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 activites 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 number 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 WOUFF-HONG

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 specific matters that arise 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 the story of amateur radio, League headquarters has grown until now it occupies an entire floor in a new office building and employs more than two 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 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.

W1MK

● For many years it was the dream of the League's officers that some day Headquarters would be able to boast a real "he-station." In 1928 this dream became an actuality, and the League today owns and operates the station shown in the frontispiece, operating under the call W1MK.

The current operating schedules of W1MK may be obtained by writing the Communications Department at Headquarters or by consulting the current issue of *QST*. While much of the operating time is devoted to prearranged schedules, the station is always ready at other times for a call from any amateur.

Traditions

● As the League has come down through the years, certain traditions have become a part of amateur radio.

The Old Man with his humorous stories on "rotten radio" has become one of amateur radio's principal figures. Since 1915 his pictures of radio and radio amateurs as revealed by stories in *QST* are characteristic and inimitable. There is much speculation in amateur circles concerning the identity of T.O.M., but in twenty years of writing he has not once given a clue to his real name or call.

The Wouff-Hong is amateur radio's most sacred symbol and stands for the enforcement of law and order in amateur operation. It came into being originally in a story by T.O.M. For some time it was not known just what the Wouff-Hong looked like, but in 1919 The Old Man himself supplied the answer by sending in to League Headquarters the one and only original Wouff-Hong, shown here. It is now framed and hangs on the wall of the Secretary's office at A.R.R.L. Headquarters.

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 single simple 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 25c if you are unable to obtain one at your local newsstand.

CHAPTER TWO

Getting Started

THE AMATEUR BANDS—LEARNING THE CODE—OBTAINING LICENSES

Having related, briefly, the origin and development of amateur radio in this country, we can now go on to the more practical business of describing in detail how to get in on the amateur radio of today. Subsequent chapters will treat of receiver and transmitter construction and adjustment, station operation, etc. This chapter deals with the first two *bêtes noires* of every beginning amateur—learning the code and getting your licenses.

A high-frequency (short-wave) receiver alone will bring you hours of pleasure and will repay the little effort necessary to assemble it. Sooner or later, however, it is probable that you will build yourself either a radiotelephone or radiotelegraph transmitter. While many amateurs build 'phone transmitters, the majority both in this country and abroad operate radiotelegraph sets. There are several reasons for this. First, the code must be learned regardless of whether you operate a 'phone or telegraph set; the United States government won't issue any kind of amateur license without a code test. Secondly, radiotelegraph apparatus is far less expensive to build and less complicated to adjust than radiophone apparatus; less equipment and power are required and fewer tubes used. And lastly, code signals will usually cover four or five times the distance possible from the same or more complicated radiophone equipment, and are less susceptible to interference, fading and distortion.

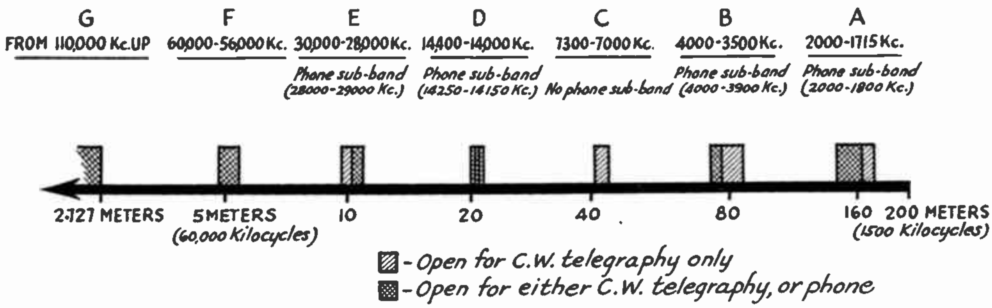
There is nothing particularly difficult incident to taking your place in the ranks of licensed amateurs. The necessary steps are first, to learn the code, second, to build a receiver and a transmitter and third to get your amateur licenses and go on the air. Don't let any of these worry you. Thousands of men and women between the ages of 15 and 60 have mastered the code without difficulty by the exercise of a little patience and perseverance; these same thousands have found that only a moderate amount of study is necessary to prepare for the examination required by the government of all applicants for the combination station-operator license which every amateur must have before actually going on the air. We will treat of both of these subjects in detail later in this chapter.

Nor should you doubt your ability to build short-wave receivers and transmitters. The simpler types of receiver and transmitter described further on in this *Handbook* can be assembled and put into operation by anyone capable of using a screwdriver, a soldering iron and a little common sense. Of course, there are advanced forms of amateur equipment that are intricate, complicated to build, and more difficult to understand and adjust, but it is not necessary to resort to them to secure results in amateur radio, and it would be best to avoid them until the rudiments of the game have been learned.

Our Amateur Bands

● Most people, because they have never heard anything else, are prone to think of broadcasting as the most important radio service. 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, transocean commercial radiotelphone and telegraph messages, high frequency international broadcasting of voice and music, transmissions from government and experimental stations including picture transmission and television services, 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. These bands are in approximate harmonic relation to each other; their position in the short wave spectrum and their relative widths are shown in the sketch.



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. But in addition to daily changes, there are seasonal changes, and in addition a long-time change in atmospheric conditions which seems to coincide closely with the cycle of sun-spot or solar activity which is completed approximately each eleven years. 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. Many amateurs can use any one of the several available frequency bands at will. Let us now discuss briefly the properties peculiar to each of them.

The 1715-kc. band, which carried all our 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 greatly on the increase.

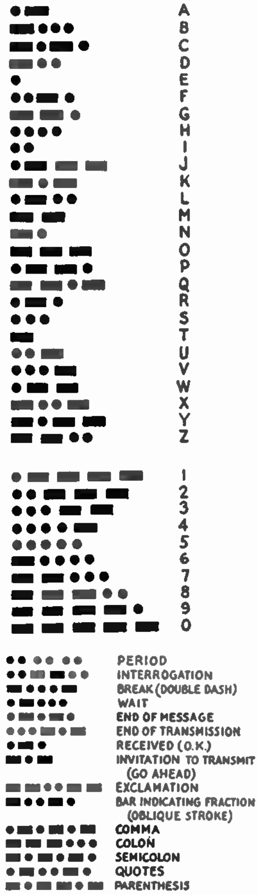
The band is popular especially for radiotelephone work. The very fact that it is less congested and occupied makes it an extremely attractive band for the amateur operator who would communicate effectively and avoid interference. Code practice transmissions are made in this band for beginning amateurs 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. In the next year or so, it may be expected to take more of the present properties of the 3500-kc. region, and its use by amateurs continue to increase. The band is open to amateur television and picture transmission. If you are just getting on the air, plan to use this band. If you have been working on higher frequencies include this band in your plans for 1936 — or you will be missing an important part of amateur radio.

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. It is the band from which we have made excursions to the higher frequencies on occasions when foreign contacts were desired. At the present time this band is exhibiting many of its former DX properties, signals from amateur stations in this country being reported from South Africa, New Zealand and other remote points, and 'phone signals heard in Europe. As the winter evening advances, the well-known "skip effect" (explained in detail in Chap. 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 DX work for some 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 subject to the vagaries of skip-effect and uncertain transmission conditions than are the lower frequency bands, but not limited in usefulness by these things 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. This band may be expected to continue good daylight DX characteristics during 1936 if predictions based on the sun-spot cycle are correct, and at the same time, while great possibilities will exist for evening work, it is likely to be inconsistent and unreliable occasionally during the late evenings.

The 14,000-kc. or 14-mc. band is the very 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 long-distance characteristics are generally too "spotty" for reliable communication. The result is that only a few amateurs to-day operate in this territory, though it is probable that more attention will be given to its short-distance properties as the 56-mc. band fills up. The band was "hot" from the DX standpoint for a few months during the early summer and fall of 1935, however, and this condition may be encountered again in 1936.



THE CONTINENTAL CODE

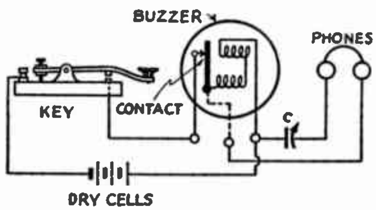
The 56,000-kc. or 56-mc. band, made available for amateur experimentation at the request of the League, has for many years been regarded as strictly a local and short-distance band for distances of ten to thirty miles. Because of the cheapness, compactness and ease of construction of the necessary apparatus 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 during 1935 and is expected to continue even stronger in 1936.

Above 110,000 kc. but little progress has as yet been made, since it was only during the summer of 1934 that the A.R.R.L. was able to secure a regulation permitting general amateur work on all the higher frequencies above 110-mc. 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 1936 it is expected that many experimenters will endeavor to exploit them to their utmost for communication purposes.

Memorizing the Code

● 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 all the characters for the alphabet, the most-used punctuation marks, and the numerals, and will be ready to practice receiving in 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 ten words a minute required by the government for your amateur operator license, and can immediately proceed to studying for the "theoretical" part of your license examination without loss of time.

Memorizing the code is no job at all if you simply make up your mind you are going 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



CONNECTIONS OF A BUZZER CODE PRACTICE SET WITH A TELEPHONE HEAD SET

The intensity of the signal can be varied by changing the setting of the variable condenser. The 'phone and condenser are connected either across the coils of the buzzer or across the vibrator contacts. The condenser may be omitted and the tone may be changed by changing the number of dry cells.

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.

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.

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.

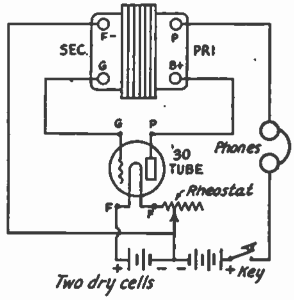
Acquiring Speed by Buzzer Practice

● When the code is thoroughly memorized, you can start to develop speed in receiving code transmission. The most enjoyable 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. One 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 of this set 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 an old audio transformer, a type '30 tube, a pair of 'phones, key, two No. 6 dry cells, tube-socket, a 20-ohm filament rheostat, and a 22½-volt B battery. These are hooked up as shown in the diagram to form an audio oscillator. If nothing is heard in the 'phones when the key is depressed, reverse the leads going to the two binding posts at either transformer winding. Reversing both sets of leads will have no effect.

Either the buzzer set or this audio oscillator



CONNECTING AN AUDIO OSCILLATOR FOR CODE PRACTICE WORK will give good results. The advantage of the audio oscillator over the buzzer set is that it gives a fine signal in the 'phones without making any noise in the room.

After the practice set has been built, and 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 ten words a minute (50 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.

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. Nor should you make the mistake of assuming that this is a more difficult and less-preferred method: it is probable that the *majority* of amateurs acquire their code speed by this method. After building a receiver and getting it in operation, the first step in "learning by listening" will be to hunt for a station sending slowly. With even the simplest short-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. Learning by this method may seem harder to some folks than learning with the buzzer. It is the opinion of the writer, who learned in this way, that the practice in copying actual signals and having real difficulties with interference, static, and fading, is far superior to that obtained by routine buzzer practice. Of course the use of a buzzer is of value at first in getting familiar with the alphabet.

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.

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 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 We Hear

● As soon as we finish our receiver and hook it up we shall 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 time of day, remote stations may or may not be louder than relatively near-by stations.

U. S. AMATEUR CALL AREAS

The first letters we 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 W9GP, W8CMP, W3BZ, W1MK, etc., the number indicating the amateur call area (see map) 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.

The commercial stations use a procedure differing in some respects from amateur procedure, and to some extent the procedure of army, naval and government stations is different from this, each service having a modified procedure meeting its own requirements. On the other hand, the International Radiotelegraph Convention has specified certain regulations, abbreviations and procedures which govern all services and insure basic uniformity of methods and wide understanding between stations of all nations, regardless of services.

"Tape" or "machine" transmission and reception is used to speed up traffic handling to the limit fixed by relays and atmospheric conditions. Most beginners are puzzled by certain abbreviations which are used. Many code groups are sent by different commercial organizations to shorten the messages and to reduce the expense of sending messages which often runs as high as 25 cents a word. Unless one has a code book it is impossible to interpret such messages. Five- and ten-letter cypher groups are quite common and make excellent practice signals. Occasionally, a blur of code will be heard which results when tape is speeded up to 100 words per minute and photographic means are used to record the signals.

League O.B.S. System

● Official Broadcasting Stations of the A.R.R.L. send the latest Headquarters' information addressed to members *on amateur frequencies*. The messages are often interesting and many of them are sent slowly enough for code practice between 15 and 20 words a minute. Lists and schedules appear from time to time in the membership copies of *QST*.

The very latest *official and special information of general interest*, addressed to A.R.R.L. members, is broadcast twice nightly (except Wednesday and Saturday) simultaneously on two frequency bands from the Headquarters' amateur station, W1MK. The schedule for these transmissions is as follows:

Sun.	8:30 p.m. EST–13 w.p.m.	— 3825 and 7150 kcs.
Sun.	Midnight EST–22 w.p.m.	— 3825 and 7150 kcs.
Mon.	8:30 p.m. EST–22 w.p.m.	— 3575 and 7150 kcs.
Mon.	10:30 p.m. EST–13 w.p.m.	— 3575 and 7150 kcs.
Tues.	8:30 p.m. EST–13 w.p.m.	— 3575 and 7150 kcs.
Thurs.	8:30 p.m. EST–13 w.p.m.	— 3825 and 7150 kcs.
Thurs.	Midnight EST–22 w.p.m.	— 3825 and 7150 kcs.
Fri.	8:30 p.m. EST–22 w.p.m.	— 3825 and 7150 kcs.
Fri.	10:30 p.m. EST–13 w.p.m.	— 3825 and 7150 kcs.

As you can see from this schedule, W1MK sends these bulletins simultaneously on two different frequency bands, so if you are unable to hear the station on the 3500-kc. band you may be able to pick it up on the 7000-kc. band, and *vice versa*.

These transmissions are sent at the indicated rates of speed and are frequently used by advanced beginners for *code practice* work.

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.

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 shouldn't send fast. Keep your transmitting speed down to the receiving speed, and rather bend your efforts to sending *well.*

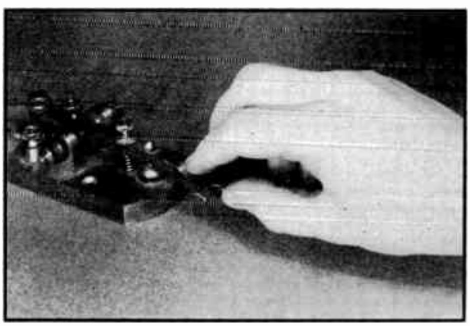
When sending do not try to speed things up too soon. A slow, even rate of sending is the mark of a good operator. Speed will come with time alone. Leave special types of keys alone until you have mastered the knack of properly handling the standard-type telegraph key. Because radio transmissions are 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.

When signals can be copied "solid" at a rate of ten words a minute it is time to start practicing with a key in earnest. While learning to receive, you have become fairly familiar with good sending. Try to imitate the machine or tape sending that you have heard. This gives a good example of proper spacing values.

When beginning to handle a key do not try to send more than six or seven words a minute. A dot results from a short depression of the key. A dash comes from the same motion but the contact is held three times as long as when making a dot. A common mistake of beginners is to make it several times too long. There is no great space between the parts of a letter. Particular care should be exercised when sending letters such as *c* to make them "all at once" like this (— – — –) and *not* irregularly spaced like this (— –   — –).

Key practice should not be extended over too long periods at first. The control of the muscles in the wrist and forearm should be developed gradually for best results.

Individuality in sending should be suppressed rather than cultivated. Speed needs to be held in check. "Copiability" is what we want. Repeats waste valuable time. When you find that you are sending too fast for the other fellow, slow down to his speed.



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

A word may be said about automatic and "double-action" keys. These make dots automatically. The rate of making dots is regulated by changing the position of a weight on a swinging armature. Dots are made by pressing a lever to the right. Dashes are made by holding it to the left for the proper interval. A side motion is used in both types of keys.

These keys are useful mainly for operators who have lots of traffic to handle in a short time and for operators who have ruined their sending arm. Such keys are motion savers. However, a great deal of practice is necessary before readable code can be sent. The average novice who uses a "bug" tries to send too fast and ruins his sending altogether. The beginner should keep away from such keys. After he has become very good at handling a regulation telegraph key, he may practice on a "bug" to advantage.

Obtaining Government Licenses

● When you are able to copy ten 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 nine 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 (October, 1935) 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 Department of Marine and Fisheries, Radio Branch, 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.

CHAPTER THREE

Fundamental Electrical Principles

ESSENTIAL ELEMENTS IN ALTERNATING AND DIRECT CURRENT CIRCUITS

AMATEUR radio is a part of the great field of electrical communication, both wire and radio, which has its foundation in the knowledge of electricity that has been in process of development for centuries. Although Marconi's actual radio communication did not come into being until the turn of the present century, its accomplishment resulted directly from the earlier scientific work of Hertz with electro-magnetic waves (in the eighteen-eighties); while this work, in turn, had as its foundation the still earlier contributions of Maxwell (in the eighteen-sixties). And preceding these developments, which we associate more directly with present-day radio, were the discoveries of Faraday and a host of others, extending back to Thales in ancient Greece. The names of many of these builders of our radio structure remain with us to-day in the familiar designations of electrical units and phenomena; the "volt" for Volta, the "ampere" for Ampere, the "ohm" for Ohm, the "farad" for Faraday, the "henry" for Henry, and so on.

While it is possible for the practical amateur to set up and operate a station more or less successfully by diving into the game with little or no understanding of these fundamental electrical principles, more certain progress and greater enjoyment follow when the rudiments are familiar to him. Starting without them, one is certain, sooner or later, to be stuck by problems that demand a knowledge of fundamental things for their solution, necessitating turning back to cover the neglected groundwork. Of course a thoroughly complete treatment of these principles in all their aspects would be beyond the possible scope of this book. Hence, our purpose here is to give essential information on those fundamentals which have been shown by experience to be most useful in the practical building and operating of a station.

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	~	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. or mc.	Watt (watts)	w.

For further study the advanced amateur is referred to the selected references given in the Appendix and listed in the "Amateur's Bookshelf" elsewhere in this volume.

What Is Electricity?

In the not distant past the nature of electricity was considered something beyond understanding but in recent years much of the mystery has been removed. We know now that what we call electricity is the evidence of activity of electrons.

"*Electrons in motion constitute an electric current.*"

But what is the electron and what is the source of those that constitute electric current? The accepted theory is that the electron does not ordinarily exist in an isolated state but normally has a sort of family life, in combination with other electrons, in the *atom*. Atoms make up *molecules* which, in turn, make up the substances familiar to us, copper, iron, aluminum, etc. Atoms differ from each other in the number and arrangement of the electrons that constitute them.

The atom has a nucleus which is considered to be composed of both positive and negative electrons, but with the positive predominating so that the nature of the nucleus is positive. For purposes of identification the positive electrons are referred to as *protons* and the negative electrons simply as *electrons*. The electrons and protons of the nucleus are intimately and closely bound together. But exterior to the nucleus are negative electrons which are more or less free agents that can leave home with little urging. Ordinarily the atom is electrically neutral, the outer negative electrons balancing the positive nucleus. It is when something happens to disturb this balance and when the foot-loose electrons begin to leave home that electrical activity becomes evident.

Electron Flow — Electric Current

● It is considered likely that there is a continuous interchange of electrons between the atoms of a solid body, such as a piece of copper wire, but that the net effect under ordinary conditions is to make the average in any one direction practically negligible. If, however, there is an electric field through the wire, as when the ends are connected to the terminals of a battery, there sets in a consistent drift of the negatively charged electrons, from atom to atom, towards the end of the wire connected to the positive battery terminal, somewhat as shown in Fig. 301. This drift of electrons constitutes an electric current. The rate at which the current flows will be determined by the characteristics of the conductor, of course, and by the strength of the electric field.

Each electron, and they are all alike irrespective of the kind of atom from which they come, is unbelievably minute and a measure of electric current in terms of number of electrons would be impracticable. Therefore a larger unit is used, the *ampere*.

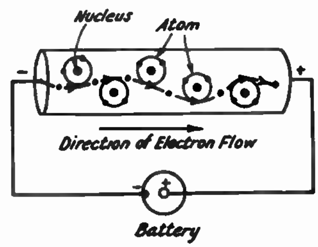


FIG. 301 — ILLUSTRATING CURRENT CONDUCTION IN A SOLID SUBSTANCE SUCH AS A COPPER WIRE

Electrons are relayed from atom to atom, from the negative towards the positive end.

A current of 1 ampere represents 10^{18} (ten million, million, million) electrons flowing past a point in 1 second; or a micro-ampere (millionth of an ampere) 10 million electrons per microsecond (millionth of second).

Direction of Flow

● There is one point in connection with current flow which is likely to cause confusion if particular attention is not paid to it. *The drift of electrons along a conductor* (which constitutes a current flow) *is always from the negative to the positive terminal.* On the other hand, the conventional conception is that of electricity flowing from the positive to the negative terminal. The discrepancy results from the fact that the pioneer electrical experimenters, having no accurate understanding of the nature of electricity, arbitrarily assumed the direction to be from positive to negative. However, just so long as the facts are recognized clearly, no confusion need result.

A helpful practical rule to remember is: *The conventionally "negative" (or "—") terminal of a device, such as a direct-current meter, is always connected to the side of a circuit from which electrons are flowing.* For instance, a d.c. meter connected in the external circuit of the vacuum tube illustrating thermionic emission in Fig. 302, in series with the battery, would have its negative terminal towards the plate and its positive terminal towards the cathode, since the electrons are flowing from the plate back to the cathode in this "return" circuit.

This would be true whether the meter was connected between the positive side of the battery and plate, or between the negative side of the battery and cathode. A voltmeter connected across the battery to measure the supply voltage would have its negative terminal connected to the negative of the battery and its positive terminal to the positive of the battery, since in this case the electron flow through the meter would be from the negative terminal of the battery to its positive, as shown by the illustration of conduction in Fig. 301.

Conductors and Insulators

● The ease with which electrons are able to be transferred from one atom to another is a measure of the conductivity of the material. When the electrons are able to flow readily, we say that the material is a good *conductor*. If they are not able to chase off to another atom quite so readily, we say that the substance has more *resistance*. Should it be almost impossible for the electrons to break from their normal path around their own nucleus, the material is what we term an *insulator*. Copper, silver and most other metals are relatively good conductors of electricity; while such substances as glass, mica, rubber, dry wood, porcelain and shellac are relatively good insulators.

The resistance of most substances varies with changes in temperature. Sometimes the variation is so great that a body ordinarily considered an insulator becomes a conductor at high temperatures. The resistance of metals usually increases with an increase in temperature while the resistance of liquids and of carbon is decreased with increasing temperature.

Conduction in Liquids and Gases

● Besides the case of conduction in the solid copper wire, in which there is electron drift from atom to atom but with the individual atoms remaining more or less stationary and each being but momentarily deficient in electron content, there are other forms of conduction important in radio communication. The general case of conduction in liquids is one.

Ionization

● For instance, take that of conduction in a solution of sodium chloride (common table salt) in water. In such a solution there is a number of *molecules* of salt that have separated into two parts, one of which has the nucleus of the sodium atom while the other has the nucleus of the chlorine atom. But the two parts are not truly atoms because the chlorine part has one excess electron and is *negative* in character while the sodium part is deficient by one electron and therefore is *positive* in character. No longer true atoms, they are now *ions* and the spontaneous process of *disassociation* in solution is one form of *ionization*. If plates connected to the terminals of a battery are now placed in the solution, the positive sodium ions travel to the negative plate where they acquire negative electrons; and the negative chlorine ions travel to the positive plate where they give up their excess electrons; and both again become neutral atoms. The energy supplied by the battery is used to move the ions through the liquid and to supply or remove electrons. Thus there is a flow of electric current through the liquid by *electrolytic conduction*. This kind of conduction plays a part in the operation of such radio equipment as electrolytic rectifiers.

Another type of conduction important in the operation of radio equipment is that which takes place in gases. This also involves ionization, although here the ionization is not spontaneous as in the electrolytic conduction just described but is produced by rapidly moving free electrons colliding with atoms, and hence, is called *ionization by collision*. Such conduction is illustrated by the ordinary neon lamp. The bulb contains a pair of plates and is filled with neon gas. In addition to the molecules of the gas, there will be a few free electrons. If a battery of sufficient voltage is connected to the two plates, the initial free electrons will make a dive for the positively charged plate, their velocity being accelerated by the electric field. In their headlong dash they collide with neon atoms and knock off outer electrons of these atoms, converting the latter to positive ions. The additional free electrons produced by collision now join the procession, and ionize more atoms. As they are freed, the electrons travel towards the positive plate. In the meantime, the more sluggish positive ions have been traveling towards the negative plate, where they acquire electrons and again become neutral atoms. The net result is a flow of electrons, and hence of current, between the

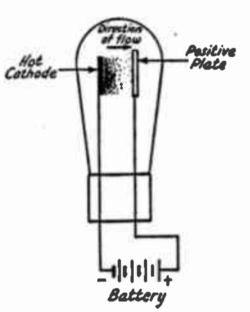


FIG. 302 — ILLUSTRATING CONDUCTION BY THERMIONIC EMISSION OF ELECTRONS IN A VACUUM TUBE

When the cathode is heated electrons are stimulated to fly off from the cathode surface and are attracted to the positive plate. Clouding of electrons near the cathode constitutes what is known as the space charge.

electrodes, 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 by ionization* is utilized in the operation of the gaseous rectifiers used in radio power supplies.

Electron Emission

● Still another form of conduction very important in radio communication is pure *electronic conduction*. In the case of the copper wire we saw that the individual electrons did not make the complete trip from one end of the circuit to the other but that the flow was a sort of relay process. We also saw that the electrons could not leave the wire in random directions but, under the influence of the electric field, progressed only from the negative towards the positive end. They were restrained from leaving the surfaces of the conductor. But they can be made to fly off from the conductor when properly stimulated to do so, as is illustrated by the familiar radio vacuum tube. Here we have electrons being freed from the *cathode*, a conductor that would nominally retain them, and actually traveling through vacuum to the plate that attracts them because it is connected to the positive terminal of a battery, as illustrated in Fig. 302. The reason that the electrons are freed from the cathode is that it has been heated to a temperature that activates them sufficiently to enable them to break away. This is known as *thermionic electron emission*, sometimes called simply *emission*. Once free, most of the emitted electrons make their way to the plate, although some return, repelled from traveling farther by the cloud of negative electrons immediately surrounding the cathode. This electron cloud about the emitting cathode constitutes what is known as the *space charge*. A few electrons that reach the plate may have sufficient velocity to dislodge one or more electrons already on the plate. This dislodging of electrons from the plate by other fast moving electrons constitutes *secondary emission*. When it occurs there is actually simultaneous electron flow in two directions. The various phenomena connected with electronic conduction, briefly outlined here, are of such extreme importance in the operation of vacuum tubes that they cannot be emphasized too greatly.

Photoelectric Emission

● In addition to the two types of electron emission just described, there is also a third type known as *photoelectric emission*. Such emission occurs when electrons are liberated from matter under the influence of light rays. While it has little practical application in amateur radio, it is utilized widely in other fields where photo-electric cells or tubes are used. A photoelectric tube contains a cathode of material which liberates electrons readily when exposed to light and an anode (positive plate) which attracts the liberated electrons.

Electromotive Force (e.m.f.)

Just as soon as electrons are removed from one body and become attached to a second one, there is created a firm desire on the part of the estranged electrons to return to their normal position. For instance, the excess electrons on the negatively charged pole of a battery, attempting to return to the positively charged pole, create an *electrical pressure* between the two terminals. This pressure is termed *electromotive force* and the unit of measurement, widely used in our radio work, is the *volt*. In the ordinary dry cell (when fresh) the electromotive force between the two terminals is of the order of 1.5 or 1.6 volts. Should we have two such cells, and should we connect the negatively charged terminal of one to the positively charged terminal of the second cell we would then have twice the voltage of one cell between the remaining two free terminals. In this example we have connected the cells in *series* and the combination of the two cells becomes what we know as a *battery*. In the common "B" battery, so widely used with radio receivers, a great many small cells are so connected in series to provide a relatively high electromotive force or voltage between the outer terminals.

Another method of connecting a battery of cells together is to join all the positive terminals and all the negative terminals. The cells are then said to be connected in *parallel*. The voltage between the two sets of terminals will then be just the same as that of a single cell but it will be possible to take a greater amount of current from the battery than would have been possible from the single cell.

In practical work we use meters to measure voltage and current. The *voltmeter* is connected across the points between which the unknown voltage exists while the *ammeter* is connected in series with the conductor in which the current flows. With this arrangement, the ammeter becomes a part of the conductor itself. In both cases, the reading in volts or amperes will be indicated directly on the calibrated scale of the instrument. Such instruments, and measurement methods, are treated in a later chapter.

Direct and Alternating Current (d.c. and a.c.)

Of course, all electric currents do not flow continuously in the same direction along a conductor. The currents produced by batteries and by some generators flow in this manner, and therefore are termed *direct currents*. Should the current, for some reason or other, increase and decrease at periodic intervals or should it stop and start frequently it is still a direct current as long as the flow is always in the same direction, though it would be a fluctuating or intermittent one.

The type of current most generally used for the supply of power in our homes does not flow in one direction only, but *reverses* its direction many times each second. The electron drift or flow in a conductor carrying such a current first increases to a maximum, falls to zero, then reverses its direction, again rises to a maximum and again falls to zero — to reverse its direction again and continue the process.

Frequency (f)

● In most of the power circuits, the current flows in one direction for 1/120th of a second, reverses, flows in the opposite direction for another 1/120th of a second and so on. In other words, the complete *cycle* of reversal occupies 1/60th of a second. The number of complete cycles of flow in one second is termed the *frequency* of the current. In the instance under discussion we would say that the frequency is 60 cycles per second. All currents which reverse their direction in this manner are known as *alternating currents*. We are to find that they are not by any means limited to the circuits which supply power to our homes. Telephone and radio circuits, for instance, are virtually riddled with alternating currents having a wide variety of frequencies. The currents which are produced by the voice in a telephone line may have frequencies between about 100 and 5,000 cycles per second while the alternating currents which we are to handle in the circuits of a radio transmitter may have a frequency as high as 60 million cycles per second. Because of the high frequencies used in radio work the practice of speaking in terms of cycles per second is an awkward one. It is customary, instead, to use *kilocycles per second* or, simply, *kilocycles* (kc.) — the kilocycle being one thousand cycles. Yet another widely used term is the *megacycle* (mc.) — a million cycles.

Alternating current, unlike direct current, cannot be generated by batteries. For the supply of commercial power it is almost always produced by rotating machines driven by steam turbines. In radio work we make use of this current for the power supply of our radio apparatus, while the very high frequency alternating currents in the radio transmitter are produced by vacuum tubes connected in appropriate circuits.

Resistance (R)

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

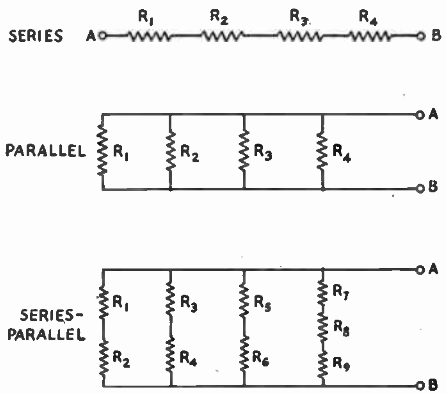


FIG. 303 — DIAGRAMS OF SERIES, PARALLEL AND SERIES-PARALLEL RESISTANCE CONNECTIONS

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, providing 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.* At a later stage it will be shown just how valuable may be the practical application of this law to the ordinary problems of our radio work.

Resistors

● The resistors used in electrical circuits to introduce a known amount of resistance are made up in a variety of forms. One common type consists of wire, of some high resistance metal, wound on a procelain former. To obtain very high values of resistance the wire must be extremely fine. Because this introduces manufacturing difficulties, some of the high value resistors which are not required to carry heavy current are made up of some carbon compound or similar high resistance material.

Series and Parallel Connections

● Resistors, like 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. 303 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:

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

Resistances in parallel:

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

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

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

Resistances in series-parallel:

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

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, 1 coulomb equals 1 ampere-second.

One joule represents the work done in moving 1 coulomb against an electrical pressure of 1 volt. 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 $I = \frac{E}{R}$

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

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.

Alternating Current Flow

In all of these examples we have been assuming that direct currents are being considered. When we impress an alternating voltage on circuits such as those discussed we will cause an alternating current to flow, but this current may not be of the same value as it would be with direct current. In many instances, such as that of a vacuum tube filament connected to a source of alternating current by short wires, the behavior of the circuit would follow Ohm's Law as it has been given and if alternating current meters were used to read the current and voltage we could compute the resistance of the circuit with sufficient accuracy for all ordinary practical purposes. Should there be a coil of wire in the circuit, however, or any electrical apparatus which is not a pure resistance, it would not necessarily be possible to apply our simple formula with satisfactory results. An explanation of the reason for this involves an understanding of the characteristics of other electrical apparatus, particularly of coils and condensers, which have very important parts to play in all radio circuits.

Electromagnetism

When any electric current is passed through a conductor, magnetic effects are produced. *Moving electrons produce magnetic fields.* Little is known of the exact nature of the forces which come into play but it is assumed that they are in the form of lines surrounding the wire; they are termed *lines of magnetic force.* It is known that 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 think of the 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 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.

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

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

The magnetic field about wires and coils may be traced with a compass needle or by sprinkling iron filings on a sheet of paper held above the coil through which current is passing. When there is an iron core the increased magnetic force and the concentration of the field about the iron are readily discernible.

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 than 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. The permeability of iron varies somewhat depending on the treatment it receives during manufacture. Soft iron has low *reluctivity*, another way of saying that its permeability is extremely high. The molecules of soft iron are readily turned end to end by bringing a current-carrying wire or a permanent magnet near. When the influence is removed they just as quickly resume their former positions.

When current flows around a soft iron bar we have a *magnet*. When the circuit is broken so the current cannot flow, the molecules again assume their hit-or-miss positions. Little or no magnetic effect remains. When a steel bar is subjected to the same magneto-motive force in the same way, it has less magnetic effect. However, when the current is removed, the molecules tend to hold their end-to-end positions and we have produced a *permanent* magnet. Compass needles are made in this way. Permanent magnets lose their magnetism only when subjected to a reversed m.m.f., when heated very hot or when jarred violently.

Inductance (L)

● The thought to be kept constantly in mind is that whenever a current passes through a coil it sets up a magnetic field around the coil; that the strength of the field varies as the current varies; and that the direction of the field is reversed if the direction of current flow is reversed. It is of interest now to find that the converse holds true — that if a magnetic field passes through a coil, an electro-motive force is *induced* in the coil; that if the applied field varies, the induced voltage varies; and that if the direction of the field is reversed, the direction of the current produced by the induced voltage is reversed. This phenomenon provides us with an explanation of many electrical effects. It serves in the present instance to give us some understanding of that valuable property of coils — *self-inductance*. Should we pass an alternating current through a coil of many turns of wire, the field around the coil will increase and decrease, first in one direction and then in the other direction. The varying field around the coil, however, will induce a varying e.m.f. in the coil and the current produced by this induced e.m.f. will always be in the opposite direction to that of the current originally passed through the wire. The result, therefore, is that because of its property of self-induction, the coil tends constantly to prevent any change in the current flowing through it and hence to limit the amount of alternating current flowing. The effect can be considered as electrical inertia.

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 the *microhenry* (μh), one-millionth henry. The practical formula for computing the inductance of radio coils is given in the Appendix, while 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.

Transformer Action

● We have seen that if a magnetic field passes through a coil, an electromotive force is induced in the coil. Not only does this phenomenon provide us with an explanation of self-inductance in coils but it also permits an understanding of how transformers operate. Transformers are very widely used in radio work. In many applications their essential purpose is to convert an alternating current supply of one voltage to one of higher or lower voltage. In transmitters, for instance, there will be one or more transformers serving to step down the 110-volt supply voltage to 2.5, 6.3, 7.5 or 10 volts for the filaments of the transmitting tubes. Then there will be another transformer to step up the 110-volt supply to 500, 1000 or perhaps several thousand volts for the plate supply of the transmitting tubes. These transformers will consist of windings on a *core* of thin iron laminations. The 110-volt supply will flow through a primary winding and the magnetic field created by this current flow, because it is common to all windings on the core, will induce voltages in all the windings. Should one of the secondary windings have twice the number of turns on the primary winding, the secondary voltage developed will be approximately twice that of the primary voltage. Should one of the secondary windings have one third of the primary turns, the voltage developed across the secondary will be one third the primary voltage. Direct current flowing in the primary of such a transformer would build up a magnetic field as the current started to flow but the field would be a fixed one. So long as the primary current remained steady there would be no voltages developed in the secondaries. This is the reason why transformers cannot be operated from a source of continuous direct current.

Of course all transformers used in radio circuits are not of the iron-core type. Many air-core transformers are employed; and, in more recent times, cores having powdered iron molded in insulating materials also have come into use. More concerning such coils for radio frequencies will be found in the following chapters.

Magnetic Energy Storage (W)

● The above-mentioned tendency of coils to prevent change 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.

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

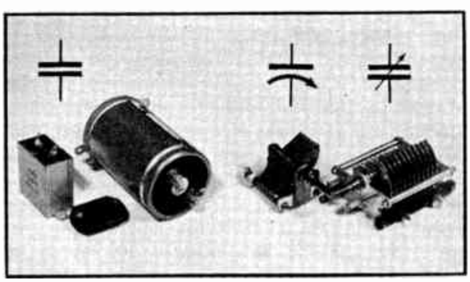


FIG. 304 — TYPES OF FIXED CONDENSERS (LEFT) AND VARIABLE CONDENSERS (RIGHT) WHICH ARE USED IN RADIO CIRCUITS

The schematic symbols are drawn in above the respective groups. Note that two alternative symbols are shown for variable condensers, the curved arrow indicating the rotor plates in the one at the left.

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 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.

The Condenser or Capacitor

● In radio circuits condensers play just as important a part as coils. Condensers and coils, in fact, are almost always used together. The condenser consists essentially of two or more metal plates separated by a thin layer of some insulating medium from a second similar plate or set of plates. The insulating medium between the metal elements of the condenser is termed the *dielectric*. Unvarying direct current cannot flow through a condenser because of the insulation between the plates. But a steady voltage applied to the terminals of such a condenser will cause it to become charged. The effect, to return to a discussion of electrons, is simply that one element of the condenser is provided with an excess of electrons — thus becoming negatively charged — while the other plate suffers a deficiency of electrons and is therefore positively charged. Should the charging voltage be removed and the two elements of the condenser be joined with a conductor, a flow of electrons would take place from the negative to the positive plate. In other words, a current would flow.

Capacity or Capacitance (C)

● The characteristic which permits a condenser to be charged in this manner 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 *dielectric constants* for different materials and the formula used for computing the capacity of condensers are to be found in the Appendix.

The unity of capacity is the *farad.* A condenser of one farad, however, would be so large that its construction would be impractical. 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 *micro-microfarad* (abbreviated μμfd.). The μfd. is one millionth of a farad; the μμfd. is one millionth of a microfarad.

Types of Condensers

● 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.

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 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 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 slightly 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

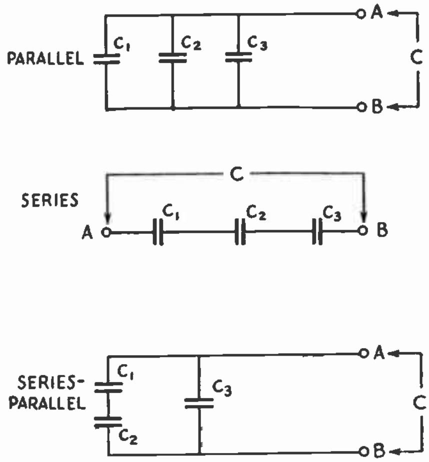


FIG. 305—DIAGRAMS OF SERIES, PARALLEL AND SERIES-PARALLEL CAPACITANCE CONNECTIONS

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. 305. 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.

Connecting condensers in series increases the breakdown voltage of the combination although, of course, it decreases the capacity 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 capacity, 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 complete information on this matter the chapter on Power Supply should be consulted.

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 was 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:

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

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

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

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 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.

Distributed Inductance, Capacity and Resistance

● So far we have considered three very important properties of electrical circuits and apparatus: Resistance, inductance and capacity. Resistors, coils and condensers usually are all built to have as much as possible of one of these properties with as little as possible of the other two. These "lumped" properties can then be utilized in a circuit to produce the required effect on the current and voltage distribution. In every sort of coil and condenser, however, we find not just the one property for which the instrument is used but a combination of all the electrical properties we have mentioned. And for this reason most design work is somewhat of a compromise. Every coil and transformer winding has resistance and distributed capacity between the turns in addition to the inductance that makes it a useful device. Then, every condenser has some resistance and more or less inductance. Resistors, as another example, quite often have appreciable inductance and distributed capacity.

Impedance (Z)

● We start to realize the importance of these characteristics just as soon as we endeavor to apply Ohm's Law to circuits in which alternating current flows. If inductances did not have any resistance we could assume that the current through the coil would be equal to the voltage divided by the reactance. But the coil will have resistance, and this resistance will act with the reactance in limiting the current flow. The combined effect of the 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 of the coil and where X is the reactance of the coil. 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

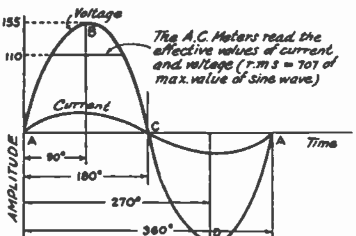


FIG. 306 — REPRESENTING SINE-WAVE ALTERNATING VOLTAGE AND CURRENT

manner as was the resistance of the coil in the example just given. The impedance of the condenser-resistance combination is then computed and used as the Z term in the Ohm's Law formulas.

The Sine Wave

In Fig. 306 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 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,

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

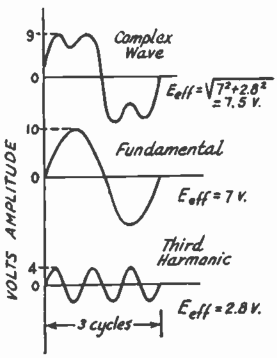


FIG. 307 — A COMPLEX WAVE AND ITS SINE-WAVE COMPONENTS

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 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 Seventeen.

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. 307. The 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

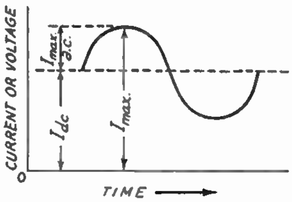


FIG. 308 — PULSATING CURRENT COMPOSED OF ALTERNATING CURRENT SUPERIMPOSED ON DIRECT CURRENT

of the fundamental and harmonics. The same relation also applies where currents of different frequencies not harmonically related flow in the same circuit. Further aspects of complex waves are discussed in connection with distortion in the following chapter. The subject is of particular importance in 'phone transmission, as shown in Chapters Eleven and Twelve.

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 current is *superimposed* on a direct current. As shown in Fig. 308, 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.

Power With Pulsating Current

● In a resistance circuit, the power developed by a pulsating current 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,

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

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 Eleven.

Phase

● It has been mentioned that in a circuit containing inductance, the rise of current is

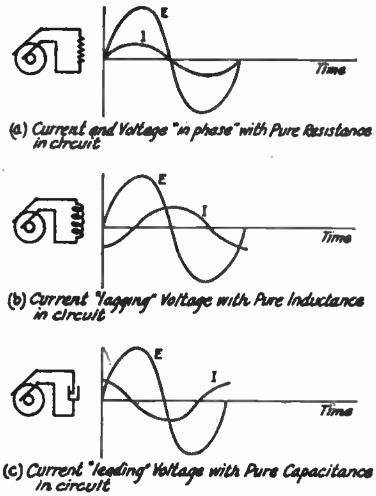
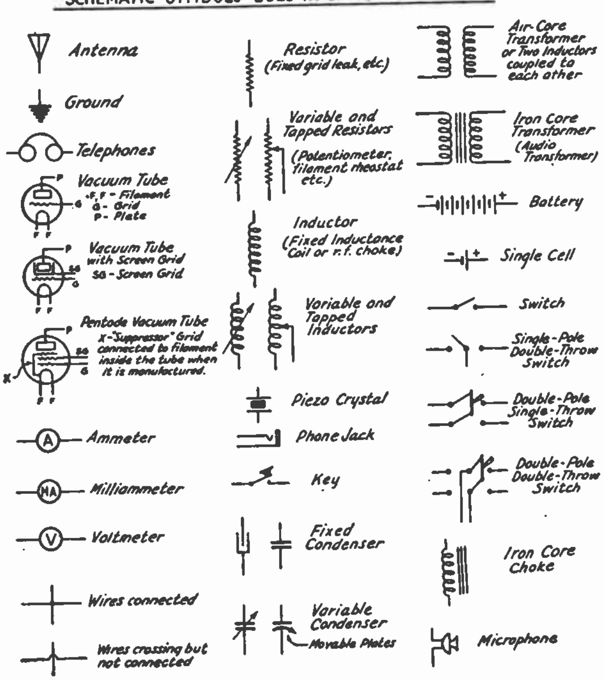


FIG. 309 — VOLTAGE AND CURRENT PHASE RELATIONS WITH RESISTANCE AND REACTANCE CIRCUITS

delayed by the effect of electrical inertia presented 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. 309 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 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*.

SCHEMATIC SYMBOLS USED IN CIRCUIT DIAGRAMS



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 circuits (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 approaching 100%.

Reading Diagrams — Schematic Symbols

● Schematic diagrams show the different parts of a circuit in skeleton form. Pictures show the apparatus as it actually appears in the station or laboratory. A little study of the symbols used in schematic diagrams will be helpful in understanding the circuits that appear in this book, *QST* and in other radio publications. The diagrams are easy to understand once we have rubbed shoulders with some real apparatus and read about it. Schematic diagrams are used in all electrical work because they save so much space and time when discussing the various circuits. Photographs of apparatus show the actual arrangement used but the wiring is not as clear as in the schematic diagrams. In building most apparatus a schematic diagram and a photograph will make everything clear. It is suggested that the beginner carefully compare a few pictures and schematic diagrams if not entirely familiar with the latter.

The symbols used in schematic diagrams throughout this book will be easily understood by reference to the accompanying figure. Most of the diagrams shown are plainly labelled or worded so that it is only necessary to know the general scheme which differentiates coils, condensers, and resistors to read the diagram. Reference to the text will help in understanding fully what is intended, since diagrams and text have been prepared to complement each other. In general, coils are indicated by a few loops of wire, resistances by a jagged line, and variable elements in the circuit by arrowheads. If a device has an iron core it is usually shown by a few parallel lines opposite the loops indicating coils or windings.

When you can draw and talk about circuits in terms of the various conventional symbols you are on what is familiar ground to every amateur and experimenter. Then you can meet the dyed-in-the-wool expert and understand what he talks about.

Practical Examples

● There is no greater aid to the understanding of principles than their actual application to practical problems. The following typical examples involving only simple arithmetic, show how the principles outlined in this chapter are directly useful in giving the right answers to many of the problems which arise in designing and building amateur equipment. It is suggested that they be worked through by the reader in connection with study of the various topics throughout the chapter. The calculations have been made with practical "slide-rule" accuracy.

Ohm's Law Calculations

● 1. *Q.* — With 10 volts applied across a resistance of 1000 ohms, how much current will flow?

A. — $I = \frac{E}{R} = \frac{10}{1000} = .01$ amp. = 10 ma.

2. *Q.* — What value of resistance should be used to reduce voltage from 1000 v. to 250 v. when the current is 50 ma. (.05 amp.)?

A. — The necessary voltage drop is 1000 v. − 250 v. = 750 v.

$$R = \frac{E}{I} = \frac{750}{.05} = 15{,}000 \text{ ohms.}$$

3. *Q.* — If the grid-leak resistance of a transmitting tube is 10,000 ohms and the grid current measured with a d.c. milliammeter is 15 ma. (.015 amp.), what is the grid-bias voltage developed across the resistor?

A. — $E = IR = .015 \times 10{,}000 = 150$ volts.

4. *Q.* — What power is dissipated by the grid-leak resistor of *Q.* 3?

A. — $P = I^2R = .015^2 \times 10{,}000 = 2.25$ watts

or $P = EI = 150 \times .015 = 2.25$ watts.

5. *Q.* — What resistance (R_2) should be connected in series with 7500 ohms (R_1) to give a total resistance (R) of 10,000 ohms?

A. — $R = R_1 + R_2$

Therefore, $R_2 = R - R_1 = 10{,}000 - 7500 = 2500$ ohms.

6. *Q.* — What resistance (R_1) should be connected in parallel with a resistance (R_2) of 5000 ohms to give a total resistance (R) of 4000 ohms?

A. — $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

Therefore, $R_1 = \frac{RR_2}{R_2 - R} = \frac{4000 \times 5000}{5000 - 4000} =$ 20,000 ohms.

7. *Q.* — If the power input to a load circuit is 25 watts and the load resistance is 10,000 ohms, what will be the voltage and current?

A. — $E = \sqrt{PR} = \sqrt{25 \times 10{,}000} = 500$ volts.

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{25}{10{,}000}} = .05 \text{ amp.} = 50 \text{ ma.}$$

(Check: 500 v. × .05 amp. = 25 watts.)

Coil Calculations

● 8. *Q.* — What will be the total inductance of a filter choke of 30-henry inductance in series with another of 20-henry inductance, the two being separated to eliminate magnetic interaction?

A. — $L = L_1 + L_2 = 30 + 20 = 50$ henrys.

9. *Q.* — What will be the inductance with the two chokes of *Q.* 3 connected in parallel?

A. — $L = \frac{L_1 L_2}{L_1 + L_2} = \frac{30 \times 20}{30 + 20} = 12$ henrys.

(NOTE. — As pointed out in Chapter Fifteen, the inductance of chokes is reduced by d.c. flowing through the windings. Therefore the series inductance would tend to be less than the calculated value, while the parallel inductance might be higher than that calculated if the total direct current should be the same in both cases.)

10. *Q.* — What would be the approximate number of turns on the 6.5-volt secondary of a small filament transformer having a 115-volt primary of 865 turns?

A. — The secondary-to-primary voltage ratio is $\frac{6.5}{115}$. This is also the approximate secondary-to-primary turn ratio. Therefore,

No. secondary turns $= 865 \times \frac{6.5}{115} = 49$ turns.

11. *Q.* — How much energy is stored in a 30-henry choke with a current flow of 100 ma. (0.1 amp.)?

A. — Energy stored $= LI^2 = 30 \times 0.1^2 =$ 0.3 watt-second.

12. *Q.* — What is the reactance of a 30-henry choke at a frequency of 100 cycles per second?

A.— $X_L = 2\pi fL = 2 \times 3.14 \times 100 \times 30 =$ 18,850 ohms.

Condenser Calculations

● 13. *Q.* — What is the approximate reactance of a 2-μfd. condenser at 100 cycles per second?

A. — $X_C = \frac{10^6}{2\pi fC} = \frac{1{,}000{,}000}{6.28 \times 100 \times 2} = 796$ ohms.

14. *Q.* — What is the total capacitance of a 0.001-μfd. condenser (C_1) and a 150-$\mu\mu$fd. condenser (C_2) in parallel?

A. — $C = C_1 + C_2 = .001\ \mu\text{fd.} + .00015\ \mu\text{fd.} = .00115\ \mu\text{fd.}$

(Note that both capacitance values must be converted to the same units.)

15. *Q.* — What is the total capacitance when the same two condensers are connected in series?

A. — $C = \frac{C_1 C_2}{C_1 + C_2} = \frac{1000 \times 150}{1000 + 150} = 130\ \mu\mu\text{fd.}$

16. *Q.* — What is the energy stored in 2-μfd. condenser with 1000 volts applied?

A. — Energy stored $= \frac{CE^2}{10^6} = \frac{2 \times (1000)^2}{1{,}000{,}000}$ $= 2$ watt-seconds.

17. *Q.* — After the 1000-volt supply was shut off, what time would be required for the voltage across this condenser to drop to 370 volts with a 20,000 ohm resistance connected between its terminals? To drop to 100 volts?

A. — The time required for the voltage to fall to 37% is the time constant.

Time constant $= \frac{RC}{10^6} = \frac{20{,}000 \times 2}{1{,}000{,}000} = .04$ sec.

Time for 90% voltage fall $= \frac{RC}{10^6} \times 2.4 =$ .096 second.

(NOTE. — A painful shock can be obtained by touching the terminals of an *unloaded* filter condenser long after the power has been shut off. Without a bleeder resistor the time constant may be as great as several days!)

18. *Q.* — What would be the approximate impedance at 100 cycles of a series circuit consisting of a 30-henry choke having 100 ohms resistance, a 2-μfd. condenser of negligible resistance and a 10,000-ohm resistor?

A. — From *Q.* 12 the reactance of this choke is 18,850 ohms, and from *Q.* 13 the reactance of the condenser is 796 ohms. The net reactance is 18,850 − 796 = 18,054 ohms (inductive).

$$Z = \sqrt{R^2 + X^2} = \sqrt{(10{,}100)^2 + (18{,}054)^2} = 20{,}650 \text{ ohms.}$$

Complex Wave Calculation

● 19. *Q.* What would be the effective voltage of a complex wave consisting of a fundamental and third harmonic, when the maximum value of the fundamental is 10 volts and the maximum value of the third harmonic is 4 volts?

A. The effective values of the respective components will be practically 70% of their maximum values, or 7 and 2.8 volts. The effective value of the complex wave is then:

$$E = \sqrt{E_1^2 + E_2^2} = \sqrt{7^2 + 2.8^2} = \sqrt{56.84} = 7.54 \text{ volts.}$$

CHAPTER FOUR

Radio Circuit and Wave Fundamentals

PRACTICAL PRINCIPLES OF TUNED CIRCUITS—COUPLED CIRCUITS—IMPEDANCE MATCHING—FILTERS—BRIDGE CIRCUITS—LINE CIRCUITS—ANTENNAS—RADIO WAVES

In our discussion of fundamental electrical principles, we have seen how a flow of electrons through a wire constitutes an electric current, and how this current, under certain conditions, gives rise to electric and magnetic effects as changes in the current flow take place. In addition to the effect which resistance produces in direct and alternating current circuits, we have learned how an inductance or coil tends to prevent any change in the current flowing through it because of the existence, around the coil, of a magnetic field, which varies in strength with every variation in the current flow. We have also seen how this field around a coil can link with the turns of a second coil, so inducing voltages in it — voltages which vary in accordance with the changes in the original current flow. Further, we have seen how a condenser can be charged by an applied voltage and how the energy represented by this charge can cause a current to flow in any conductor which is connected across the condenser terminals. Lastly, we have learned that in an alternating current circuit, inductance causes the current to lag behind the voltage while capacity causes the current to lead the voltage.

Equipped with an understanding of these principles we are now ready to study inductance, capacitance and resistance as combined in the circuits of our radio transmitters, receivers and other equipment. Examination of the circuit diagram of almost any piece of radio equipment will reveal one or more combinations of coil and condenser (inductance and capacitance) and, hence, of inductive reactance and capacitive reactance. Let us now consider how they work together to form the *tuned circuit*.

The Tuned Circuit

Let us assume that a condenser C and coil L are connected as shown in Fig. 401, and that the condenser is initially charged as indicated

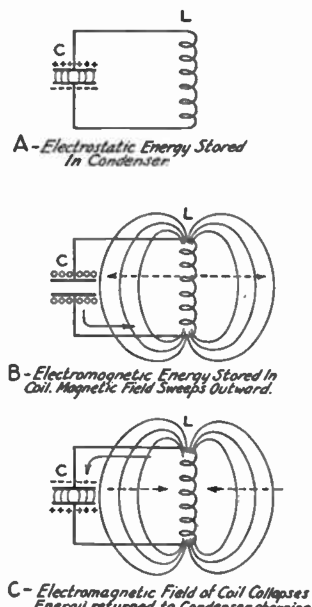


FIG. 401 — THE SEQUENCE IN A HALF-CYCLE OF OSCILLATION IN A RESONANT CIRCUIT

in A, one plate having a surplus of electrons and therefore being negative while the other plate, being correspondingly deficient in electrons, is positive. The instant that the condenser plates are connected together through the coil L there will start a flow of current as shown by the arrow in B. 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 even though the velocity of flow is constant. As the current continues to flow from the condenser into the coil, the energy initially stored in the condenser as an electrostatic field will become stored in the electromagnetic field of the coil. When substantially all the energy in the circuit has become stored in this field the lines of force about the coil begin to collapse, and thus cause a continued flow of current through the circuit, the flow being in the same direction as the initial current. This again charges the condenser *but in opposite polarity to the initial charge.* Then, when all the energy again has been stored in the condenser, the sequence is repeated in the opposite direction. The process is one of *oscillation.* During one complete cycle the energy is alternately stored in the condenser and in the coil twice, and there is one reversal in the direction of current flow. This represents a complete cycle of alternating current. The process would continue indefinitely were there only inductance and capacitance in the circuit but, as has been pointed out in Chapter Three, all circuits contain some resistance. Therefore during each cycle a part of the energy will be dissipated in the resistance as heat, each cycle will be of lesser amplitude than the preceding one and the process will finally stop because there is no longer energy to sustain it. This *damping* caused by resistance is overcome in practical circuits by continuously supplying energy to replace that dissipated in resistance of one form or another, as will be shown later.

Oscillation Frequency

● In such an oscillatory circuit, the larger the coil is made the greater will be its inductance and the longer will be the time required for the condenser to discharge through it. Likewise, the larger the condenser and the greater its capacitance, the longer it will take to charge or discharge it. Since the velocity of the current flow is substantially constant, it is clear that the circuit with the larger coil or condenser is going to take a longer period of time to go through a complete cycle of oscillation than will a circuit where the inductance and capacitance are small. Putting it differently, the number of cycles per second will be greater as the inductance and capacitance values become smaller. *Hence the smaller the coil or condenser, or both, in the tuned circuit, the higher will be the frequency of oscillation.*

Resonance

● The important practical aspect of all this is that in any circuit containing capacitance, inductance and not too much resistance, the introduction of a pulse of electrical energy will cause an alternating current oscillation of a frequency determined solely by the values of inductance and capacitance; and that for any combination of inductance and capacitance there is one particular frequency of applied voltage at which current will flow with the greatest ease. Recalling the explanations of inductive reactance and capacitive reactance given in Chapter Three, this becomes readily understandable. It has been shown that the inductive reactance of the coil and the capacitive reactance of the 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 inductive reactance must equal the capacitive reactance, then

$$X_L = X_C \text{ or } 2\pi fL = \frac{1}{2\pi fC}$$

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 microhenries (μh.)
C is the capacitance in micro-microfarads (μμfd.)

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 only 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 micro-microfarads, 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.

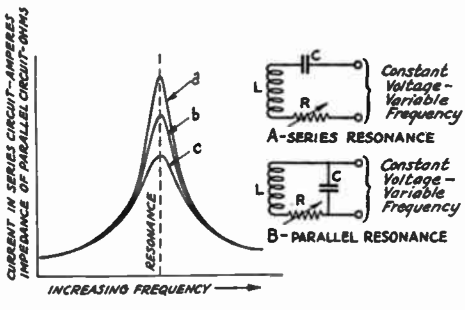


FIG. 402—CHARACTERISTICS OF SERIES-RESONANT AND PARALLEL-RESONANT CIRCUITS

Series and Parallel Resonance

All practical tuned circuits can be treated as either one of two general types. One is the *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. 402 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. 402 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. 402. 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 frequency is illustrated by the same curves of Fig. 402 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 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 discussed in Chapter Three, and is designated by Q.

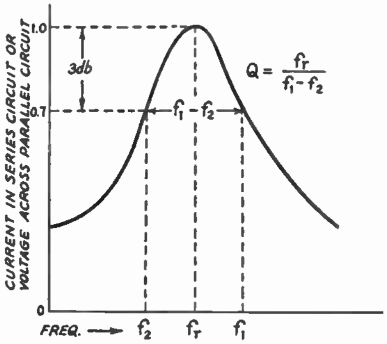


FIG. 403 — HOW THE VALUE OF Q IS DETERMINED FROM THE RESONANCE CURVE OF A SINGLE CIRCUIT

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

The value of Q is determined directly from the resonance curve of either a series-resonant or parallel-resonant circuit as shown in Fig. 403. 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 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 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. 404. 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. Note that the reactance component becomes practically equal to half the resistance component, capacitively above and inductively below resonance. This occurrence is especially important in the variable-selectivity action of the quartz crystal filter circuit used in Single-Signal superhet receivers, as described in Chapter Six.

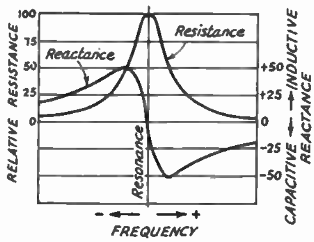


FIG. 404 — THE IMPEDANCE OF A PARALLEL-RESONANT CIRCUIT SEPARATED INTO ITS REACTANCE AND RESISTANCE COMPONENTS. THE PARALLEL RESISTANCE IS EQUAL TO THE PARALLEL IMPEDANCE AT RESONANCE

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.

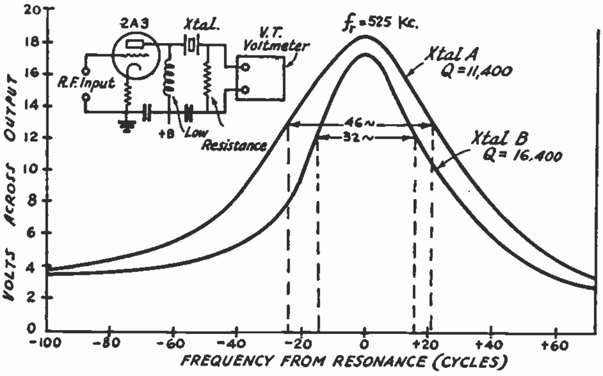


FIG. 406 — RESONANCE CURVES OF TWO PRACTICAL CRYSTAL RESONATORS, SHOWING THEIR HIGH Q

The Piezo-Electric Crystal Circuit

● All of the tuned circuits used in radio transmitters and receivers are not purely electrical

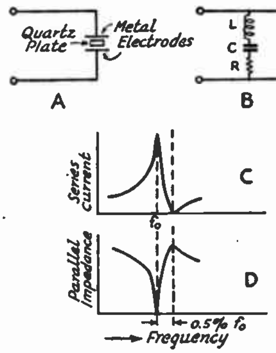


FIG. 405 — THE EQUIVALENT ELECTRICAL CIRCUIT OF THE QUARTZ CRYSTAL PLATE

in nature. Electro-mechanical or peizo-electric types are used as well. Of the latter, the quartz crystal is most generally employed. The schematic representation of a quartz crystal plate mounted between a pair of metal electrodes is shown in Fig. 405-A and the equivalent electrical circuit is shown in Fig. 405-B. It consists of inductance, L, capacitance, C, and resistance R, in the series combination, paralleled by C_1, which is the capacitance between the electrodes with the quartz as dielectric.

As with any series circuit containing inductance and capacitance, resonance occurs at the frequency for which the inductive and capacitive reactances are equal. This frequency (f_o) is termed the *natural frequency* of the crystal. In contrast to the parallel-resonant case, *at frequencies below resonance the series circuit has capacitive reactance and above resonance it has inductive reactance.* At a certain frequency above series resonance in the crystal circuit, the inductive reactance of the series combination becomes equal to the capacitive reactance of the parallel capacitance C_1. *At this frequency parallel resonance occurs and the crystal acts as an anti-resonant circuit.*

The ratio of the parallel capacitance C_1 to the series capacitance C is approximately 125–to–1, irrespective of the constants of the crystal, so that this anti-resonant frequency is always approximately 0.5 percent higher than the natural series-resonance frequency, as shown by Curves C and D of Fig. 405. The value of this frequency is determined by the dimensions of the quartz plate and the angle of its cut with respect to the axes of the natural crystal. Data on cuts and frequencies are given in Chapters Six and Eight, along with practical information on the use of quartz crystals as series circuits in receivers and parallel circuits in transmitters.

The ratio of equivalent inductance to resistance is very large in a quartz crystal, which gives it an extraordinarily high Q. This is illustrated by the series resonance curves of Fig. 406, taken for frequencies near resonance with two apparently identical 525-kc. crystals. The difference between the two is probably the result of slight variations in their cutting and grinding. But both show Q values running 50 or more times higher than could be obtained with a good coil at the same frequency. Hence the wide use of crystals as selective radio-frequency circuits and for stabilizing oscillators.

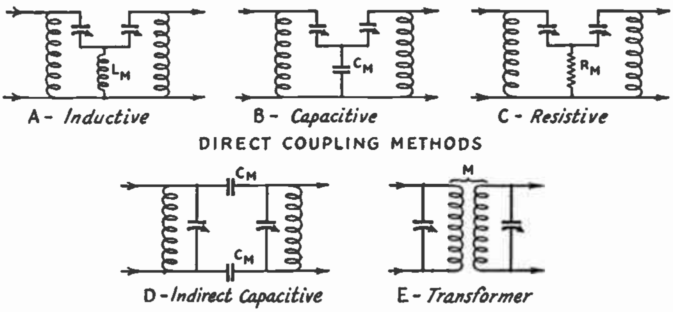


FIG. 407 — BASIC TYPES OF CIRCUIT COUPLING

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. 407, 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). The arrangement then performs in a manner similar to the transformer described in the previous chapter.

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*. Many turns in two coils very close together give us tight coupling and a big transfer of power. Few turns at right angles or far apart give us loose coupling with little actual energy transfer.

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. As was shown for closed iron-core transformer in Chapter Three, 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, the resonance curve usually having 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.

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 we have been discussing, and modify the constants that they would have by themselves. In practice it is seldom possible for the amateur to pre-calculate 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.

Impedance Matching

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 *matched* by the load resistance. Although this particular statement is literally true, it might not describe the most desirable condition for loading the tube. 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.

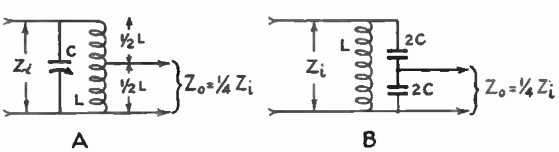


FIG. 408 — METHODS OF TAPPING THE PARALLEL IMPEDANCE OF RESONANT CIRCUITS FOR IMPEDANCE MATCHING

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 look like 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.*

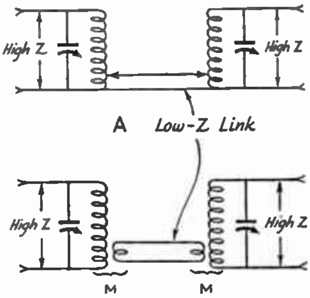


FIG. 409 — METHODS OF USING LINK COUPLING FOR IMPEDANCE MATCHING

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

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, incidentally, as was shown in Chapter Three.

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. 408. 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 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_o 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.

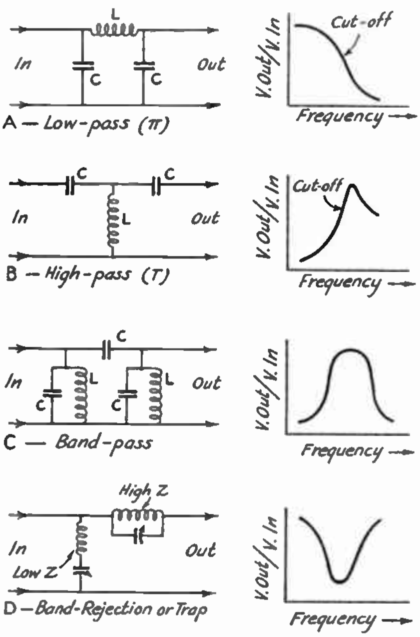


FIG. 410 — TYPES OF FILTERS AND APPROXIMATE CHARACTERISTICS OF EACH

Link Coupling

● Another coupling arrangement used for impedance matching radio-frequency circuits is that known as *link coupling.* It is used for transferring energy between two tuned circuits 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. 409. 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. 409-A will be recognized as an adaptation of the impedance-tapping method previously shown in Fig. 408-A. It is sometimes called auto-transformer link coupling, because the link turns are also included in the tuned-circuit turns. The arrangement of 409-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 Chapters Eight and Nine.

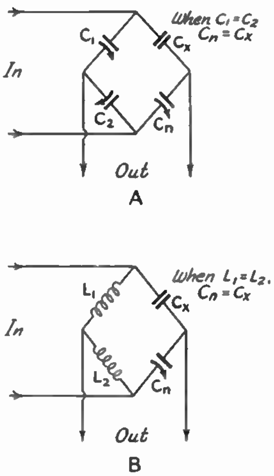


FIG. 411 — CAPACITANCE AND INDUCTANCE-CAPACITANCE BRIDGE CIRCUITS WIDELY USED FOR NEUTRALIZING IN TRANSMITTERS AND RECEIVERS

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 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. 410. A *low-pass* filter, as shown in *A*, is used to transmit energy below a given frequency limit and to attenuate 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 attenuating lower frequencies and therefore being designated *high-pass*. The one shown is known as a "T" section, because its form resembles that letter. Such filters are not used to any great extent in amateur work.

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. 407. 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 circuits intended to attenuate over a narrow band of frequencies and transmit at frequencies outside that band is shown in *D* of Fig. 410. 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, as described for use with receivers further on.

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.

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. 411. 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 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 $C_n = C_x$. 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 a 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 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 in which no condensers and coils are to be found. Such circuits utilize the distributed capacitance and inductance that are inevitable even in a circuit consisting of a single straight conductor. Our 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. Several types of compact multi-section r.f. chokes are available from manufacturers and have largely displaced bulkier single-layer chokes in recent times.

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 on the wire is nearly the same as the velocity in space, which is 300,000 kilometers or 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 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 will be shown in the chapter on Antennas, this length is (very nearly) a half-wavelength for an ungrounded (Hertz) antenna and a quarter-wavelength for a grounded (Marconi) antenna. Therefore 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"

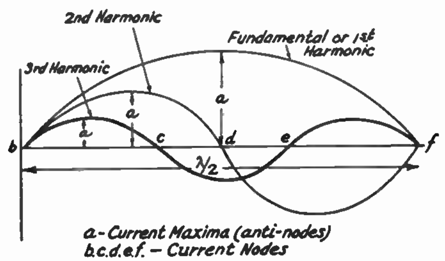


FIG. 412 — STANDING-WAVE CURRENT DISTRIBUTION ON AN ANTENNA OPERATING AS AN OSCILLATORY CIRCUIT AT ITS FUNDAMENTAL, SECOND HARMONIC AND THIRD HARMONIC FREQUENCIES

are synonymous. A chart showing the relationship between frequencies and wavelengths, including those of the amateur bands, is given in the Appendix. The resonance equation of a tuned circuit, previously given for frequency, is expressed in terms of wavelength as follows:

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

where

λ is the wavelength in meters
$L_{\mu h}$ is the inductance in microhenries
$C_{\mu\mu fd}$ is the capacitance in micro-microfarads.

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 which are integral multiples of the fundamental frequency (or wavelengths that are integral fractions of the fundamental wavelength). These frequencies are therefore in *harmonic* relationship to the fundamental frequency 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. For example, a Hertz antenna having a fundamental of 1780 kc. (in the amateur 1750-kc. band) also will oscillate at the following harmonic frequencies: 3580 kc. (2nd), 5370 kc. (3rd), 7160 kc. (4th), 8950 kc. (5th), 10,740 kc. (6th), 12,530 kc. (7th) and 14,320 kc. (8th). Hence the one antenna can be used for four amateur bands, resonating at its first, second, fourth and eighth harmonics. A "free" antenna (Hertz) may be operated at the fundamental or any harmonic frequency, odd or even; a grounded (Marconi) type only at its fundamental or harmonics that are *odd* multiples of the fundamental frequency.

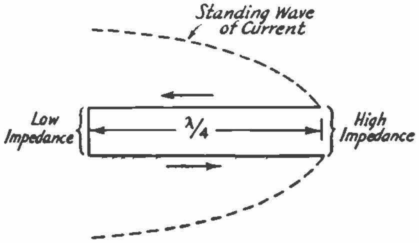


FIG. 413 — STANDING WAVE AND INSTANTANEOUS CURRENT CONDITIONS OF A FOLDED RESONANT-LINE CIRCUIT

Fig. 412 illustrates the distribution of the standing waves on a Hertz antenna for its fundamental, second and third harmonics. 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 By Antennas

● So far we have discussed the antenna with respect to its ability to perform as a resonant circuit. We now come to the practical use that is made of the energy that oscillates in the antenna. It will be remembered that in the preceding chapter it was shown that current flow in a conductor was accompanied by a magnetic field about the conductor; and 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.* Now this is quite true when the alternating current is of low frequency, such as the 60-cycle kind commonly used. 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. This we know. Just how radiation occurs is not clearly understood at the present time. But we know enough for practical purposes about what happens in the antenna and about how the waves behave after leaving the antenna.

Some radiation will occur with any conductor that has high-frequency current flowing in it but the radiation is greatest when the antenna is resonant to the frequency of the current. If the antenna is essentially "in free space" (isolated from other wires, pipes, trees, etc., that might absorb energy from it), nearly all the energy put into it will be radiated as radio waves. As was seen in the paragraph on "Radio-Frequency Resistance," *the radio-frequency resistance is equal to the actual power in the circuit divided by the square of the maximum effective current.* Energy radiated by an antenna is equivalent to energy dissipated in a resistor. The value of this equivalent resistance is known as *radiation resistance.* Its average value for a Hertz (ungrounded) antenna operating at its fundamental frequency is approximately 70 ohms; and for a Marconi (grounded) antenna operating at its fundamental is about half this value, or 35 ohms. 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 (Amperes²)

The antenna must, of course, be coupled to the transmitting equipment that generates the radio-frequency power. Practical methods of doing this are described in Chapter Twelve, together with details of the antenna systems most useful in amateur transmission.

The receiving antenna is the reciprocal of the transmitting antenna in operation. Whereas radio-frequency current in the transmitting antenna causes the radiation of electro-magnetic waves, the receiving antenna intercepts such waves and has a voltage induced in it. This voltage causes a flow of radio-frequency current of identical frequency to the radio receiver and through its tuned circuits. Generation of radio-frequency power by the transmitter and reception of radio-frequency waves will be discussed in succeeding chapters.

Folded 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. 413, 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. 413, 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 Sixteen, as well as for stable oscillator circuits in ultra-high frequency transmitters, as shown in Chapter Fourteen. Resonant lines having effective lengths of odd multiples of a quarter-wavelength, or multiples on 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 the later chapter on antenna systems.

Non-Resonant Transmission 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

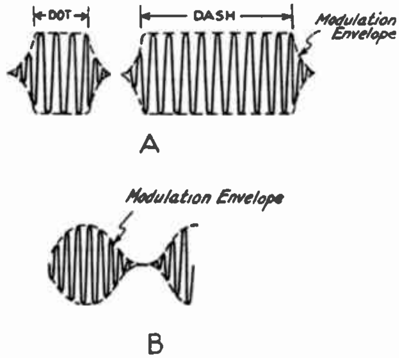


FIG. 414 — REPRESENTING THE MODULATED CURRENT OF A TELEGRAPH WAVE (A) AND SINUSOIDALLY MODULATED SPEECH WAVE (B), AMPLITUDE MODULATION

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-system radiators. Although somewhat less adaptable than the resonant type line, they are considered more efficient for transmission of radio-frequency power when the line length is a wavelength or more, the line losses and incidental radiation being less with the standing waves eliminated. The practical design features of these lines also are discussed in Chapter Sixteen.

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 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 to make the message understandable to our human senses. This is accomplished by a process of *detection* or, as it is sometimes known, *demodulation.* It is necessary because the modulated radio wave in its transmitted form cannot be detected directly by our ears, eyes, feeling or smell, as would be possible with sound or light waves, slow mechanical vibrations — or even "modulated" odors! Practical methods of modulation and detection by vacuum-tube circuits are described separately in the next and subsequent chapters. Only a generalized explanation which suggests their broad general 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

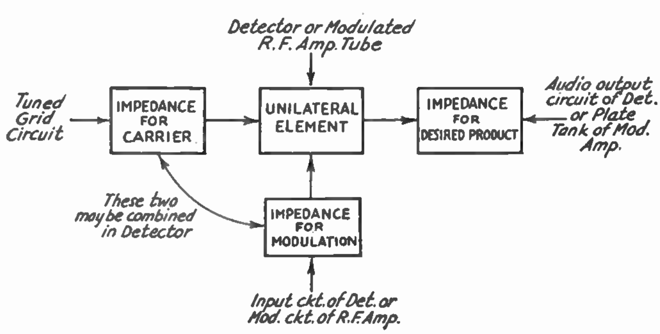


FIG. 415 — GENERALIZED SYSTEM FOR MODULATION OR DETECTION, INDICATING THE ESSENTIAL ELEMENTS

modulation by these two types of signal are shown in Fig. 414. 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 Chapter Three, 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

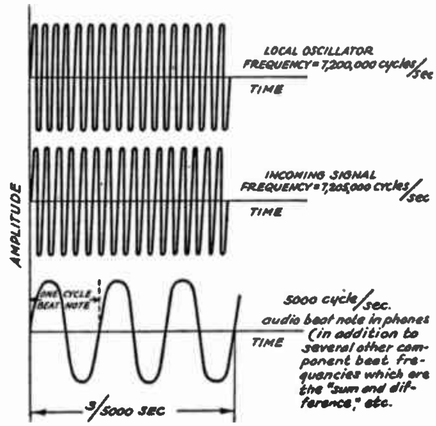


FIG. 416 — A COMBINATION OF TWO RADIO-FREQUENCY WAVES OF DIFFERENT FREQUENCIES TO PRODUCE A BEAT NOTE BY HETERODYNE ACTION

The two waves would have to be simultaneously detected in the same circuit to produce the beat note, which would not be of sinusoidal wave form unless one of the combining waves was considerably greater in amplitude than the other.

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 of the original frequency and the modulation frequency, and equal to the difference between 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, so that the side-band frequencies differ but the same few cycles from the carrier frequency. 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. With such amplitude modulation the communication band is twice the highest modulation frequency, 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. 415 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. 415. 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 of a circuit which is essentially a counterpart of that used for transmission, as is also indicated in Fig. 415.

Heterodyne Action

● For reception of telegraph waves modulated only by keying, however, an additional modulation to make the dots and dashes come out with continuous tone is necessary, because the side-band components resulting from keying occur only at the times when the wave amplitude is being changed (at the beginning and end of each dot and dash). Only a "click" would be heard at these times and there would be no sound in between if there were no additional modulation. This tone is obtained by applying to the detector circuit a modulating signal from a local source, this signal differing from the received radio wave frequency by a frequency equal to the desired tone — say 1000 cycles per second. There will then be produced in the detector output audible dots and dashes, corresponding to those transmitted, having a pitch of this frequency. This process is called *heterodyne* detection, and the tone produced is known as the *beat note.* The production of such a beat note by combining two waves of slightly different frequency is suggested by Fig. 416. The beat product is not likely to be of sinusoidal wave-form, however, unless the locally generated signal is much greater in amplitude than the wave with which it is heterodyned.

Polarization and Reflection of Radio Waves

Radio waves are of the same nature as light waves, traveling with the same velocity of 160,000 miles or 300,000 kilometers per second. They are *electro-magnetic* waves, having an electric component and an accompanying magnetic component. These vector components are in phase *quadrature,* or at a phase angle of 90 degrees, in space. The waves are *plane waves;* the plane of the electric and magnetic vectors 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 vector perpendicular to the earth, and are said to be *horizontally polarized* when the electric vector 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.

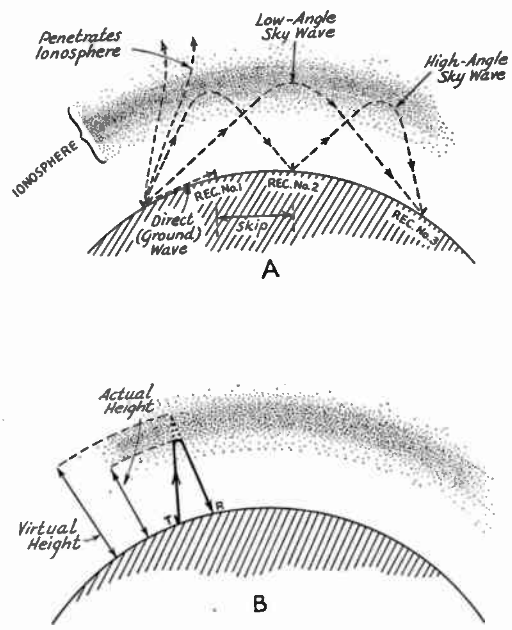


FIG. 417 — ILLUSTRATING GROUND-WAVE AND SKY-WAVE TRANSMISSION OF RADIO WAVES

The density of the dots indicates that the electron density in the ionosphere increases and then decreases as the altitude becomes greater.

Radio waves, like light waves, can be *re-*

flected and *refracted*. Reflection occurs when the wave strikes a conductor, such as a wire. A current is consequently set up in the wire, which causes the wire to radiate an electromagnetic wave of its own. If the reflector wire is placed near to the antenna giving the primary radiation, the radiation from the reflector may be made to cancel that from the primary antenna in the direction toward the reflector. Practical use of such reflection is described in Chapters Fourteen and Sixteen. Reflection also can occur in the upper atmosphere, as described in the following paragraphs.

Radio Waves in Space

Radio waves not only travel along the surface of the earth in the more or less dependable lower atmosphere, for short-distance communication; they also travel through the upper regions far above the earth in the highly variable *ionosphere*, 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. 417-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*. But 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). This is shown by the "ground wave" curve of Fig. 418. The short-distance nature of this direct wave is apparent.

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*, however, would travel on outward into space indefinitely, and would be of no practical use for our communication, if they were not bent back to earth again. Just such bending is what makes our long-distance communication possible. 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*. The ionosphere is not strictly a single layer, however. Dr. Kennelly suggested this in his original proposal and more recent investigations have shown that there are several virtual layer heights, 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. As has been previously pointed out, such ionization by collision makes free electrons and positive ions. These continuously recombine into neutral molecules as other molecules are ionized, then recombine, and so on. 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

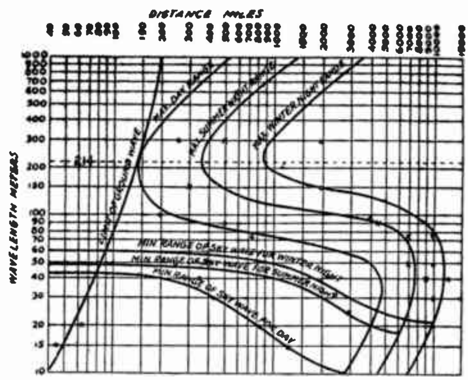


FIG. 418 — APPROXIMATE AVERAGE TRANSMISSION PERFORMANCE OF DIFFERENT WAVELENGTHS AT DIFFERENT DISTANCES

The received signal is assumed to have a field-strength of 10 microvolts per meter at the receiving point. The transmitter is assumed to have 5000 watts in the antenna. The chart is explained as follows. To the left of the line marked "limit of ground wave" it should be possible to receive at all times. After that, one must pick a pair of curves of the same sort (that is for the same time) and if the distance is between the curves one should hear the signal. Thus, a 30-meter wave should be reliable at all times to 70 miles for the conditions mentioned. From there to 400 miles its daylight performance will probably be uncertain while from 400 on it will gradually die down until at 4600 it will again be below 10 microvolts per meter. There are, of course, numerous exceptions where one does hear the signal when it should be absent. The curves are based on skip-distance observations, mainly from data by A. H. Taylor.

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 curve 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 skv waves in Fig. 417.

Skip Distance

● The sharpness with which this bending occurs is the greater as the frequency of the wave is lower. At 3500 kc. (80-meter band) 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 usually 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, as indicated by the curves of Fig. 418, until at frequencies in the 28-mc. (10-meter) band it becomes so great that the returning signal is likely to miss the earth and not to be heard under ionosphere conditions prevailing most of the time.

Layer Height

● When the skip distance becomes so short that the sky wave returns literally at the transmitting point, the effect is that of *reflection*. This occurs commonly at frequencies in the 3500-kc. band and generally in the 1750-kc. (160-meter) band and on lower frequencies. Of course less-sharp refraction is also probable at these frequencies, for waves radiated at lower angles than the vertical and striking the ionosphere at angles correspondingly smaller than 90 degrees. Such effective reflection has made possible determination of the effective ionosphere layer heights by direct measurement of the difference in time between receipt of the direct wave from a transmitter and receipt of the sky wave which has traveled up to the ionosphere and back. Assuming the velocity to be 186,000 miles per second, the height is directly proportional to the time difference. This gives what is called the *virtual height*, or the height the wave would reach if it were completely reflected by a perfect reflector. The actual height reached by the wave may be somewhat less than the virtual height as measured. Fig. 417-B illustrates the difference between the two. At present the only height which can be measured experimentally is the virtual height, of course.

These measurements have shown that there are three 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 on frequencies between 2500 and 4400 kc. 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 (towards 4000 kc.) 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. At this time the *E* layer becomes increasingly unable to reflect even the lower frequency (2500 kc.) in this range, as the ionization in this region decreases. Later at night even the *F* layer becomes less able to give direct reflection, so that the frequencies around 4000 kc. penetrate it so far as reflection is concerned. Occasionally it will not reflect the lower frequency, either.

From this it is evident that the layer principally effective for long-distance communication at night is the *F* layer, while any one of the three may be effective for indirect sky-wave transmission during the daytime, depending on the frequency and degree of ionization. It must be remembered, however, that these height figures are mean averages and may vary widely as ionization conditions change with seasons, and as variations in solar radiation accompany different degrees of sunspot activity.

Angle of Radiation

● 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 transmitting antenna should concentrate the energy more nearly horizontal than vertical. That is, *low-angle* radiation is preferable, especially on the 7- and 14-mc. bands where radiation at angles below approximately 20 degrees is desirable. Certain types of antennas are more suitable for giving low-angle radiation than others, as shown in Chapter Sixteen. Lower-frequency transmission for intermediate distances may be better suited by higher-angle radiation, however, something like 45 degrees being considered more generally satisfactory for frequencies in the 3500-kc. band.

Another practical point should be mentioned with reference to the receiving antenna and polarization of the waves. On the 7- and 14-mc. band frequencies it has been found that the sky waves arrive at the receiving point with horizontal polarization, irrespective of how they were polarized at transmission. 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. For this reason a horizontal receiving antenna is generally preferable. Also, it appears that most local electrical interference (from machines, etc.) is vertically polarized. The horizontal antenna therefore discriminates against such interfering waves and further aids reception.

Ultra-High Frequency Waves

● Although waves of ultra-high frequency (above 30 mc.) are only rarely bent back to earth by the ionosphere, recent 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 show 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 Thirteen and Fourteen.

Fading

● Whenever radio waves can travel between the transmitting and receiving points over more than one path, there is opportunity for simultaneously transmitted oscillations to arrive at the receiver at slightly different times, since one path is likely to be longer than the other. This is especially so when the short-distance ground wave and the longer-path up-and-down sky wave are simultaneously received, or when two sky-wave paths differ as shown in Fig. 417-A. As a result of this time difference, there will be a difference in phase. As we saw in Chapter Three, two voltages of different phase but of the same frequency will augment or cancel each other in effect when detected. Such action is the cause of what is known as *fading* in radio reception. The two paths may not have a constant difference, because there are continuously changing ionization conditions in the upper atmosphere for high frequencies (and of temperature conditions in the lower atmosphere for ultra-high frequencies). Therefore the phase difference between the two sets of waves will shift from instant to instant, causing more or less rapid fluctuations in the effective received signal. The difference in path lengths does not have to vary much to give this effect, since a phase change of 180 degrees would make the difference between inphase aiding and out-of-phase opposition. That is, the corresponding variation in path length could be only one-half wavelength. Shifting polarization also can cause fading effect, although this does not appear to be so important.

Fading is not always evidenced by a simple variation up and down in the strength of the complete signal, but often has this along with disagreeable distortion or poor quality. The latter effect is known as *selective fading* and results because all the frequency components, in a speech modulated wave for instance, do not differ uniformly in path length, some cancelling more than others.

Many methods of attempting to overcome fading have been devised, such as the use of receiving antennas that respond only to waves arriving over one path, automatic gain control in receivers, diversity reception, and so on. Several of these are described in later chapters in this book.

CHAPTER FIVE

Vacuum Tubes

OPERATING PRINCIPLES — TYPES OF AMPLIFIERS — RECTIFIERS — TUBE TYPE DATA

IT CAN be truthfully said that the art of radio communication as now practiced is based fundamentally upon the vacuum tube. The vacuum tube works to change alternating to direct current in our power supplies, to amplify sound from a whisper to a roar, to generate the radio-frequency power used in transmission and to amplify and detect weak radio waves in our receivers. Vacuum tubes appear in many sizes and in a variety of structures, but all operate on the same principle. Most commonly, the vacuum tube has a glass bulb from which practically all air and other gas has been removed, and within which there are two or more elements, ranging from a filament (cathode) and plate (anode) on up to these two in combination with three, four and even more elements.

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.* As was explained in Chapter Three, the hot cathode emits electrons which flow from cathode to plate within the tube *when the plate is positive with respect to the cathode.* The tube is a conductor in one direction only. If there should be a battery connected with its negative terminal to cathode and positive to plate (the "B" battery in Fig. 501) this flow of electrons would be continuous. But if a source of alternating current 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, and hence no current 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, as described in Chapter Fifteen, or even to use it as a rectifier (detector) of radio-frequency current in receivers.

Characteristic Curves — Space Charge

● 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. A characteristic curve is one which 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.

With the cathode temperature fixed, the total number of electrons emitted is always the same regardless of the plate voltage. The sample curve of Fig. 501 shows, however, that despite the fact that the same number of electrons always is available, less plate current

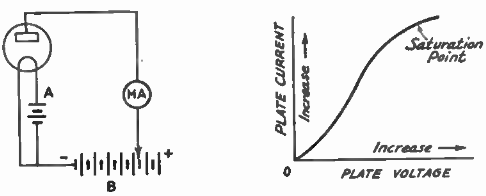


FIG. 501 — THE DIODE OR TWO-ELEMENT TUBE AND A TYPICAL CHARACTERISTIC CURVE

will flow at low plate voltages than when the plate voltage is large. The reason for this is that the electrons emitted from the cathode form a "cloud" between cathode and plate, much the larger proportion of them occupying the space immediately surrounding the cathode. 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. The repulsion of electrons by the electron cloud 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. When this point is reached a further increase in plate voltage can cause no increase in plate current, as shown by the flattening of the characteristic. The point at which all electrons are attracted to the plate is called the *saturation point.*

How Vacuum Tubes Amplify — Tube Characteristics

● 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 acquires utility 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 plate or "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 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. The important thing about this is that 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), an important *tube characteristic.* The amplification factor 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 a tube's *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).

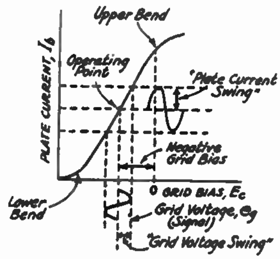


FIG. 502 — OPERATING CHARACTERISTICS OF A VACUUM-TUBE AMPLIFIER

Class-A amplifier operation is depicted.

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 different with tubes of different types, being dependent primarily on the tube structure (spacing between elements, spacing and size of wires in grid, etc.).

Amplifier Operation

● The operation of a vacuum tube amplifier is graphically represented in Fig. 502. The sloping line represents the variation in plate current obtained at a constant plate voltage with grid voltages from a value sufficiently negative to reduce the plate current to zero to a value slightly positive. It should be kept in mind that grid voltage is with reference to the cathode or filament. This is known as the *static grid-voltage plate-current characteristic.* Notable things 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 in the range of the curve.

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. With 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 so 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 be *distorted*. If the

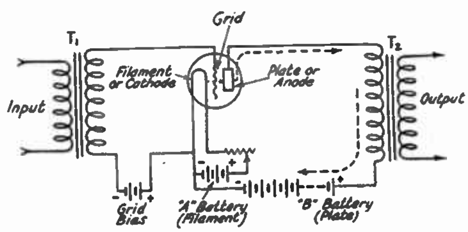


FIG. 503 — A TYPICAL AUDIO-FREQUENCY AMPLIFIER USING A TRIODE TUBE

operating point is set towards the bottom or towards 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. This kind of distortion may be undesirable or desirable, as will be shown later.

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

Static and Dynamic Characteristics

● A tube characteristic of the type shown in Fig. 502 is meaningless for design purposes unless certain operating conditions not shown by the curve itself are specified. For instance, if the curve illustrated is a *static characteristic*, it will show only the plate current that will flow at specified plate and grid voltages in the absence of any output device or *load* in the plate circuit. Fig. 504-A illustrates a sample static characteristic and indicates the method by which the data are obtained. With the plate voltage E_b fixed, the grid voltage E_g is varied, plate current readings being taken for each change in grid voltage. A complete series of readings will give one of the curves at the left. Several of these may be taken with a number of different plate voltage values. Since the path for the flow of plate current consists only of the plate battery and the plate-cathode circuit of

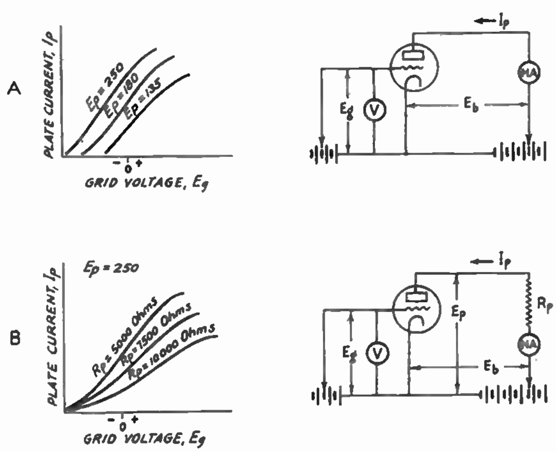


FIG. 504 — STATIC (A) AND DYNAMIC (B) CHARACTERISTICS

The values shown on the curves are purely arbitrary, and are used simply to illustrate the relative behavior with different applied voltages or with different load impedances.

the tube itself, it is plain that no provision has been made for transferring the plate current variations with signal input, illustrated in Fig. 502, to an external circuit. Obviously the utility of such a characteristic is limited.

A more useful type of curve is the *dynamic characteristic*, illustrated in Fig. 504-B. 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 the terminals of 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 may be a device such as a headset or loud-speaker having a self-impedance, at the frequency being amplified, of a value suitable to be connected in 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. Several different values of load impedance may be used in making up a set of dynamic characteristics, as shown in Fig. 504-B, giving the designer a choice of several values.

In making up a characteristic of this type, the plate battery voltage, E_b, usually is chosen so that the voltage actually operating between plate and cathode, E_p, is the rated value for the tube at the normal operating plate current. E_b must therefore equal the sum of E_p plus the drop through R_p at rated plate current. To illustrate, suppose the tube is rated at 250 volts and 30 milliamperes plate, and the load impedance is 5000 ohms. The voltage drop in R_p is 5000×0.03, or 150 volts, E_p is 250 volts; $E_b = 150 + 250$, or 400 volts. If the grid bias is made more negative, the plate current will decrease and the drop in R_p also will decrease, leaving more voltage effective at the plate itself. If the grid bias is made more positive with respect to the cathode, the converse will be true. The limit in the negative-grid direction would be the cut-off grid voltage, when the plate current would be zero, the drop in R_p likewise zero, and E_p would equal E_b, or 400 volts. The limit in the positive-grid direction would be reached at saturation, when the plate current is maximum, the drop in R_p also is maximum, and the plate voltage, E_p, reaches its lowest value. When the grid voltage is high (positive) the plate voltage is low (negative swing of a.c. component). The alternating components of the grid and plate voltages are therefore opposite in phase, or 180° out of phase.

If the load has high a.c. impedance but low d.c. resistance, E_b may equal E_p at normal grid voltage and plate current, since in the absence of signal the d.c. drop through the load will be small. The increase and decrease of plate voltage with changing grid voltage then comes about because of the reactive voltage developed in the impedance. For example, if the load is assumed to have an a.c. impedance of 5000 ohms but negligible d.c. resistance, the battery voltage E_b in our previous example would be 250 instead of 400 volts, the whole 250 volts being effective at the plate under no-signal conditions. When a signal of suitable amplitude is applied to the grid, the plate voltage would swing between the same values as before, reaching a peak of 400 volts at cut off, even though the supply voltage is only 250, because of the reactive voltage induced in the load. This would occur only when an alternating voltage is applied to the grid, however, and could not be reproduced with fixed values of grid voltage.

FIG. 505 — A TYPICAL "PLATE FAMILY," SHOWING THE METHOD OF DRAWING A LOAD LINE

The Plate Characteristic Family

● The type of characteristic shown in Fig. 504-B is somewhat inconvenient to use because a separate curve must be plotted for each value of load impedance considered. A more general type of characteristic, known as the plate-voltage plate-current type, or commonly called the *plate family*, is shown in Fig. 505. In this characteristic, plate voltage is plotted against plate current for different fixed values of grid voltage throughout the usable range for the tube. The load impedance on such a characteristic can be represented by a line drawn through the operating point chosen, as shown. The impedance represented by the line is determined by its slope; if the line is extended so that it intersects both the vertical and horizontal reference lines, the plate voltage at the point of intersection divided by the plate current at its point of intersection will be the impedance. In the drawing these values are 420 volts and 60 milliamperes, giving an impedance of 420/.06, or 7000 ohms.

The voltage developed across the load and the value of alternating plate current can be found from the points of intersection of the load line with the various grid voltage values. For instance, if the peak grid voltage swing about the operating point, B, is 20 volts, the peak positive grid voltage will be 40 − 20, or 20 volts, and the peak negative voltage will be 40 + 20, or 60 volts. The plate voltage and plate current at $E_g = -20$ volts are 200 volts and 30 ma. respectively; at $E_g = -60$ volts, 340 volts and 10 ma. The plate voltage swing is therefore 340 − 200 volts/2, or 70 volts (it is necessary to divide by 2 because the two values so obtained are the extremes of the positive and negative — or "up" and "down" — swings, while an alternating voltage is measured with respect to the zero point, which is the operating point in this case). Similarly, the plate current swing is 30 ma. − 10 ma./2, or 10 ma.

In the figure, if it is assumed that the grid voltage is not to go beyond zero in the positive direction, the maximum grid voltage swing from the bias of 40 volts would likewise be 40 volts. It is evident that the maximum total output voltage and current swings under the assumed operating conditions would then be 395 − 130 volts and 41 − 2 milliamperes. The *power output* of the tube is then equal to these two values multiplied together and divided by 8, or

$$PO = \frac{(E_{pmax.} - E_{pmin.}) \times (I_{pmax.} - I_{pmin.})}{8}$$

In our example, the power output would be 265 × .039/8, or 1.3 watts, approximately.

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. The term "harmonic" already has been explained in Chapter Three. 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 only one of importance.

It has been found by listening tests that the presence of a second harmonic having an amplitude as high as 5% of the fundamental amplitude is undetectable aurally. The greater the harmonic content tolerable in the output, the greater is the permissible voltage or power output of the tube. For this reason triode power amplifiers usually are given an output rating based on the presence of a second harmonic having 5% of the amplitude of the fundamental rather than on the lowest distortion obtainable; commonly, the output is said to have 5% distortion. This means that, considering Fig. 504-B, the load resistance and grid swing are chosen so that a small part of the curved portion of the characteristic is used. Similarly, in Fig. 505 the up-voltage swing along the load line may be smaller than the down swing, the difference, if any, between these two values representing distortion. If the up-swing (to the right along the load line) is not less than 9/11ths of the down swing, the distortion will not exceed 5%.

The load line shown in Fig. 505 represents 5% distortion, because with a peak grid swing of 40 volts on either side of the operating point, the length of line BA is 11/9ths of line BC. As the load resistance is increased by making the slope of the load line less, line BC will approach AB in length and the distortion decreases; conversely a lower load resistance than that shown (greater slope to the load line) will give more than 5% distortion.

Parallel and Push-pull Amplifiers

● It is sometimes necessary to obtain more power output than one tube is capable of giving. To do this 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. When this is done the power output will be in proportion to the number of tubes used; the exciting voltage required, however, is the same as for one tube. Parallel operation of tubes involves certain considerations which will be considered more fully in later chapters. It is seldom that more than two tubes are connected in parallel because of circuit considerations.

An increase in power output also can be secured by connecting two tubes in *push-pull,* in which the grids and plates of the two tubes are connected to opposite ends of the circuit, respectively. Parallel and push-pull operation are illustrated in Fig. 506. A "balanced" circuit, in which the cathode returns are made to

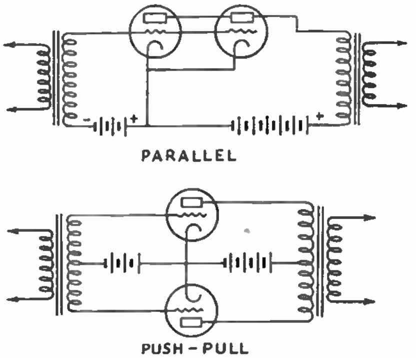


FIG. 506 — PARALLEL AND PUSH-PULL AMPLIFIER CONNECTIONS

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, in the same way that the motion of the familiar child's "see-saw" is distributed. Hence the name "push-pull." The power output with two tubes in push-pull is the same as with two tubes in parallel, assuming the same operating conditions, but twice as much exciting voltage is required. However, 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, of course, that for a given degree of distortion, the push-pull amplifier is therefore capable of delivering more power than a parallel amplifier. Only odd harmonics are present in the output of a push-pull amplifier, and since these harmonics are of small amplitude with triode tubes, the power output from a pair of tubes in push-pull can be made considerably greater than with the same tubes in parallel before distortion becomes objectionable.

Methods of Coupling

● In multi-stage amplifiers a variety of coupling methods may be used between stages. Three fundamental forms of coupling are shown in Fig. 507. That at *A* is known as *transformer coupling,* because a transformer is used to convey the signal from the output circuit of the first tube to the input or grid circuit of the second. The grid of the second tube cannot be connected directly to the plate of the first because of the wide difference in their steady d.c. operating potentials. The method shown at *B* is called *resistance coupling;* the output voltage of the first tube is developed across the resistor in its plate circuit and transferred to the grid of the second tube through the coupling condenser *C*, appearing across the resistor in the grid circuit of the second tube. The third method, at *C*, is known as *impedance coupling* because a choke coil is used as the coupling element. There are many variations of these three circuits. The iron-core transformer of *A* may be replaced by a tuned air-core transformer in radio-frequency circuits, the impedance and resistor in *C* may be interchanged, etc. Coupling methods will be considered fully in the following chapters.

Voltage and Power Amplifiers

● Amplifiers may be divided broadly into two general types, those whose chief purpose is to

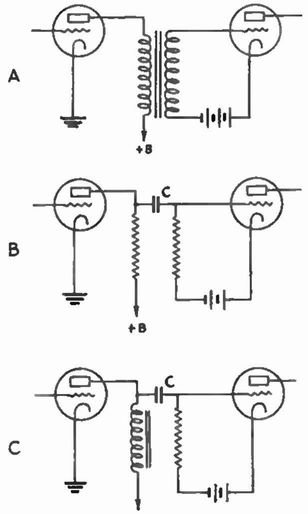


FIG. 507 — METHODS OF COUPLING BETWEEN AMPLIFIER TUBES

A, transformer coupling; B, resistance coupling, C, impedance-resistance coupling.

give a greatly magnified reproduction of the input signal without regard to the power delivered, and those which are intended to deliver a relatively large amount of power to a load (for example, a loud-speaker, in the case of an audio amplifier, or an antenna, in the case of a radio-frequency amplifier). The former is known as a *voltage amplifier*, while the latter is called a *power amplifier*.

Generally speaking, the last stage of any amplifier, whether audio or radio, is a power amplifier, since power is required for the operation of sound-reproducing devices and for the excitation of antennas. Amplifier stages preceding the last may be either voltage or power amplifiers, depending upon the purpose for which the equipment is designed. In audio circuits, the power tube or output tube in the last stage usually is especially 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. Triode audio power amplifiers of this type often will give a power amplification ratio almost infinite, while the voltage amplification ratio may be less than 3 to 1. To get the voltage swing required for the grid circuit of such a power tube it becomes necessary to use voltage amplifiers, employing tubes of high μ which will greatly increase the 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.

As explained in the preceding sections, the portion of the tube characteristic which can be utilized for distortionless amplification is limited. In radio-frequency circuits, where the input and output circuits are resonant, harmonic distortion of the r.f. wave form often can be neglected, since most of the harmonics so generated are filtered out in the tuned circuits, with the result that the whole tube characteristic can be used. This leads to increased efficiency and higher power output for a given tube capacity. To obtain high efficiency in the plate circuit it is necessary that the grid be driven positive during part of the exciting signal cycle; during the time that the grid is positive with respect to the cathode electrons are attracted to the grid and a flow of grid current results. This in turn requires that the source of the exciting signal be capable of supplying power. For this reason it is usually found that all the amplifier stages in a transmitter, where high efficiency and maximum power output are desirable, are power stages. The voltage amplification in such a case is secondary. Certain types of high-efficiency audio amplifiers to be discussed later also require some power in the grid input circuit, so that such amplifiers often will be preceded by a smaller power amplifier.

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. It is one of three fundamental types of amplifiers, the other two being designated as *Class B* and *Class C*.

Certain operating conditions distinguish the Class A amplifier from other types. As most 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.

Specially designed tubes, capable of being excited or driven by voltage amplifiers, are used for Class-A power amplification. In general, a relatively large signal is required to drive them to full output, even though no power is consumed in the grid circuit. It should be understood, however, that any tube operated so that the output signal is a distortionless reproduction of the input signal, and whose operating conditions are such that plate current flows during the entire cycle of exciting grid voltage, is a Class A amplifier, regardless of whether or not grid current is drawn, and whether the tube is used as a power or voltage amplifier.

Class-A Amplifiers of the power type find their chief application as output amplifiers in audio systems, operating loud speakers in radio receivers and public-address systems, and as modulators in radio telephone transmitters. Class-A voltage amplifiers are found in the stages preceding the power stage in the same 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

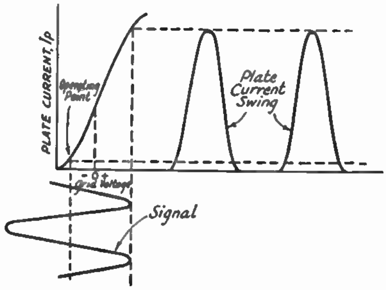


FIG. 508 — OPERATION OF THE CLASS-B AMPLIFIER

current, this can be put in another way by saying that the power output of a Class-B amplifier is proportional to the square of the exciting grid voltage.

The distinguishing operating conditions of Class-B service are 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. 508 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, as indicated on the drawing. Grid current flows, therefore, and the driving source must be capable of furnishing power to supply the grid losses.

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.

Class-B amplifiers 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 radio telephone transmitters after modulation has taken place. For this service it is essential that the output power be proportional to the square of the excitation voltage, which varies at an audio-frequency rate. The tube can be driven into the upper-bend region of its characteristic, giving some flattening of the plate current pulse at the top, but since the distortion is only present in the radio-frequency wave and not in the audio-frequency modulation, it can be filtered out in the resonant plate circuit.

In transmitters, Class-B r.f. amplifiers often are used where a fairly high power gain is required even though it is not essential that the amplification be linear. With the bias set to cut-off the excitation requirements are not as severe as with the high-efficiency Class-C amplifier, now to be discussed.

Class-B Audio Amplifiers

● For audio-frequency amplification, two tubes must be used to permit Class-B operation. It is apparent from Fig. 508 that al-

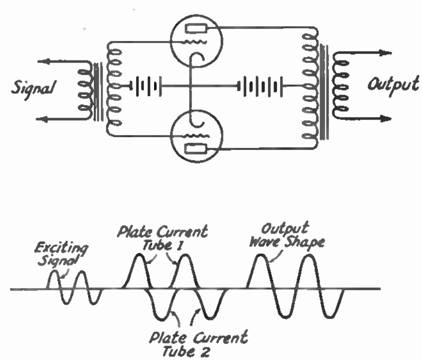


FIG. 509 — THE CLASS-B AUDIO AMPLIFIER, SHOWING HOW THE OUTPUTS OF THE TWO TUBES ARE COMBINED TO GIVE DISTORTIONLESS AMPLIFICATION

though the plate current pulses are of the same shape as the positive signal swing, yet considerable distortion at audio frequencies would be introduced if only one-half of each cycle were present in the output. For this reason a second tube, working alternately with the first, must be included in the amplifier circuit so that both halves of the cycle will be present in the output. A typical method of arranging the tubes and circuit so that this end is achieved is shown in Fig. 509. 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, the plate voltage being fed in at the center-tap. 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 output, for a given tube size, than is obtainable from a Class-A amplifier. In contrast to the Class-A amplifier with its steady plate current, the average plate current drawn by the Class-B audio amplifier is proportional to the amplitude of the exciting voltage. Tubes most suitable for Class-B audio service are generally those with high μ's, for reasons to be discussed in a later chapter in connection with the design of Class-B modulators.

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

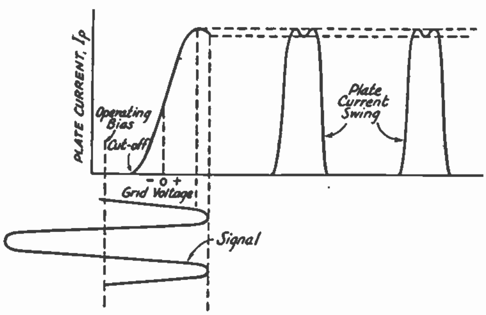


FIG. 510 — CLASS-C AMPLIFIER OPERATION

power is therefore proportional to the square of the plate voltage. An amplifier so operated is capable of being modulated linearly by plate voltage variation, as will be described in Chapter Eleven. 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. 510. 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 exclusively as radio-frequency power amplifiers, since the Class-C type of operation at present has no 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, it naturally becomes possible to adopt a set of operating conditions which partakes 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 to as great an extent as in Class-B operation. The Class-AB amplifier is also occasionally called Class-A Prime.

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.

Harmonic Generation

● It has been stated that distortion is equivalent to combining the original wave shape with one or more harmonics of the fundamental frequency. Although harmonic generation is undesirable in audio amplifiers, it has a very important place in radio-frequency amplification, as we shall see in the chapters on transmitters. Hence it is advantageous in some applications to adjust the tube operating conditions so that the output wave shape is greatly distorted. High input-signal amplitude or grid swing and high negative bias are favorable to the production of harmonics, as is evident from study of Fig. 510 in comparison with Figs. 508 and 502. By proper choice of operating conditions and tuning the output circuit to the desired harmonic frequency, a vacuum tube may be operated as a frequency doubler or frequency tripler, etc. Harmonics cannot be generated at frequencies below the fundamental but always occur at higher frequencies.

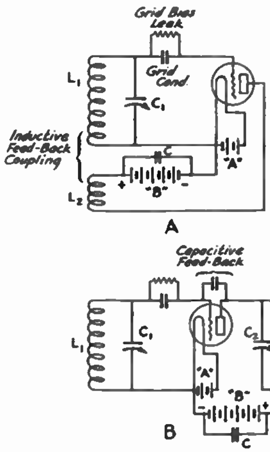


FIG. 511 — TWO GENERAL TYPES OF OSCILLATOR CIRCUITS

Generating Radio Frequency Power — Oscillators

● 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. 511. In *A* the feed-back coupling between the grid and plate 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. To insure the proper phase relationship between plate and grid voltage, with the inductive feed-back of *A* the grid and plate should be connected to the opposite ends of the plate and grid coils when these coils are wound in the same direction, while in the arrangement of *B* the plate circuit should be tuned to a slightly higher resonant frequency than the grid circuit (plate circuit reactance inductive with respect to the grid circuit). At the high radio frequencies used in amateur work 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.

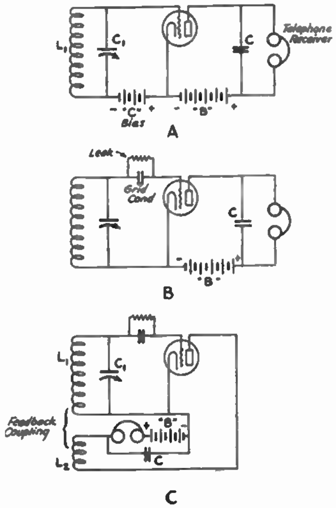


FIG. 512 — DETECTOR CIRCUITS OF THREE TYPES

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

There are many other arrangements of oscillator circuits but all utilize either the inductive or capacitive feed-back typified in the two shown here. Several of these other types are treated in Chapter Eight. A special type of oscillator of exceptional frequency stability is the piezo-electric or crystal-controlled type. Most commonly it resembles the tuned-grid tuned-plate circuit of *B* with the exception that the tuned grid circuit is replaced by a plate of quartz crystal mounted between metal electrodes. This crystal acts like a tuned circuit, its electrical equivalent being shown in Chapter Four.

Power type oscillators and amplifiers are used in combination in radio transmitters, both for radiotelegraphy and radiotelephony, and later chapters will describe practical aspects of these applications.

Detection

● Since the frequencies used in radio transmission are much higher than those audible to the ear, 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 in effect detached from the carrier wave and made audible. Taking the case of a modulated wave, such as a 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 circuit or plate circuit.

Plate Detectors

● The circuit arrangement of a typical plate detector is shown at *A* of Fig. 512. Its operating characteristics are illustrated at *A* of Fig. 513. The circuit L_1C_1 is tuned to resonanace with the radio frequency and the voltage developed across it is applied between the grid and cathode in series with the grid-bias battery. A telephone headset (or the primary of a transformer feeding an audio amplifier) is connected in the plate circuit, a small fixed condenser *C* being connected across the plate load to bypass radio frequency. As shown at *A* in Fig. 513, 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 superimposed 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.

It is apparent from the drawing that a carrier signal will cause an increase in the average plate current.

This type of detection is called plate detection because the rectification takes place in the plate circuit after radio-frequency amplification from grid to plate.

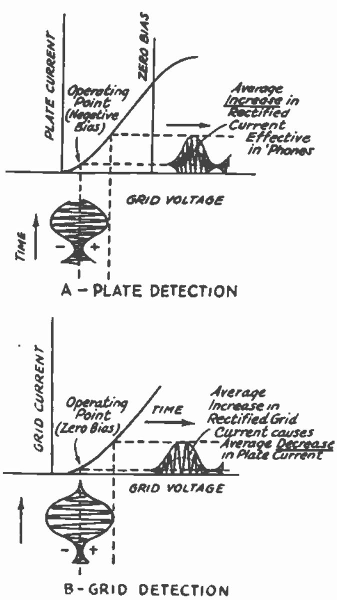


FIG. 513 — OPERATING CHARACTERISTICS OF PLATE AND GRID DETECTORS

Grid Detectors

●The circuit arrangement of a triode used as a *grid detector* (also called *grid leak detector*) is shown in *B* of Fig. 512. Here again we have an input circuit tuned to the frequency of the radio wave and 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, but instead a small fixed condenser (*grid condenser*) and resistor of high value (*grid leak*) in parallel are connected between tuned circuit and grid. The plate circuit connections are 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 which are reproduced in the 'phones. In contrast to plate detection, with grid detection the rectification takes place in the grid circuit and there is audio-frequency

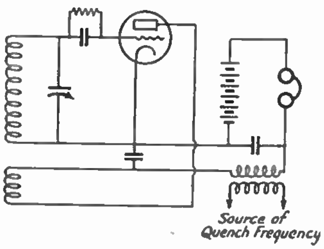


FIG. 514 — AN ELEMENTARY SUPERREGENERATIVE CIRCUIT

amplification to the plate circuit. With grid rectification as shown, the increase in grid current when a carrier signal is applied causes an increase in grid voltage in the negative direction, consequently the average plate current of the grid detector decreases when a signal is applied.

Grid detection is generally used in amateur receivers of limited r.f. amplification because grid detectors are capable of greater sensitivity for small signals than plate detectors, using similar tubes. Plate detection is more commonly used where detector sensitivity is of minor importance, since a larger signal can be handled with less distortion than with grid detection.

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. 512, and re-amplified a number of times. This *regeneration* gives a tremendous increase in detector sensitivity and is used in most amateur receivers. 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 oscillator shown in Fig. 507-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 controlling regeneration are described in Chapter Six.

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, but 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. An elementary form of superregenerative circuit is shown in Fig. 514.

Superregeneration is relatively difficult to attain at ordinary frequencies, and does not possess the property of discriminating between signals of different frequencies characteristic of other types of detectors—in other words, the selectivity is poor. For this reason the superregenerative circuit finds its chief field in the reception of ultra-high-frequency signals, for which purpose it has proved to be eminently successful.

Multi-Element Tubes

● So far only tubes with two and three elements have been considered. Other elements may be added to the structure to make a tube particularly suitable for certain 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

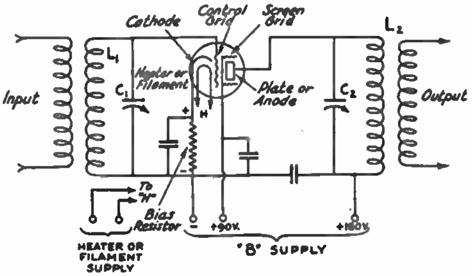


FIG. 515 — A TUNED RADIO-FREQUENCY AMPLIFIER CIRCUIT USING A SCREEN-GRID TETRODE

combinations and structures become possible as the number of electrodes is increased, but only a few have practical applications. Of the possible four-element arrangements, the only one in general use is that known as the *screen-grid* type.

Screen-Grid Tetrodes

● 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. 511-B being used as an illustration. This circuit without the feed-back condenser is exactly the one we would want to use 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. Consequently a triode cannot be used as an amplifier at radio frequencies without the use of special circuits. These are not very satisfactory when a considerable frequency range is to be covered, as in a receiver.

If a second grid, made in the form of an electrostatic shield between the control grid and plate, is added to the tube the grid-plate capacity can be reduced to a value which will not permit oscillations to occur. The *screen grid*, as it is called, has a definite effect on the characteristics of the tube. It 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 of less 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. A typical screen-grid receiving amplifier is shown in Fig. 515.

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. It has very little application in audio-frequency amplifiers, however.

Pentodes

● The addition of the screen grid in the 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 tube is delivering high output voltage.

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 than from the tetrode.

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, since the pentode resembles the tetrode in having a high amplification factor. Pentode tubes also are suitable as audio-frequency power amplifiers, having greater plate efficiency than triodes and requiring less grid swing for maximum output. The latter quality can be indicated in another way by saying that the *power sensitivity*—ratio of power output to grid swing causing it—is higher. In audio power pentodes the function of the screen-grid is chiefly that of accelerating the electron flow rather than shielding, so that the grid often is called the *accelerator grid*. In radio-frequency voltage amplifiers the suppressor grid, in eliminating the secondary emission, makes it possible to operate the tube with the plate voltage as low as the screen voltage, which cannot be done with tetrodes.

As audio-frequency power amplifiers pentodes have inherently greater distortion (principally odd-harmonic distortion) than triodes. The output rating usually is based on a total distortion of 10%.

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 Six—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 section incorporated.

Another type is the pentagrid converter, a special tube working as both oscillator and first detector in superheterodyne receivers. There are five grids between cathode and plate in the pentagrid converter; 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 from all other tube elements. The pentagrid converter eliminates the need for special coupling between the oscillator and detector circuits.

Another type of tube consists of a triode and pentode in one bulb, for use in cases where the oscillator and first detector are preferably separately coupled; while still another type 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 screen-grid 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 frequencies near that of the desired station 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.

Receiving Tubes — Types of Cathodes

● In the practical construction of receiving tubes there are two types of envelopes or "enclosures", glass and metal. Glass bulbs have been the rule since the early days of tube manufacture; recently, however, welded metal envelopes have been introduced. The metal envelope can be utilized to act as an electrostatic shield for the tube elements.

Receiving tubes can be divided into groups according to the type of cathode used. Cathodes have been the subject of much research and development, so it is but natural to find that several tube types more or less duplicate each other except for the type of cathode.

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. In modern receiving tube types, directly-heated cathodes are confined to audio power-output tubes, power rectifiers and the groups intended for operation from dry-cell batteries, where economy of filament current is highly important.

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. Even though the hum can be reduced considerably by proper circuit design, it is still too high in level to be tolerated in multi-tube amplifiers, since the hum appearing at the first tube is amplified through the whole set. 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 of the two parts being brought out to separate base pins.

The first receiving tube filaments were intended to be operated from a six-volt storage battery through a rheostat, hence we find them designed for a terminal voltage of five volts d.c. These and a few early dry-battery types have now been superceded. The first tubes for a.c. heating of the cathodes were designed for 2.5 volts; a very large number of tubes having this cathode voltage are available, some directly and some indirectly heated. When auto radio sets first became popular, a new series of tubes designed for operation at 6.3 volts was made available. The present tendency is to make all receiving tubes except dry-battery types operate at this cathode voltage. The battery series operates with a terminal voltage of two volts.

In addition to grouping by cathode voltages, it is also necessary to make some distinction between older and newer types of 2.5-volt tubes according to the heater current consumed, and also to differentiate between glass and metal tubes. In each series will be found general-purpose triodes, sharp cut-off screen grid tubes, variable-μ screen grid tubes, power amplifiers of the triode or pentode type, and special purpose tubes. There are also rectifier tubes for the power supply. The logical groupings of tubes are given in the form of tables with the essential characteristics and operating conditions of each type.

Ratings and Characteristics

● The tables give maximum ratings for the various types of tubes listed. In the interests of long tube life, filament or heater voltages should be maintained as nearly as possible at the rating given (variations 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. Methods of obtaining bias will be treated in the chapters on receiver and transmitter design.

The important characteristics of the tubes, such as amplification factor, mutual conductance, etc., also are given. In addition, the *inter-electrode capacitances* are listed in the tables of transmitting tubes. Since transmitting tubes often are large in physical structure, these capacities can be quite high with 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.

Base Connections and Pin Numbering

● Excepting the metal tubes, bases will be found to have from four to seven pins for element connections. In all except the five-prong type, the two cathode pins are heavier than the others, making them readily distinguishable. The pins 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. The metal tubes all have 8-pin bases — only those pins needed for connections being actually molded into the base, however — consequently a single type of socket will handle any

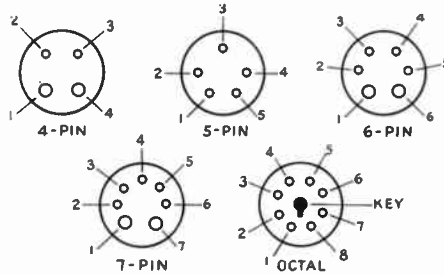


FIG. 516 — TUBE-BASE PIN NUMBERING SYSTEM

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 cathode pins are heavier than the others; on the 5-pin and octal bases the No. 1 pin is readily identified from the drawings above.

tube of the metal series. The base and pin-numbering diagrams are shown in Fig. 516.

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

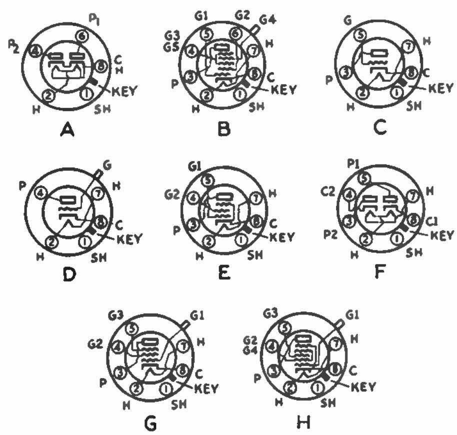


FIG. 518 — BASE DIAGRAMS OF METAL RECEIVING TUBES

Legends have the same significance as in Fig. 517 with the addition of SH, shield; the shield is the metal envelope of the tube, in all cases connected to pin No. 1. Views are of bottoms of tube bases or sockets.

TABLE I — 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
6A4 [3]	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
6B5	Special Power Amplifier	6-pin M.	Y	Htr.	6.3	0.8	Class-A Amplifier	300	0		6 [5]	45	24100	2400	58	7000	4.0	6B5
							Push-Pull Amplifier	400	−13		4.5 [5]	40	—	—	—	10000	20	
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	200 250	0 0	— —	— —	0.2 0.25	Target Current 4.0 ma. Target Current 4.5 ma.				— —	6E5
6F7	Triode Pentode	7-pin S.	W	Htr.	6.3	0.3	Triode Unit Amplifier	100	−3.0	—	—	3.5	17800	450	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				—	
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					—	

TABLE 1—*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
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	—	—	—	—	—	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								
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	

[1] Refer to Fig. 517.
[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.

TABLE II — 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	100000	2200	220	7000	3.0	2A5
2A6	Duplex-Diode High-μ Triode	6-pin S.	K	Htr.	2.5	0.8	Triode as Class-A Amp.	250	−1.35	—	—	0.4	—	—	Gain per stage = 50-60			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
2B7	Duplex-Diode Pentode	7-pin S.	Q	Htr.	2.5	0.8	Pentode R.F. Amplifier	100 250	−3.0 −3.0	100 125	1.7 2.3	5.8 9.0	300000 650000	950 1125	285 730	—	—	2B7
							Pentode A.F. Amplifier	250	−4.5	50	—	0.65	—	—	—	—	—	
24-A	Tetrode R.F. Amplifier	5-pin M.	I	Htr.	2.5	1.75	Screen-Grid R.F. Amplifier	180 250	−3.0 −3.0	90 90	1.7 1.7	4.0 4.0	400000 600000	1000 1050	400 630	—	—	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	135 250	−9.0 −21.0	—	—	4.5 5.2	9000 9250	1000 975	9.0 9.0	—	—	27
							Bias Detector	250	−30.0	—	Plate current adjusted to 0.2 ma. with no signal							
35	Variable-μ Tetrode R.F. Amplifier	5-pin M.	I	Htr.	2.5	1.75	Screen-Grid R.F. Amplifier	180 250	−3.0 min.	90 90	2.5 2.5	6.3 6.5	300000 400000	1020 1050	305 420	—	—	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	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	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				—	

TABLE II—2.5-VOLT RECEIVING TUBES

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	

[1] Refer to Fig. 517.
[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.

TABLE III—METAL 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
6A8	Pentagrid Converter	8-pin O.	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
6C5	Triode Detector Amplifier	6-pin O.	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	5-pin O.	D	Htr.	6.3	0.3	Class-A Amplifier	250	−1.3	—	—	0.2 to 0.4	66000	1500	100	0.25 to 1.0 meg.	—	6F5
6F6	Pentode Power Amplifier	7-pin O.	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	7-pin O.	F	Htr.	6.3	0.3	Rectifier	Max. a.c. voltage per plate = 100 r.m.s. Max. output current 2.0 ma. d.c.										6H6
6J7	Triple-Grid Detector Amplifier	7-pin O.	G	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	—	—	6J7
							Bias Detector	250	−4.3	100	Cathode current 0.43 ma.		—	—		0.5 meg.	—	
6K7	Triple-Grid Variable-μ Amplifier	7-pin O.	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				
6L7	Pentagrid Mixer Amplifier	7-pin O.	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				

[1] Refer to Fig. 518.
[2] O.—small octal base.
[3] Screen tied to plate.
[4] Zero signal currents per tube.

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 element connected to the cap have very low capacity to other tube elements.

Tube Numbering

● Until recently arbitrary numbers were assigned to tubes as they were placed on the market. For the past few years, however, a numbering system has been in effect which to some extent indicates the nature of the tube. These designations consist of a number, a letter, and a final number. The first number indicates the cathode voltage, the letter the individual tube of the series, the first being designated A, the second B, and so on, except for rectifiers, which start with Z and go backwards; the last number indicates the number of useful elements brought out to pin connections. Cathode voltages are indicated by 1 for

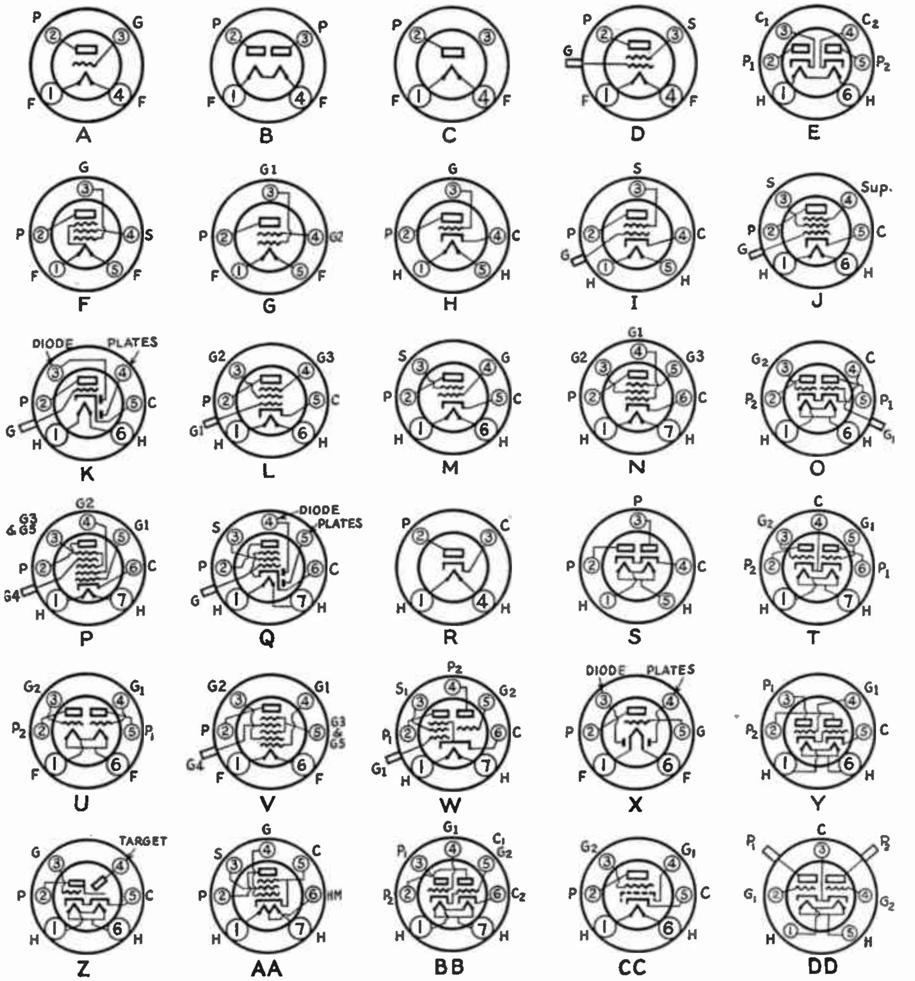


FIG. 517 — BASE DIAGRAMS OF GLASS RECEIVING TUBES

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.

TABLE IV — 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
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
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
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
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	

[1] Refer to Fig. 517.
[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 V—SPECIAL 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
12A5	Pentode Power Amplifier	7-pin M.	AA	Htr.	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
43	Pentode Power Amplifier	6-pin M.	M[2]	Htr.	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	Htr.	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
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
885	Gas Triode	5-pin S.	H	Htr.	2.5	1.4	Sweep-Circuit Oscillator	200	—	—	—	0.5	Tube voltage drop 15 v.			—	—	885
954[1]	Pentode Detector, Amplifier	None	—	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[1]	Triode Detector, Amplifier	None	—	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	
RK10	Triode Power Amplifier	4-pin M.	A	Fil.	7.5	1.25	Characteristics same as Type 10. Isolantite Base											RK10
RK15	Triode Power Amplifier	4-pin M.	A[5]	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
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
							Oscillator	180	−45	—	—	20	Grid leak 10000 ohms				—	
RK34	Twin Triode Amplifier	5-pin M. 7-pin M.	DD[6]	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	Cathanode (G1) current 250 ma.				20000	50	—	—	RK100

[1] Refer to Fig. 517.
[2] Suppressor grid, connected to filament inside tube, not shown on base diagram.
[3] M.—medium; S.—small.
[4] "Acorn" type; miniature unbased tubes for ultra-high frequencies.
[5] Grid connection to top cap; no connection to No. 3 pin.
[6] Early models; later tubes have 7-pin bases. Connections same as Fig. 517-T except that pins 2 and 6 are unconnected; plate leads brought out to top caps.

TABLE VI—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
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	—	—	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
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

[1] Refer to Fig. 517.
[2] M.—medium; S.—small.

2-volt tubes, 2 for 2.5 volts, 5 for 5 volts, 6 for 6.3 volts, 12 for 12 volts, and 25 for 25 volts. In the final number, the filament or heater counts as one element, although always having two connections.

For example, the 2A6 is a 2.5-volt tube having six elements brought out to connections (cathode, heater, triode grid, triode plate, and two diode plates) and is the first six-element tube of the 2.5-volt series, designated by the "A". The 5Z3 is a five-volt rectifier having three elements (cathode and two plates) brought out to connections, and is the first rectifier numbered according to this system. Other examples readily can be worked out.

Multi-Grid Tubes — Element Connections

● A number of receiving tubes are so constructed that one type can be made to serve several different purposes simply by re-arranging the element connections. Thus we find power amplifier tubes with two or three grids, which can be connected in various ways to make the tube suitable for use as a Class-A triode power amplifier, as a Class-B triode amplifier, or as a Class-A pentode amplifier. The Type 59, a triple-grid tube, is an example. If the inner grid, No. 1, is used as the control grid while Nos. 2 and 3 are connected to the plate, the tube is a triode suitable for Class-A power amplification. If, however, No. 1 grid is connected to the middle grid, No. 2, while No. 3, the outer grid, is connected to the plate, the tube can be used without bias as a Class-B amplifier. Still a third method of connection makes the 59 a Class-A pentode; Grid No. 1 is the control grid, No. 2 the screen or accelerator, while No. 3, connected to the cathode, becomes the suppressor. The connections to be used with the several types of tubes falling in this classification are indicated in the tables.

Equivalent Types

● Although in each series of tubes there will be found types which correspond more or less closely with tubes in the other series designed for the same use, such tubes are not generally interchangeable; that is, a circuit design based on one type of screen-grid amplifier, for instance, will not necessarily give identical performance when a screen-grid tube from another series is substituted. In the 6.3- and 2.5-volt glass series, however, certain types are duplicated in all respects except for the heaters, hence these types are wholly interchangeable, the only adjustment needed being that of providing the proper heater voltage. The list of such tubes follows:

2A5 — 42	57 — 6C6
2A6 — 75	58 — 6D6
2A7 — 6A7	55 — 85
2B7 — 6B7	56 — 76
53 — 6A6	

In addition to those listed above, some tube manufacturers also make a complete line of 6.3-volt glass tubes corresponding in characteristics to those of the metal-tube series. These tubes have octal bases and carry the same type designations with the addition of a "G". For example, the glass counterpart of the 6L7 is known as the 6L7G.

Special Types of Tubes

● Tubes designed for special purposes or differing widely in characteristics from those listed in the other tables are shown in Table V. Included in these are power tubes intended for operation from 110-volt d.c. mains. The 43 and 48 are power amplifiers of the vacuum-tube type for this purpose, while the RK100 is a mercury-vapor tube of special design built to give large power outputs at this voltage. The 12A5 is a multi-purpose type particularly designed for use with "universal" or a.c.-d.c. receivers. The 954 and 955 are miniature tubes — "acorn" type — which function well at ultra-high frequencies where tubes of ordinary construction are inoperative; they can be used for amplification, detection and oscillation at wavelengths as short as ¾ meter. The 864 is a non-microphonic triode amplifier for battery-operated amplifiers such as are used with condenser microphones. The 885, a gas-filled triode, is used as a relaxation oscillator in oscilloscope sweep circuits.

In addition to these, there are also available cathode-ray tubes for oscilloscope use. These are described in Chapter Seventeen. Many other types of tubes, including low-grid current tubes for measurements purposes and grid-controlled rectifiers, or thyratrons, are manufactured, but because of their limited application in amateur work or the difficulty of obtaining them, are not included in the tables.

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-

TABLE VII — RECTIFIERS — RECEIVING AND TRANSMITTING

Type No.	Name	Base [2]	Socket Connections [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	Type [7]
5Z3	Full-Wave Rectifier	4-pin M.	B	Fil.	5.0	3.0	500	250	—	—	V
5Z4	Full-Wave Rectifier[3]	5-pin O.	A [4]	Htr.	5.0	2.0	400	125	1100	—	V
12Z3	Half-Wave Rectifier	4-pin S.	R	Htr.	12.6	0.3	250	60	—	—	V
25Z5	Rectifier-Doubler	6-pin S.	E	Htr.	25.0	0.3	125	100	—	—	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
84/6Z4	Full-Wave Rectifier	5-pin S.	S	Htr.	6.3	0.5	350	50	—	—	V
RK19	Full-Wave Rectifier	4-pin M.	B [8]	Htr.	7.5	2.5	1250	—	3500	600	V
866	Half-Wave Rectifier	4-pin M.	A [8]	Fil.	2.5	5.0	—	—	7500	600	M
866-A	Half-Wave Rectifier	4-pin M.	A [8]	Fil.	2.5	5.0	—	—	10000	600	M
872	Half-Wave Rectifier	4-pin J.	P [8]	Fil.	5.0	10.0	—	—	7500	2500	M

[1] Refer to Fig. 517.
[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. 519.

vapor molecules dislodge other electrons, "ionizing" the gas, as explained in Chapter Three. This increases the conductivity and results in a lower voltage drop in the rectifier, giving better voltage regulation (see Chapter Fifteen) and higher efficiency. 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. Their uses are explained in Chapter Fifteen.

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 of 750 or more are universally provided with thoriated tungsten filaments.

Transmitting tubes are generally rated by plate dissipation, which is the amount of power than 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 uses of the various columns in the transmitting tube tables is explained in the chapters dealing with transmitters and radiotelephony.

Only three types of transmitting tubes are in

TABLE VIII—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	Recommended Grid Leak Ohms	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	Peak Power Output Watts	Approx. Carrier Output Power Watts	Type
10*	15	7.5	1.25	500	60	15	8.0	10000	4.0	7.0	3.0	4-pin M.	C	Class-C Amplifier	500	−135	60	10	3	—	20	10
														Grid-Bias Modulated Amp.	500	—	45	1-2	1	30	7.5	
841	15	7.5	1.25	450	60	20	30.0	5000	4.0	7.0	3.0	4-pin M.	C	Class-C Amplifier	450	−32	50	12.5	1.25	—	14	841
843	15	2.5	2.5	450	40	7.5	7.7	10000	4.0	4.5	4.0	5-pin M.	D	Class-C Amplifier	450	−140	30	5	1	—	7.5	843
801*	20	7.5	1.25	600	70	15	8.0	10000	4.5	6.0	1.5	4-pin M.	C	Class-C Amp. (Telegraphy)	600	−150	65	15	4	—	25	801
														Class-C Amp. (Telephony)	500	−190	55	15	4.5	—	18	
														Class-B Amp. (Telephony)	600	−75	45	—	—	30	7.5	
														Grid-Bias Modulated Amp.	600	—	50	2	2	40	10	
800*	35	7.5	3.25	1250	115	25	15	10000	2.75	2.5	1.0	4-pin M.	E	Class-C Amp. (Telegraphy)	1250	−175	70	15	4	—	65	800
														Class-C Amp. (Telephony)	1000	−200	70	15	4	—	50	
														Class-B Amp. (Telephony)	1000	−55	42	—	—	56	14	
														Grid-Bias Modulated Amp.	1000	−150	50	4-5	2	60	15	
830	40	10.0	2.15	750	110	18	8.0	10000	4.9	9.9	2.2	4-pin M.	C	Class-C Amplifier	750	−180	110	18	7	—	55	830
														Grid-Bias Modulated Amp.	1000	−200	50	2	3	60	15	
RK18*	40	7.5	2.5	1250	85	15	18.0	10000	3.8	5.0	2.0	4-pin M.	F	Class-C Amplifier	1000	−135	85	10	5	—	50	RK18
RK31*	40	7.5	3.0	1250	85	15		5000				4-pin M.	F	Class-C Amplifier	1000	−50	85	15	5	—	50	RK31
304-A*	50	7.5	3.25	1250	100	20	11.0	5000	2.0	2.5	0.7	4-pin M.	E	Class-C Amp. (Telegraphy)	1250	−200	100	—	—	—	85	304-A
														Class-C Amp. (Telephony)	1000	−180	100	—	—	—	65	
														Class-B Amp. (Telephony)	1250	−110	50	—	—	84	21	
50T*	50	5.0	6.0	3000	100	30	12	10000	2.0	2.0	0.4	4-pin M.	E	Class-C Amplifier	1000 2000 3000	−200 −400 −600	100 100 100	25 25 25	Power Output Ratings at 75% Eff.		75 150 250	50T
203A	100	10.0	3.25	1250	175	60	25	5000	6.5	14.5	5.5	4-pin J.	M	Class-C Amp. (Telegraphy)	1250	−125	150	25	7	—	130	203A
														Class-C Amp. (Telephony)	1000	−135	150	50	14	—	100	
														Class-B Amp. (Telephony)	1250	−45	106	—	—	170	42.5	

TABLE VIII—*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	Recommended Grid Leak Ohms	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	Peak Power Output Watts	Approx. Carrier Output Power Watts	Type
211	100	10.0	3.25	1250	175	50	12	5000	6	14.5	5.5	4-pin J.	M	Class-C Amp. (Telegraphy)	1250	−225	150	18	7	—	130	211
														Class-C Amp. (Telephony)	1000	−260	150	35	14	—	100	
														Class-B Amp. (Telephony)	1250	−100	106	—	—	170	42.5	
242A	100	10.0	3.25	1250	150		12.5	5000	6.5	13.0	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	10.0	3.25	1250	175	70		3000	6.5	8.0	5.0	4-pin J.	M	Class-C Amp. (Telegraphy)	1250	−80	150	30	6	—	130	838
														Class-C Amp. (Telephony)	1000	−135	150	60	16	—	100	
														Class-B Amp. (Telephony)	1250	0	106	60	10	—	42.5	
852*	100	10.0	3.25	3000	150	40	12	10000	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	—	75	
														Class-B Amp. (Telephony)	3000	−250	43	—	—	160	40	
354*	150	5.0	7.75	3000	175	40	11.0	10000	9.0	3.7	0.4	4-pin J.	N	Class-C Amplifier	3000	−275	150	—	—	—	300	354
150T*	150	5.0	10.0	3000	200	50	13	10000	3.0	3.5	0.5	4-pin J.	N	Class-C Amplifier	1000 2000 3000	−200 −400 −600	200 200 200	35 35 35	Power Output Based on 75% Eff.		150 300 450	150T
F108A*	175	10.0	11.0	3000	200	50	12	15000	3.0	7.0	2.0	4-pin J.	N	Class-C Amplifier	3000	−350	200	—	—	—	400	F108A
204A	250	11.0	3.85	2500	275	80	25	5000	12.5	15.0	2.3	Special	Q	Class-C Amp. (Telegraphy)	2000	−175	250	—	—	—	350	204A
														Class-C Amp. (Telephony)	1800	−250	250	—	—	—	300	
														Class-B Amp. (Telephony)	2000	−70	160	—	—	400	100	
849	400	11.0	5.0	2500	350	125	19	5000	17	33.5	3	Special	Q	Class-C Amp. (Telegraphy)	2000	−200	300	—	—	—	450	849
														Class-B Amp. (Telephony)	1800	−300	300	—	—	—	390	
														Class-B Amp. (Telephony)	2000	−95	265	—	—	700	175	
831	400	11.0	10.0	3500	350	75	14.5	10000	3.8	4.0	1.4	Special	R	Class-C Amplifier	3500	−400	275	40	30	—	590	831
F100*	500	11.0	25.0	2000	500		14.0	10000	4.0	10	2.0	Special	R	Class-C Amplifier	2000	−300	500	—	—	—	600	F100

[1] Refer to Fig. 519.
[2] M.—medium, J.—jumbo.
* Especially suited to high-frequency use.

TABLE IX — 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 Resistor	Approx. Grid Driving Power Watts	Approx. Carrier Output Power Watts	Type
802*	10	6.3	0.95	500	250	6	12	0.15	8.5	7-pin M.	G	Class-C Amp. (Telegraphy)	500	250	40	−100	45	12	2	20000	0.25	16	802
												Grid-Modulated Amp.	500	200	0	−130	25	8	1	37500	0.8	4	
												Suppressor-Modulated Amp.	500	200	−45	−90	22	28	4.5	10700	0.5	3.5	
												Class-B Amp. (Telephony)	500	200	0	−28	25	7	—	43000	0.18	3.5	
RK23* RK25*	12	2.5 6.3	2.0 0.8	500	200	6	10.0	0.04	10.0	7-pin M.	G	Class-C Amplifier	500	200	45	−100	48	15	—	—	—	15	RK23 RK25
												Suppressor-Modulated Amp.	500	150	−30	−75	30	20	7.5	—	—	3	
844	15	2.5	3.25	500	175	3	9.5	0.15	7.5	5-pin M.	H	Class-C Amplifier	500	175	—	−125	25	—	—	—	—	9	844
865*	15	7.5	2.0	750	125	3	8.5	0.1	8.5	4-pin M.	I	Class-C Amp. (Telegraphy)	750	125	—	−80	40	—	5.5	45000	1.0	16	865
												Class-C Amp. (Telephony)	500	125	—	−120	40	—	9	20000	2.5	10	
												Class-B Amp. (Telephony)	750	125	—	−30	22	—	—	45000	—	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
254B*	25	7.5	3.25	750	150	5	11.2	0.085	5.4	4-pin M.	I	Class-C Amplifier	750	150	—	−135	75	—	—	—	—	30	254B
RK20*	40	7.5	3.0	1250	300	15	11	0.012	10	5-pin M.	J	Class-C Amp. (Telegraphy)	1250	300	45	−100	92	32	5	26000	0.9	80	RK20
												Class-C Amp. (Telephony)	900	300	0	−100	62	50	6	25000	1.1	35	
												Grid-Modulated Amp.	1250	300	45	−140	44	10	1.8	95000	2.0	21	
												Suppressor-Modulated Amp.	1250	300	−40	−100	47	36	5	25000	0.9	21	
												Class-B Amp. (Telephony)	1250	300	0	−30	43	15	—	60000	0.5	16	
282A*	70	10.0	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	10.0	3.25	1250	175	10	17.0	0.2	26.0	4-pin J.	O	Class-C Amplifier	1250	175	—	−150	160	—	35	—	10	130	850
860*	100	10.0	3.25	3000	300	10	7.75	0.08	7.5	4-pin M.	K	Class-C Amp. (Telegraphy)	3000	300	—	−150	85	—	15	225000	7	165	860
												Class-C Amp. (Telephony)	2000	300	—	−225	67	—	30	100000	15	75	
												Class-B Amp. (Telephony)	3000	300	—	−50	43	—	—	225000	—	40	
RK28*	100	10.0	5.0	2000	400	35	15.5	0.02	5.5	5-pin J.	L	Class-C Amp. (Telegraphy)	2000	400	45	−100	140	60	10	26000	1.8	200	RK28
												Class-C Amp. (Telephony)	1500	400	0	−100	135	85	9	12000	1.6	100	
												Grid-Modulated Amp.	2000	400	45	−140	80	20	2.8	80000	3.0	75	
												Suppressor-Modulated Amp.	2000	400	−45	−100	85	85	11	20000	2.0	70	
												Class-B Amp. (Telephony)	2000	400	0	−38	75	30	—	55000	0.9	50	
803*	125	10	3.25	2000	600	30	15.5	0.15	28.5	5-pin J.	L	Class-C Amp. (Telephony)	2000	500	40	−30	160	42	16	36000	1.6	210	803
												Grid-Modulated Amp.	2000	600	40	−80	80	15	4	—	2	53	
												Suppressor-Modulated Amp.	2000	500	−135	−50	80	55	15	27000	1.6	53	
												Class-B Amp. (Telephony)	2000	600	40	−40	80	15	3	—	1.5	53	
861*	400	11.0	10.0	3500	600	35	17.0	0.1	13.0	Special	S	Class-C Amplifier	3500	600	—	−250	275	—	30	—	25	590	861

[1] Refer to Fig. 519.

[2] M.—medium, J.—jumbo.

* Especially suited to high-frequency use.

general use — triodes, screen-grid tetrodes, and screen-grid pentodes. Triodes are used as oscillators and as power amplifiers in special circuits, and certain types also are suitable for delivering considerable audio power for modulation purposes. Screen-grid tetrodes and screen-grid pentodes are used chiefly as power amplifiers, although also having special oscillator applications.

The characteristics and typical r.f. operating conditions of transmitting tubes suitable for amateur use are given in Tables VIII and IX. 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 are capable of better operation than others. Tubes especially designed for high-frequency use (3000 kc. and higher) are indicated.

Neon Bulbs

● Neon glow lamps, although not strictly radio tubes, are of such general utility around the amateur station that information on their characteristics should be of value. The accompanying table gives the important characteristics of General Electric neon bulbs.

The voltage required to start the lamps is given in column 4 in terms of voltage below the rating on the lamp. For example, the 3-watt lamp rated at 115 volts will glow with 115–50, or 65 volts a.c., or 115–10, or 105 volts d.c. applied. The ½-watt size is for a.c. only. All except the ¼-watt size fit into a regular lamp socket; the ¼-watt bulb has the same type of base as flashlight lamps.

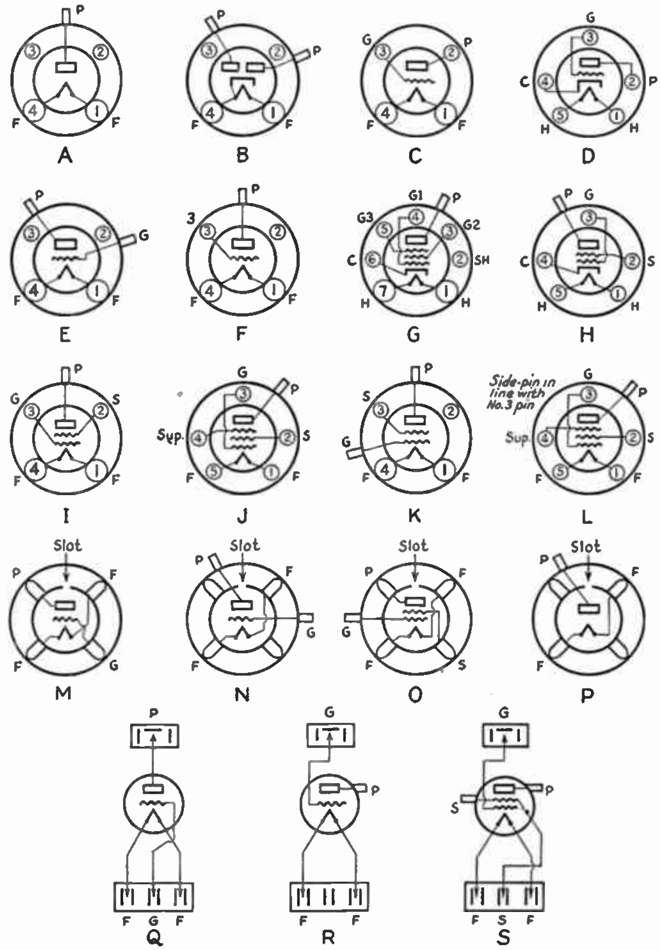


FIG. 519 — SOCKET CONNECTIONS FOR TRANSMITTING TUBES

Views are of tops of sockets. Legends have the same significance as in Figs. 517 and 518.

Watts	*App. Candle Power*	*Average Current, Amps.*	*Min. Operating Voltage — Volts below label A.C.*	*D.C.*	*App. Resistance in Base*	*Electrode Shape*
3	0.75	0.03	50	10	1900	Round plates
2	0.5	0.02	50	10	3200	Half-round plates
1	0.25	0.01	50	10	4800	Cyl. & Helix
½	0.05	0.005	10	..	3200	Cylinder
¼	....	0.002	50	10	27,500	Hemisphere

CHAPTER SIX

Receiver Circuit Design

PRINCIPLES OF REGENERATIVE AND SUPER-HETERODYNE TYPES

COMPLETE receiver circuits represent what might appear to be an infinite variety of types, and therefore are likely to be confusing when compared with each other. However, each is made up of combinations of elements which, taken by themselves, break down into a relatively small number of basic units. The purpose of this chapter is to describe the design features of these elemental units which can be combined in different arrangements to make up different types of receivers, and to show how related units work together. Complete combinations, with constructional details, will be given in the next following chapter.

Types of Receivers

Two types of receivers meeting the requirements of general amateur work are the simple regenerative receiver (autodyne), and the superheterodyne. Special types for ultra-high frequency work, the superregenerative and the super-infragenerator, are treated in Chapter Thirteen. In the regenerative receiver there is r.f. feedback in the detector circuit with the amount of this regeneration controllable to give either high amplification and selectivity without oscillation, or to give these together with oscillation to provide the heterodyne for beat-note c.w. reception, as has been explained in Chapter Five. The simplest form of receiver (Fig. 601-A) would be just one tube in a regenerative detector circuit, although the output available from such an arrangement is so small as to be generally unsatisfactory. A single stage of audio amplification following the detector gives more satisfactory results. A still further improvement is a stage of tuned radio-frequency amplification preceding the detector (Fig. 601-B). This increases sensitivity and gives somewhat greater selectivity, provides helpful isolation of the regenerative detector from the antenna circuit and allows sensitivity control ahead of the detector circuit.

Whereas the regenerative receiver's r.f. circuits handle the signal at incoming frequency, in the superheterodyne type receiver the incoming signal is converted to a lower radio frequency and then amplified in intermediate circuits prior to conversion to audio frequency in the second detector (Fig. 601-C). This method allows greater r.f. amplification and the attainment of higher selectivity, since both of these are more readily obtained in the intermediate-frequency (i.f.) amplifier. This applies particularly to the single-signal type superheterodyne, which obtains extremely high selectivity in the i.f. circuits either by means of a variable band-width quartz crystal filter or by controllable regeneration in an i.f. stage.

The regenerative and superheterodyne types are used almost exclusively on the lower-frequency amateur bands (1.75 through 30 mc.), but on the higher-frequency bands (56 mc. and upwards) the superregenerative and the newly developed super-infragenerator or S.I.G. (Figs. 601-D and 601-E) prevail. These types are described in detail in Chapter Thirteen.

The simple regenerative type receiver is less complicated than the superheterodyne, of course, and is accordingly less expensive. Until one has gained experience it is advisable to work with the simpler receiver, progressing later to the superheterodyne type.

Receiver Performance

● The three important general characteristics of a receiver are its selectivity, its sensitivity and its fidelity. These three 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 *fidelity* is the proportionate response through the audio-frequency range required for a given type of communication.

Sensitivity is fundamentally limited by the noise output, which in turn is directly related to the selectivity, being less as the selectivity is greater. Only signals that are detectable above the noise background are useful; therefore, reducing the noise output by increasing the selectivity improves the effective sensitivity in proportion. Sensitivity is thus not solely dependent on the amplification in the receiver but on the combination of amplification and selectivity. 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 band width (the "measuring stick" for selectivity) is but 20 cycles or less; for 'phone reception with usable intelligibility the band width must be proportionately greater, of course, although still considerably less than for 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.

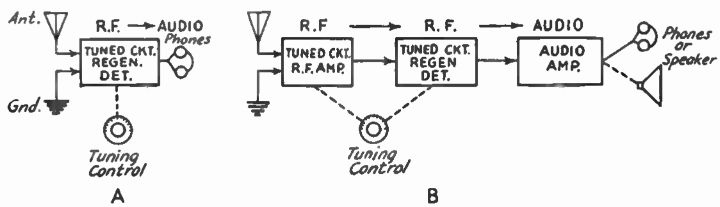
Tuning Systems

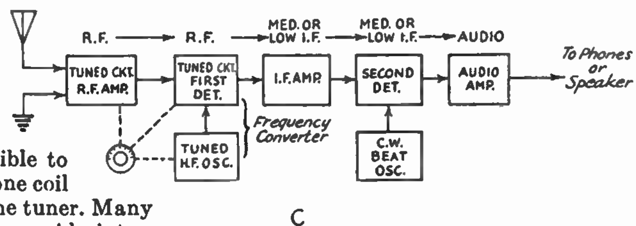
Since the amateur frequency-bands comprise narrow slices of territory widely separated, it is not possible to cover them all effectively with one coil and condenser combination in the tuner. Many schemes have been evolved to provide interchangeable coils. The use of a tube-base or a special form of larger size plugging into a tube socket is almost universal in amateur built receivers. Coils of this type are pictured later on with the constructional details of the receivers in which they are used. Larger coils with a horizontal row of plugs fitting into a similarly-arranged row of sockets are also used in some cases. The important requirements are that the coils should be readily interchangeable; the contacts should be positive; the coils should be mechanically strong so they will not be deformed in handling; and they should be small in diameter in order to avoid the existence of an extensive magnetic field around them.

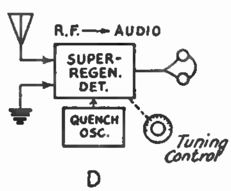
More complicated receivers, in which a number of tuned circuits must be changed for each range, also employ coil switching systems and plug-in "gangs" containing three or four coil units for each range. These units are hardly adaptable for amateur construction and are more economically purchased as tuning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

Band Spreading

● Tuning condensers used in high-frequency receivers are much smaller than those employed for the broadcast band and lower frequencies. A 350- or 250-$\mu\mu$fd. condenser will, at high frequencies, cover so wide a frequency range that tuning becomes extremely difficult. Many amateurs remove plates from standard-







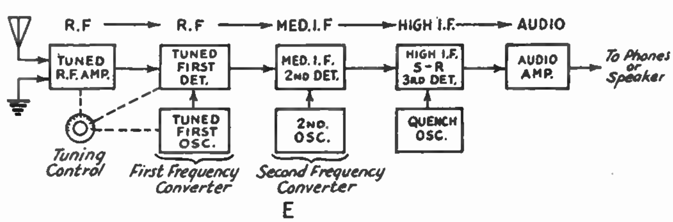


FIG. 601 — BLOCK DIAGRAMS SHOWING THE ESSENTIAL UNITS OF BASIC RECEIVER TYPES. A, SIMPLE REGENERATIVE; B, TUNED R.F. REGENERATIVE; C, SUPERHETERODYNE; D, SUPER-REGENERATIVE; E, SUPER-INFRAGENERATIVE. THE LAST TWO ARE ULTRA-HIGH FREQUENCY TYPES

sized condensers to reduce the maximum capacity, or else use midget condensers, which can be obtained in a variety of capacities. If the receiver is to cover all frequencies between 20,000 and 3000 kc., common practice is to use a tuning condenser rated at 150 μμfd. with three plug-in coils, but even this arrangement crowds the amateur bands in very small proportions of the dial scale. Most amateurs prefer to spread the bands over a large part of the dial.

The amateur bands are not entirely in harmonic relation, 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 widely used band-spreading schemes are shown in Fig. 602. At A is the parallel-condenser method. C_1 is the tuning condenser, usually with a maximum capacity of about 25 μμfd. C_2 is a "band-setting" condenser; its maximum capacity should be at least 100 μμfd. 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.

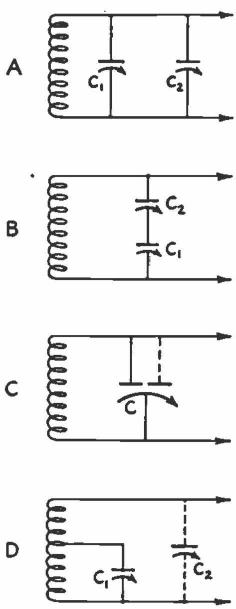


FIG. 602 — ESSENTIALS OF FOUR POPULAR BAND-SPREAD TUNING SYSTEMS

The series-condenser method is shown at B. As explained in Chapter Three, 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 μμfd. or more maximum capacity. C_2 is the band-setting condenser and is preferably small, perhaps 25 μμfd. 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 14- and 7-megacycle bands, and the second stator section, when connected in parallel with the small stator, will give good spread on 3500- and 1750-kc. The dotted connection for the two lower-frequency bands shown in C can be made by using a jumper in the low-frequency coil forms, the change being automatically made when the coils are plugged in.

The tapped-coil system at D is used in several manufactured amateur-band receivers and has also been adopted by a number of amateurs in home-built sets. Condenser C_1 may be fairly large — 100 μμfd. 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 not strictly necessary but will be found helpful in getting the spread just right, and its use will help eliminate some of the cut-and-try in winding the coils. It should have a maximum capacity of 25 to 100 μμfd.

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 the Appendix or by the *Lightning Radio Calculator* can be taken, provided the shielding is spaced from the coil by a distance equal to the coil diameter.

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 μμfd. 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. Typical values of constants for high-frequency and broadcast ranges are given in the table of Fig. 613 and in the descriptions of Chapter Seven. It is evident that full band-spread of each of the four bands with a single tuning capacitance range requires a relatively tremendous minimum capacitance on the 7- and 14-mc. bands. For this reason some compromise is usual in amateur-built receivers, the spread being somewhat less on the higher-frequency bands. Several manufactured receivers and tuner units, however, achieve nearly full spread on all bands without resort to excessively high minimum capacitance. One method combines the features of the Fig. 602-A and 602-B systems, using a trimmer condenser in parallel with the coil to raise the minimum capacitance, and another condenser in series with the main tuning condenser to restrict the maximum capacitance value to the proper value. A series condenser has relatively small effect on the minimum capacitance, since the minimum of the tuning condenser usually will be considerably smaller than the series capacitance. Therefore the reduction by the series method is principally effective at maximum of the tuning capacitance. Such series combinations are more widely used in superheterodyne tuning systems, as will be shown later.

Regeneration Control Methods

● In the regenerative receiver almost any one of a number of arrangements of the tickler coil and feed-back control in the detector circuit can be depended upon to give similarly loud signals, but some of them have the advantage of being more convenient and of permitting adjustment of regeneration without detuning the signal. It is also a great 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. 603 shows two ways in which regeneration may be controlled with a screen-grid detector. At A the regeneration control is a variable condenser having a maximum capacity of 100 or 150 μμfd. It acts as a variable by-pass between the low-potential end of the tickler coil and the cathode of the tube. If the by-pass capacity is too small the tube will not oscillate, while increasing the capacity will cause oscillations to start at a certain critical value of capacity. This method of regeneration control is very smooth in operation, causes relatively little detuning of the received signal and, since the voltage on the screen-grid of the tube is fixed, permits the detector to be worked at its most sensitive point. The sensitivity of a screen-grid detector depends a great deal upon maintaining the screen-grid voltage in the vicinity of 30 volts.

At B regeneration is controlled by varying the mutual conductance of the detector tube through varying its screen-grid voltage. The regeneration control is usually a voltage-divider — or so-called "potentiometer" — with a total resistance of 50,000 ohms or more. This circuit causes more detuning of the signal

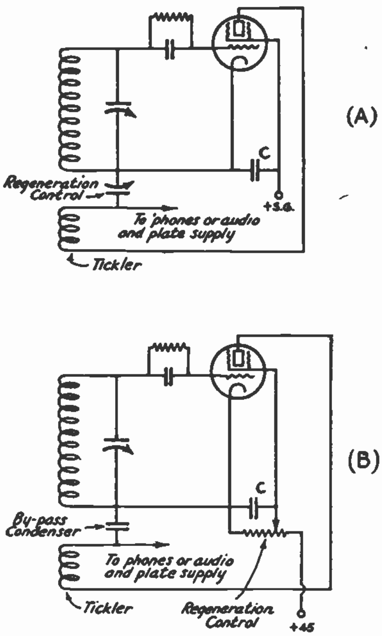


FIG. 603 — METHODS OF CONTROLLING REGENERATION

than A, and the resistor is likely to cause some noise unless by-passed by a large capacity (about 1 μfd.) at *C*. In A, condenser *C* may be .5 μfd. or larger. With circuit B it is necessary to adjust the number of turns on the tickler coil to make the tube just start oscillating with about 30 volts on the screen-grid if maximum sensitivity is desired.

Both the methods shown in Fig. 603 may be applied to three-electrode detectors, although these tubes have been largely superseded as detectors by the more sensitive screen-grid tubes. To use method B the regeneration-control resistor should be placed in series with the plate of the tube and it need not be used as a voltage-divider but simply as a series variable resistor. It can also be used as a series resistor when controlling a screen-grid tube. Another type of regeneration control, more suitable for lower radio frequencies, uses a variable resistance across the feed-back portion of the r.f. circuit.

In all methods it is essential that the tickler be mounted or wound at the filament 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.

Tuned Radio-Frequency Amplifiers

● A regenerative detector followed by a stage or two of audio-frequency amplification, when used for c.w. telegraphic work, will bring in amateur signals from all over the world on the higher frequencies. For such work, the sensitivity of this type of receiver usually proves to be ample. At times, however, a radio-frequency amplifier ahead of the detector is very desirable. The increase in sensitivity and selectivity provided by it can be put to good use in the reception of amateur radiotelephone signals. 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 and making it impossible for the antenna, swaying in a wind, to cause the received signal to waver. 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.

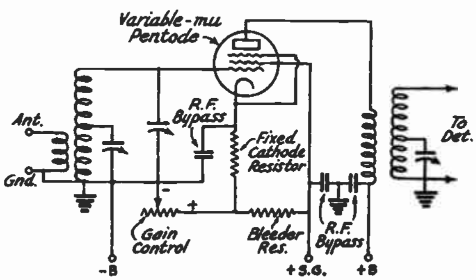


FIG. 604 — A TYPICAL RADIO-FREQUENCY AMPLIFIER CIRCUIT WITH BIAS GAIN CONTROL

It is suited to any of the variable-μ r.f. amplifier tubes such as the 58, 78, 6D6, 35, 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.

The three-element tube is almost useless as a radio-frequency amplifier in the short-wave receiver. The modern screen-grid tube, however, is most effective providing the circuit in which it is used is a suitable one. The circuit of a tuned r.f. stage is shown in Fig. 604. Examples of modern practice in such tuned amplifier stages are also shown in the receivers described in the next chapter. When the r.f. amplifier uses a screen-grid tube of the variable-mu type (such as the 58, 78, 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. 604. 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 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.

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 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 at least a distance equal to the coil diameter. For this reason small 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. Although an actual ground connection always will be best, it is sometimes sufficient to connect the shielding to a point in the receiver at zero r.f. potential, such as the negative side of the plate supply. Another point is that shields must be complete for each amplifier stage or group of apparatus shielded. Do not attempt to use a single sheet of metal to form a common wall for two shields as shown in Fig. 605; such a wall will actually couple the two shielded groups or pieces of apparatus together instead of shielding them from each other.

There are two general methods of shielding. One is to group all the apparatus forming a single stage of amplification and put it in a single shield. The three-tube receiver described in this chapter is an example of this type of shielding. The second method, exemplified by the different receivers described later, is to use individual shields around each piece of apparatus, connecting them by shielded leads where necessary. Only those leads which are not at zero r.f. potential need be shielded. Each method will give good results, and the choice is usually dictated by mechanical considerations.

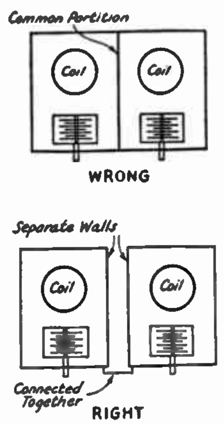


FIG. 605 — SHIELDING ALWAYS SHOULD BE COMPLETE ABOUT EACH PIECE OR GROUP OF APPARATUS SHIELDED

Do not attempt to use a common partition between shielded stages, especially when one of them contains a regenerative detector or oscillating circuit.

Although shielding is not necessary if no tuned r.f. amplifiers are used, it is often helpful. A metal cabinet about a simple receiver will prevent direct pick-up of signals by the coils

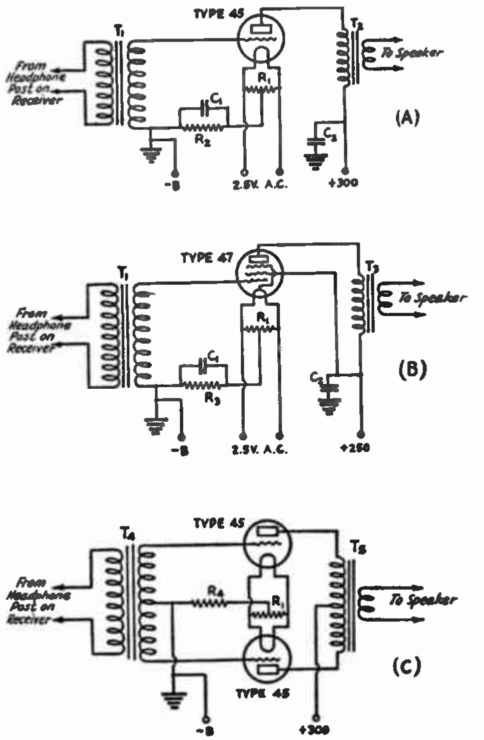


FIG. 606 — AUDIO POWER AMPLIFIERS FOR LOUD-SPEAKER OPERATION

A — using a single Type 45 tube, B — a single 47 pentode. C — two 45's in push-pull. Transformer T_1 is an ordinary audio transformer having a turns ratio of 2:1 or 3:1. T_2 is an output transformer designed to couple a 45 tube to the loud-speaker being used. T_3 is for coupling a 47 to the speaker. T_4 is a push-pull input transformer and T_5 a push-pull output transformer for a pair of 45's. It is necessary to know the impedance of the loud-speaker in order to purchase the right type of output transformer in all three cases. R_1 is a 20-ohm resistor, tapped at the center. R_2 is 1500 ohms, rated to carry approximately 50 ma. R_3 is 450 ohms, also to carry about 50 ma. R_4 is 750 ohms, rated at 75 ma. or more. Both C_1 and C_2 should be 1 to 2 μfd. C_3, which must be rated to stand the full plate supply voltage, may not be needed if the plate voltage for the amplifier comes directly from a filter condenser in the power pack.

and wiring of the set, and it will also keep out "induction hums" from unshielded house wiring.

Audio-Frequency Amplifiers — Volume Control

● A power audio stage can be added to the receiver intended for headphone output where it is desired to operate a loud speaker. Alternatively, a power stage of sufficient power sensitivity can be substituted for the usual low-output amplifier following the detector. Several power amplifier combinations capable of a watt or more output are shown in Figs. 606 and 607, including triodes as single-ended and push-pull amplifiers, and pentodes of two types. The latter have the greater power sensitivity (require less grid excitation for equal output) and are suited to connection to the detector output of the usual receiver. The circuit shown in Fig. 607 is popularly used in amateur receivers. An audio-frequency volume level control is advisable. This volume control is arranged as shown in Fig. 607, being a variable voltage divider resistor or potentiometer connected across the secondary of the input transformer so that the audio voltage applied to the grid-cathode circuit of the tube can be varied from maximum to zero.

Fixed Condensers and Resistors

● In addition to the principal receiver circuit elements — coils, variable condensers, gain- or

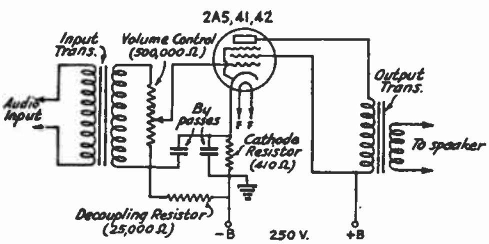


FIG. 607 — A TYPICAL PENTODE POWER AMPLIFIER CIRCUIT WITH VOLUME CONTROL

This circuit can be used with any of the indirectly heated cathode pentodes The use of a decoupling circuit to prevent "degenerative" effects or loss of amplification at the lower audio frequencies, also is illustrated.

volume-control resistors, tubes, etc. — there are also certain fixed condensers and resistors that are important. 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. Since the reactance of a condenser is inversely proportional to its capacity and to the frequency, radio-frequency coupling and by-pass condensers are of small capacity while those for audio frequencies are of relatively large capacity. Small mica or non-inductive paper-dielectric condensers of from 100 μμfd. to 0.01 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, while not especially critical as to value, 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. for paper condensers to 8 or 10 μfd. for electrolytic types. The latter should be used only as by-passes in circuits carrying audio frequency superimposed on d.c., as in cathode circuits. A fair value for most audio applications in amateur receivers is 1 μfd., although larger values may be used where better response to lower audio frequencies is desired.

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 receivers described in this chapter being typical. Decoupling resistor and condenser combinations, used principally in grid return circuits, are connected as shown in Fig. 607. They are not critical as to value, 25,000 ohms or higher being satisfactory for the resistor and usual by-pass capacity serving for the condenser in most instances. Usually such circuits are necessary only in high-gain amplifiers of two or more stages.

Superheterodyne Receivers

As has been mentioned previously, 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 (usually of from 450 to 500 kc. in high-frequency superhets) and is then amplified at the intermediate frequency prior to audio-frequency detection.

Tracing the operation through the circuit, following r.f. amplification the frequency conversion is accomplished by a heterodyne process; that is, the incoming signal and the output of the h.f. heterodyne oscillator are simultaneously detected in the mixer (first detector) whose output circuit is tuned to the intermediate frequency. The output product selected is the beat between the incoming signal and local oscillator voltages and is therefore of a frequency equal to the difference between the signal and oscillator frequencies. Whatever modulation (speech or code keying) there may be on the incoming signal wave is identically reproduced in the i.f. beat output of the first detector. Consequently, the i.f. circuits and second detector behave with respect to the i.f. signal exactly as a conventional tuned r.f. amplifier and detector circuit receiving a signal of the frequency to which the circuits are tuned. For c.w. telegraph reception, the i.f. heterodyne oscillator is used to beat with the i.f. signal, as described in Chapter Four. The second detector output is then amplified in the audio stage.

Single-Signal Selectivity

● In ordinary beat-note reception, with either a regenerative autodyne or the usual superhet receiver, identically the same beat note can be obtained with a signal beat-frequency above the local oscillator frequency as with another beat-frequency below the local oscillator frequency. For instance, if the beat note on a desired signal is 1000 cycles (with the oscillator 1 kc. higher than the signal frequency), another signal 2 kc. higher 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. 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 to the conventional tuned i.f. circuits a first intermediate circuit in which extremely high selectivity is obtained either by means of a piezo-electric filter (quartz crystal) or by regeneration.

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, of course. 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.

Frequency Converter Circuits

● The frequency converter is the heart of the superhet receiver and on its operation depends

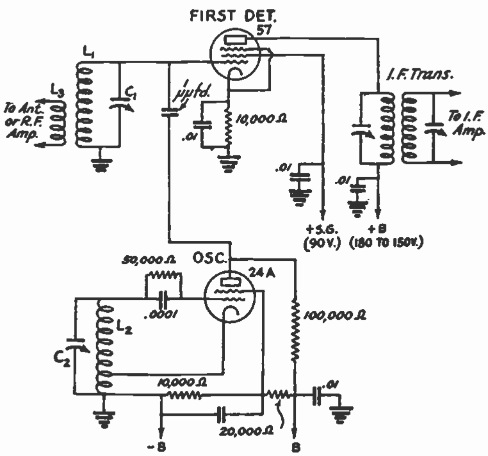


FIG. 608 — SUPERHET CONVERTER CIRCUIT USING AN ELECTRON-COUPLED OSCILLATOR AND CONTROL-GRID INJECTION

largely the performance of the whole set. Since the intermediate-frequency value adopted for short-wave supers represents a considerable difference between the signal and local oscillator frequencies, it is not feasible to use a simple autodyne detector having one tuned circuit as in the autodyne regenerative receivers used for beat-note c.w. reception. Separate circuits must be used, that of the first detector input being tuned to the signal frequency and that of the oscillator being tuned higher or lower by an amount equal to the intermediate frequency. Because of circuit convenience and other factors, it is general practice to have the oscillator tuning intermediate frequency higher than the first detector input circuit.

With the two tuned circuits, oscillator and first detector, two separate tubes may be used; or there may be a single tube designed to provide separate sets of elements for oscillator and detector circuits. Arrangements of both types are shown in Figs. 608, 609, 610, 611 and 612. These figures show standard types of oscillator-detector arrangements. In the grid injection system of Fig. 608, the signal input circuit L_1C_1 is tuned to the incoming signal and the oscillator circuit L_2C_2 is tuned intermediate-frequency higher. The oscillator is of the electron-coupled type, its output being coupled to the control grid of the first detector through a small capacitance. The 100,000-ohm plate load resistor of the oscillator may be replaced by a high-frequency r.f. choke in some instances, the operation being equivalent. The essential feature of this arrangement is that both the signal and oscillator voltages are impressed on the same grid. 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 impressed on the grid does not exceed the grid bias and run the grid positive.* Since the i.f. voltage produced is the product of the signal and oscillator voltages, it is desirable to make the oscillator voltage as high as possible without exceeding this limitation. In practice, with the circuits tuning over a number of bands and therefore likely to give wide fluctuations in oscillator output, oscillator r.f. voltage is made considerably less than the maximum limit.

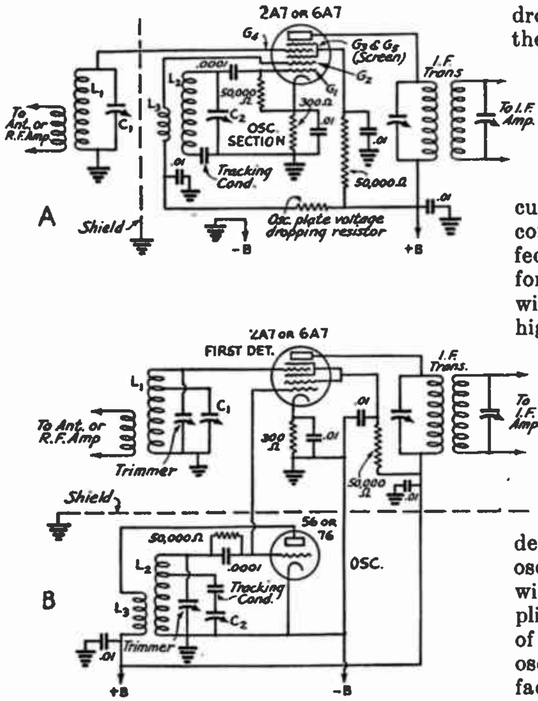


FIG. 609 — THESE FREQUENCY-CONVERTER CIRCUITS ARE FOR USE WITH PENTAGRID TUBES

The circuit at A shows how the tube is used as a combined detector-oscillator. A better arrangement for high-frequency work, making use of a separate oscillator with the pentagrid tube as detector or "mixer," is shown at B.

The circuits of Fig. 609 are considerably less critical in this respect, since the signal and oscillator voltages are applied to separate grids. The circuit at 609-A uses a combined detector-oscillator tube having internal electron coupling between the two sets of elements, such a tube being known as a pentagrid converter. Quite high conversion efficiency can be obtained as well as good input selectivity. The tube is not a particularly desirable one for high-frequency work when used in this way, however, 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," or the tendency of the detector tuning to affect the oscillator frequency. An arrangement which overcomes these defects to a considerable extent is shown at Fig. 609-B. In this circuit the oscillator grid (No. 1) of the pentagrid converter is used as the mixing element, but is fed from a separate oscillator. The better performance of the 56 or 76 tubes as contrasted with the oscillator section of the 2A7 or 6A7 at high frequencies results in more uniform output over the high-frequency range. In the circuits of Fig. 609 the oscillator voltage is not critical, so long as enough is supplied, and the grid-current limitation of the circuit of Fig. 608 is absent.

A third type of first-detector-oscillator coupling is given in Fig. 610. In these diagrams the suppressor grid of a pentode-type detector is used as the means for introducing the oscillator voltage into the detector circuit to beat with the incoming signal. Suppressor-grid coupling offers the same advantages as the circuit of Fig. 609-B, but usually will require a greater oscillator voltage because of the lesser control factor of the suppressor grid as compared to the inner grid of a pentagrid converter tube. The oscillator voltage is not critical, however, and does not affect the input selectivity of the detector. Since the suppressor must be maintained at an average voltage considerably negative with respect to the cathode, the plate impedance of the first detector is reduced. This tends to lower the gain out of the first detector, compared to the gain the same tube would give with its suppressor maintained at cathode potential as is usual in amplifier applications. The suppressor must have negative bias, it should be emphasized, since otherwise the oscillator would be ineffectual in modulating the first-detector space current.

A circuit which utilizes screen-grid injection in the first detector, with a separate oscillator, is shown in Fig. 611. This arrangement requires somewhat more power from the oscillator, since the screen-grid circuit of the detector has a relatively low resistance compared to the grids used in other methods. The oscillator voltage swing required is also considerable. However, it permits the use of a pentode type first detector and operates with a higher plate impedance than a pentode with suppressor injection. The latter feature tends to keep up the gain at intermediate frequency, where a high-impedance transformer circuit is the detector load. Proper proportioning of the oscillator circuit and coupling to the detector screen provide uniform voltage injection over wide frequency ranges with this system, although considerable care in circuit design is advisable.

Circuits using the 6L7 mixer tube as the first detector are shown in Fig. 612. This metal type has features which correct the several minor deficiencies encountered in conversion circuits of the other types. The space-charge coupling between detector input and oscillator circuits

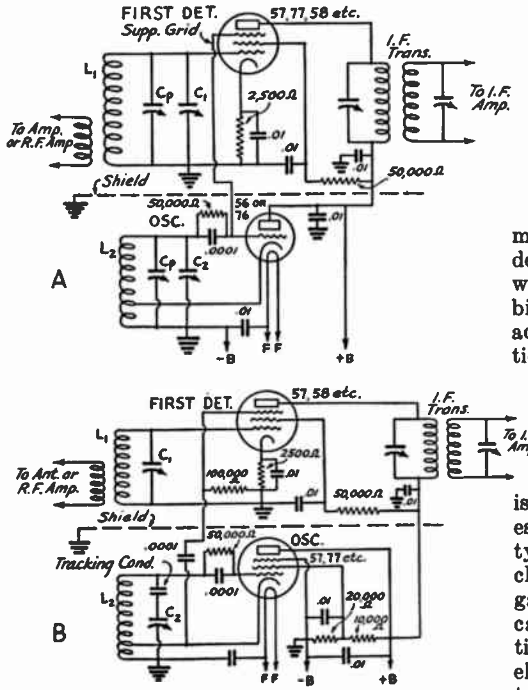


FIG. 610 — CONVERTER CIRCUITS EMPLOYING SUPPRESSOR-GRID INJECTION

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. Also, a smaller oscillator voltage is required for complete modulation than with suppressor injection, while the power demand

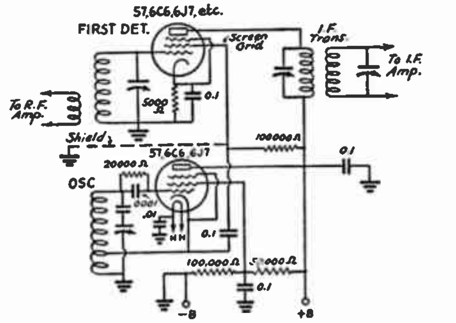


FIG. 611 — CONVERTER CIRCUIT FOR SCREEN-GRID INJECTION

is negligible as compared to screen-grid injection. The value of oscillator voltage can vary over a considerable range without affecting the conversion gain, which tolerance is advantageous in multi-band tuning systems. Either the circuit coupling method of Fig. 162-A or that of 612-B may be used. The latter is usually more adaptable with band-switch tuning systems using standard units, since the additional tube capacitance of the mixer can be made less effective in raising the minimum capacitance of the oscillator circuit. In the first circuit the No. 3 oscillator grid of the mixer is automatically biased by the voltage developed across the oscillator's grid leak, while in the second circuit the No. 3 grid is biased by the rectified voltage developed across its own leak, the bias being proportional to the oscillator voltage in both cases.

Oscillator Stability and Tracking

● In addition to the "pulling" effects previously emphasized, inherent stability in the high-frequency oscillator of the converter is highly important in amateur-band receivers, especially in high-selectivity single-signal types. Variations in oscillator frequency with changes in supply voltage, as may occur when gain adjustment varies the plate voltage because of power supply regulation, are of particular importance. It is for this reason that electron-coupled oscillator circuits, and other types using screen-grid tubes, are generally used. 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 voltage divider in which neon tubes are used to maintain a nearly constant drop.

In all these circuits it is essential that the oscillator be completely shielded from the detector. 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 for purposes of illustration; in many cases one oscillator circuit can be substituted for another without affecting the functioning of the detector or mixing circuit, since the two are generally entirely separate except for the coupling by which the oscillator voltage is introduced into the detector circuit.

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, by simply making the oscillator inductance sufficiently smaller than the signal-frequency circuit inductance. For more precise tracking over the tuning ranges, especially at the lower

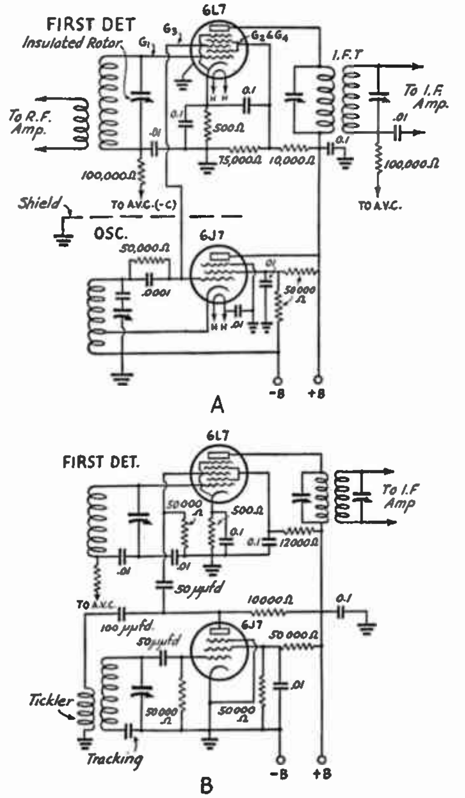


FIG. 612 — CONVERTER CIRCUITS FOR THE 6L7 METAL TUBE

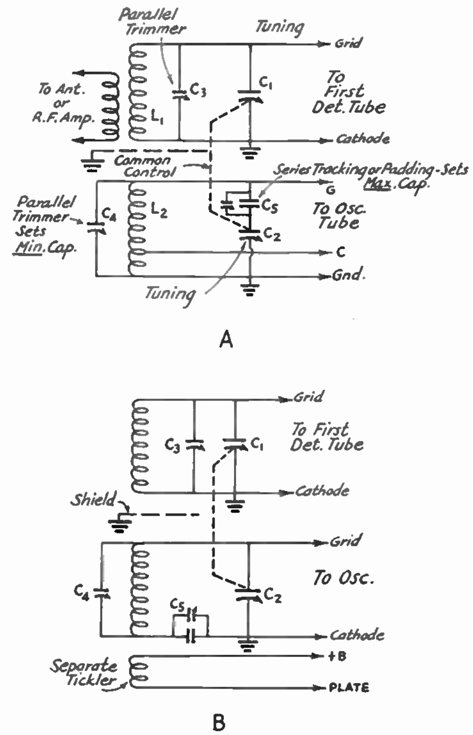


FIG. 613 — CONVERTER CIRCUIT TRACKING METHODS

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 μμfd. and the total minimum capacitance, including C_3 or C_4, being 30 to 35 μμfd.

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 μμfd. maximum, minimum capacitance including C_3 and C_4 being 40 to 50 μμfd.

Tuning Range	L_1	L_2	C_5
1.5–4 mc.	32 μh.	25 μh.	0.00115 μfd.
4–10 mc.	4.5 μh.	4 μh.	0.0023 μfd.
10–25 mc.	0.8 μh.	0.75 μh.	None used
0.5–1.5 mc.	240 μh.	130 μh.	425 μμfd.

frequencies, a tracking capacitance in series with the oscillator tuning condenser is used to maintain this difference more uniformly. Two typical arrangments are shown in Fig. 613. 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 exactly 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 of the tuning range. 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.

Pre-Selection and Image Suppression

● A peculiarity of heterodyne action is that one of the two voltages which are combined may be either higher or lower than the other (by the proper frequency difference) and still give the same beat-frequency product. In the superheterodyne converter with the oscillator tuning intermediate-frequency higher than the signal circuit, there is possibility of first detector i.f. output from a signal intermediate-frequency higher than the oscillator frequency, as well as from the desired signal which is intermediate-frequency lower than the oscillator frequency. This will occur if there is insufficient selectivity ahead of the first detector to prevent signals twice intermediate-frequency removed from the desired signal 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 described as its *image ratio;* that is, the ratio of image-frequency signal voltage input to desired-frequency signal voltage required to give the same receiver output.

Using the conventional 456- or 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., considerably greater input selectivity is required. 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 kc. and 150 at 7 mc., to only 50 at 14 mc. The apparent ratios can be made higher by introducing regeneration in the pre-selecting circuits, which has the effect of raising the circuit gain at resonance for the desired signal. One simple way to introduce this "negative resistance" effect is to connect a separate regenerative circuit in parallel with the superhet's input circuit, as by 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 feedback arrangements shown for simple regenerative detectors, with control of the screen voltage for adjustment. Regeneration tends to make the gain non-uniform over wide frequency ranges, however, and demands constant readjustment with tuning. Commercial practice is

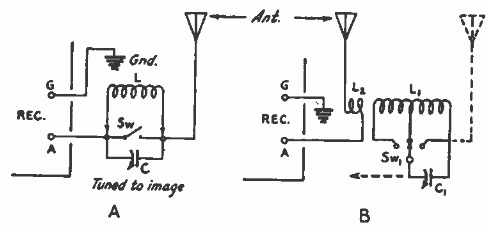


FIG. 614 — CIRCUITS FOR TWO TYPES OF WAVE-TRAP IMAGE REJECTORS

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.

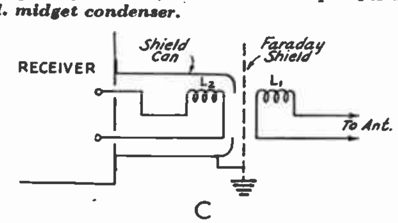


FIG. 614-C — A SUGGESTED ARRANGEMENT FOR BALANCED INPUT COUPLING WITH A FARADAY SHIELD TO MINIMIZE CAPACITY EFFECTS

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.

to avoid regeneration and depend on additional tuned circuits for image suppression, two r.f. stages being used in several types.

One simple and inexpensive method of suppressing images that is fairly effective and entirely practical is a wavetrap placed in the antenna circuit, introducing high impedance right at the unwanted (image) frequency. It is easy to install, as shown in Fig. 614-A and -B. For the usual i.f. of approximately 500 kc. the images are about 1000 kc. higher than the desired-signal frequency. Thus a trap circuit resonating 1000 kc. above the signal frequency can be used, introducing only low values of impedance at the amateur-band frequency.

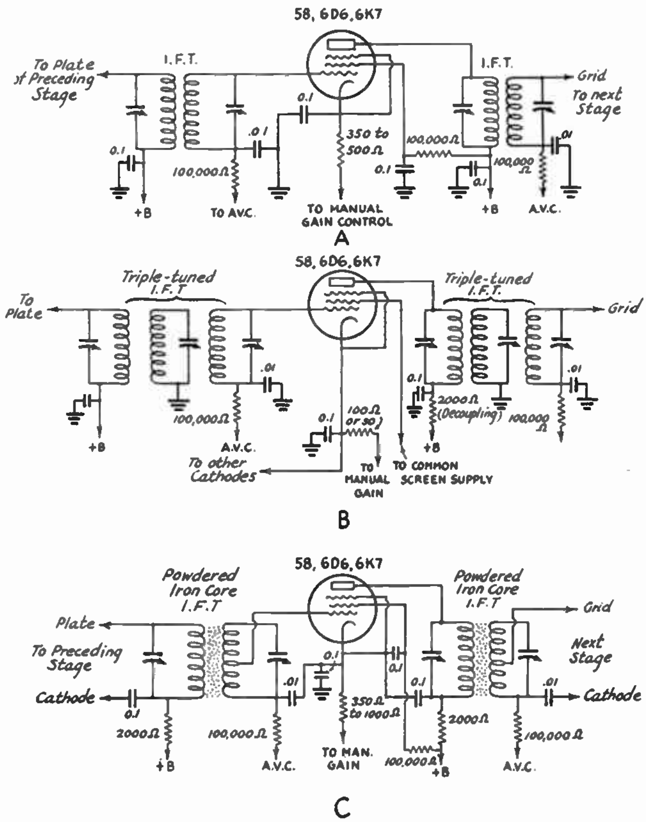


FIG. 615 — I.F. AMPLIFIER CIRCUITS FOR THREE TYPES OF TRANSFORMERS. A, DOUBLE TUNED; B, TRIPLE-TUNED; C, HIGH-GAIN IRON-CORE

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 supression 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 use of an electrostatic screen between the two coils, as shown in Fig. 614-C. This arrangement also provides a balanced termination for the two-wire type transmission line now generally used with high-frequency receivers. 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 length-wise 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 radio-frequency amplifier is also effective in improving the signal-to-noise ratio of the receiver, although some compromise is necessary in reconciling the two considerations of image suppression and sensitivity. 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, this noise being partly due to small voltages resulting from thermal agitation in the tuned circuit and from electronic variations in the first tube ("shot effect," principally). These noise voltages are distributed throughout the frequency spectrum, and hence are converted and amplified by succeeding circuits along with the signal. It is therefore important to make the signal voltage in the first tuned circuit as large as possible, to compete with the thermal agitation voltages; 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. A radio-frequency amplifier has more effective gain than a first detector, as a general rule, which makes the r.f. pre-selector stage advantageous in overcoming tube noise. Thermal agitation noise is greater at the lower frequencies, where the tuned-circuit impedance is higher, and falls off at the higher frequencies. The tendency, therefore, is for tube noise to predominate over thermal agitation noise in our high-frequency receivers.

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. for short-wave superhets. The tuned circuits of i.f. amplifiers usually are built up as transformers, consisting of a shielding containor in which the coils and condensers are mounted. The coils are of the universal-wound or honeycomb 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.

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. 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 will give all the gain usable, considering the noise level, so that additional stages would have no particular advantage. If regeneration is introduced into the i.f. amplifier — as is done in the receiver to be 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. 615. Alternative methods of gain-control biasing, by-passing and decoupling are indicated. The method of returning all by-passes to the cathode 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.

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. Two types of such transformers are illustrated in Fig. 616, one being a Hammarlund air-core model with multi-section primary and secondary windings, and the other a Sickles powdered-iron core model. The coupling is usually adjusted over a range from slight over-coupling to relatively loose coupling, giving a selectivity curve that varies from double-humped to very sharp. The bandwidth variation obtainable is approximately 7-to-1.

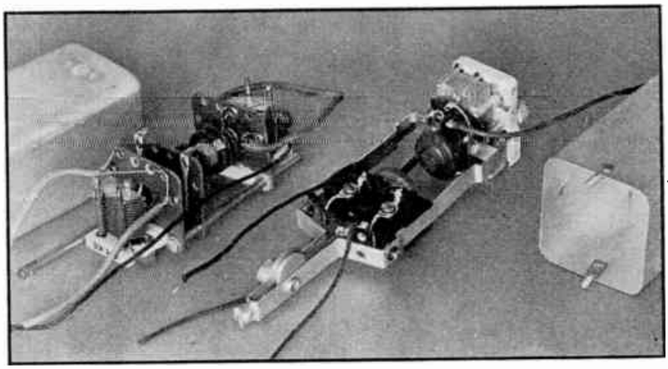


FIG. 616 — TYPES OF VARIABLE-SELECTIVITY I.F. TRANSFORMERS HAVING MECHANICALLY ADJUSTABLE COUPLING

Quartz Crystal I.F. Filters

● As has been mentioned previously, high i.f. selectivity can be obtained by the use of a quartz crystal filter and such filters are used in a number of s.s. receivers, some of commercial manufacture. When connected in a suitable series circuit, a quartz crystal having a resonant frequency corresponding to the receiver's intermediate frequency is capable of several hundred times the selectivity obtainable in the usual transformer-coupled i.f. amplifier. The selectivity obtainable is, in fact, considerably greater than is practicable for some types of communication, especially 'phone, unless means for modifying it are provided. Such provision is made in the variable-selectivity filter circuits of Fig. 617-A and -B.

The resistive component of the variable parallel impedance of the input transformer secondary in series with the crystal (which is equivalent to a high-Q electrical circuit) effects variation in the effective resistance in the crystal series circuit, thereby varying the selectivity in accordance with the principles of resonant circuits discussed in Chapter Four. The applied voltage in the crystal circuit is proportional to the parallel impedance, increasing as the effective resistance increases, so that the gain of the receiver for a single-frequency signal is but little affected over a selectivity (band-width) range of approximately 10 to 1. Minimum selectivity occurs with the parallel circuit turned to resonance, when it is purely resistive, and maximum selectivity when the parallel circuit is tuned to be considerably reactive.

The crystal is connected in a bridge circuit

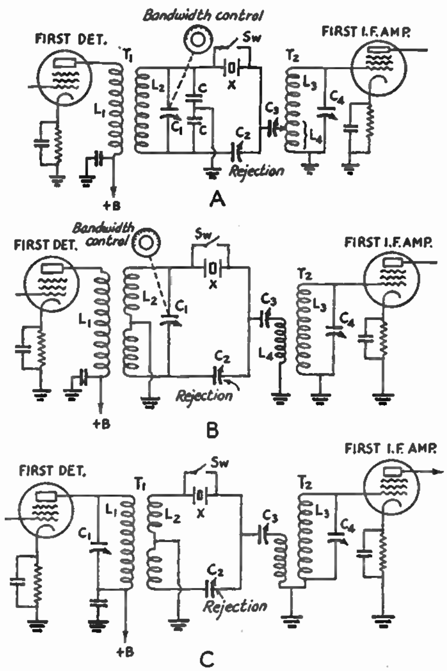


FIG. 617 — VARIABLE BAND-WIDTH CRYSTAL FILTER CIRCUITS ARE SHOWN IN A AND B, WHILE C IS THE CIRCUIT OF A FIXED BAND-WIDTH TYPE

to provide counter voltage of controllable phase, through an adjustable condenser, so as to modify the resonance curve by shifting the anti-resonant frequency of the crystal as shown in Fig. 618, thus giving particular rejection for an unwanted signal (of a frequency from several kilocycles above to several kilocycles below the crystal's resonant frequency), in addition to the sharply peaked response given for the desired signal.

The output transformer of the filter consists of the tuned secondary circuit L_3C_4 closely coupled to the primary L_4, which has but a fraction of the turns on L_3. The purpose of this is to provide an impedance transformation suitable to match the crystal impedance to high impedance in the grid circuit of the following amplifier and thus improve the efficiency of the filter.

The circuit of Fig. 617-C operates in similar fashion so far as the rejection action is concerned, but has a fixed band width determined by the constants of the crystal series circuit. A variable impedance in the crystal network is not provided.

Second Detectors and Beat Oscillators

● The second detector of a superhet receiver performs the same function as the detector in the simpler 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 in the detector itself. Grid-leak and plate detection are used to some extent, but the diode detector is by far 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 operation, 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. Practical circuits which are preferred are shown in the receivers described in the next chapter.

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 to the i.f. frequency. The oscillator may be coupled to the second detector in any one of a number of ways, several of which are also shown in the receivers described in Chapter Seven. 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 for good beat-note strength.

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. This is readily accomplished in the modern type superheterodyne by using the average rectified voltage developed by the received signal across a resistance in a detector circuit to vary the bias on the r.f. and i.f. amplifier tubes. This voltage being 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

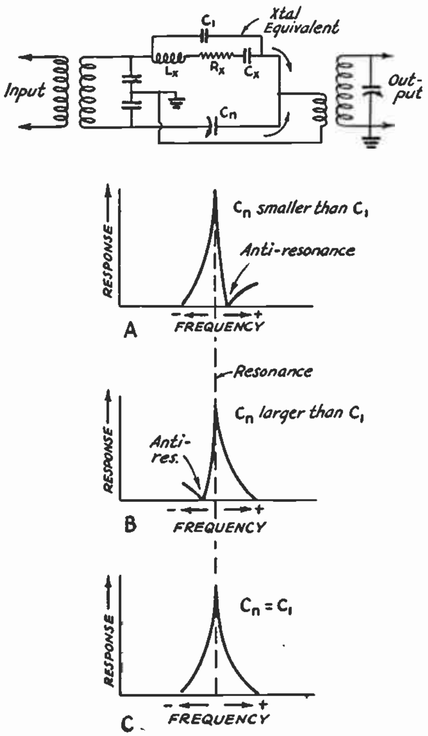


FIG. 618 — THE REJECTION ACTION OF THE CRYSTAL FILTER CIRCUIT

number of stages to which the a.v.c. bias is applied is greater. It is hardly feasible to attempt to use a.v.c. on less than two stages, because the gain regulating action "can't keep up with the signal level," and control of at least three stages is preferable. Even then there is some tendency for the signal level to keep ahead of the control, since the control voltage is derived from the detector input signal and is, in effect, working against itself. This can be overcome by using a separate amplifier stage and a separate rectifier for the a.v.c. voltage, the a.v.c. amplifier being operated at full gain while the amplifier feeding the detector is controlled. An arrangement of this kind is shown in the 12-tube receiver described in the next chapter. The separate a.v.c. rectifier is also advantageous in c.w. telegraph reception, when the beat oscillator is on. With a.v.c. derived from the audio detector the rectified voltage from the beat oscillator input will be quite large, and therefore will act as a very strong constant signal in reducing the gain. With the separate a.v.c. rectifier circuit, however, the oscillator voltage will not affect the control action, since the oscillator is coupled to the audio detector and not to the a.v.c. unit. This permits the use of a.v.c. for both c.w. and 'phone reception, and allows the beat oscillator to be switched on for beat-note checking on a 'phone carrier without disturbing the a.v.c. action. The separate a.v.c. circuit also allows adjustment of the bias in the rectifier circuit to give any degree of limit on initial action which may be desired, as also shown in the 12-tube receiver of the next chapter.

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 relatively small time constant is preferable, as compared to general practice in broadcast-band receivers. Capacitance and resistance values given for the superhet receivers described in the following chapter are generally satisfactory. The time constant can be estimated from total resistance effective in the a.v.c. circuit (including the rectifier load resistance and the grid-feed filtering resistors) and the total capacitance to ground (including the grid-return bypasses of the respective controlled stages). These resistance and capacitance values should be substituted in the time-constant equation given in Chapter Three. A value of a few hundredths of a second is usual.

CHAPTER SEVEN

Receiver Construction

BUILDING, OPERATING AND SERVICING MODERN TYPES

Having examined the fundamentals of receiver design, we are now ready to consider the construction of representative receivers of the various types now in general use. The construction and operation of a number of representative high-performance designs is described in this chapter, beginning with the simpler types and continuing through advanced superheterodyne models. Most of the parts used in the simpler receivers can be adapted later to use in the more intricate sets; thus it is possible for the neophyte to pick out a simple and inexpensive design for his initial attempt, one which he will find relatively easy to get working, at the same time realizing that the investment for the equipment in it will not be wasted. Although it is probable that the simpler outfits will not be retained as permanent receivers in the finished amateur station, all of the sets described in this chapter are thoroughly practicable, capable of giving excellent service in regular amateur operation if carefully built and correctly operated.

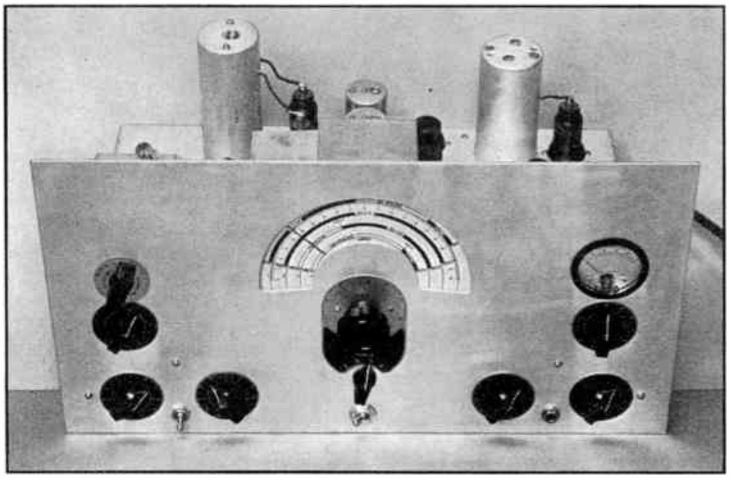


FIG. 701 — A TWELVE-TUBE SINGLE-SIGNAL SUPERHETERODYNE RECEIVER OF ADVANCED DESIGN

A complete description of this metal-tube receiver is contained in this chapter.

Tools

● While it is possible to put a set together with the aid of only the proverbial jackknife, a few good tools of the proper sort will be found invaluable in saving time and helping to make a good job mechanically. The following list is typical of the tools which most amateurs consider adequate:

Soldering iron (preferably electric)
Large and small side-cutting pliers
Large and small screwdrivers
Hand drill stock with a few drills of different sizes (Nos. 11, 18 and 28 will be most useful)
File (not too large)
Knife (Boy-Scout kind)
Hammer
Vise (the small 4″ size will do)
Steel rule (6″ or 12″)

With these tools it is possible to construct practically any of the apparatus ordinarily built at home. Others will be found useful at times, however. A small tap-holder, a die-holder and three or four taps and dies covering the 6-32, 8-32 and 10-32 sizes can be obtained from a hardware store at reasonable cost. With the dies you can thread brass rod and run over threads that become "bunged-up" on machine screws. With the taps you can thread the holes you drill so that they will take machine screws to hold the apparatus you wish to mount. A hacksaw, reamer, center-punch, scriber, tweezers, square and some other inexpensive tools are also desirable but not entirely necessary.

In building equipment for experimental

purposes and for temporary use it is just as desirable to use system in laying out the apparatus and in wiring up as when the more permanent panel job is built. Some square "breadboards," a bunch of General Radio plugs and jacks, Fahnestock clips, some scrap bakelite pieces for building terminal boards, angles for supports and an assortment of different sized brass machine screws, wood screws, nuts, and washers will make it easy to build up and try out new circuits. It is a good idea to keep some hook-up wire on hand, and various sized spools of magnet wire will prove useful in doing temporary wiring if you are an experimenter.

A metal chassis is preferable for permanent equipment, both for mechanical rigidity and electrical shielding. Bases can be formed from aluminum sheet, such material of approximately 1/16-inch to 3/16-inch thickness being easily worked in the home workshop. Alternatively, standard bases of "Electroloy," cadmium plated steel, "radio metal," etc., can be purchased in a variety of dimensions to fit almost any design. Panels of various metal compositions also can be obtained cut to suitable dimensions. With these economical foundation units, much of the tedious work of construction is escaped.

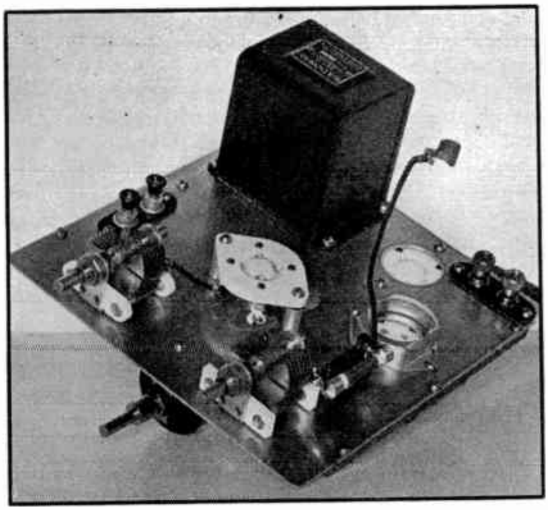


FIG. 703—THE "CHASSIS" OF THE TWO-TUBE RECEIVER

All parts are mounted on the square sheet-aluminum base. The location of the components is described in the text.

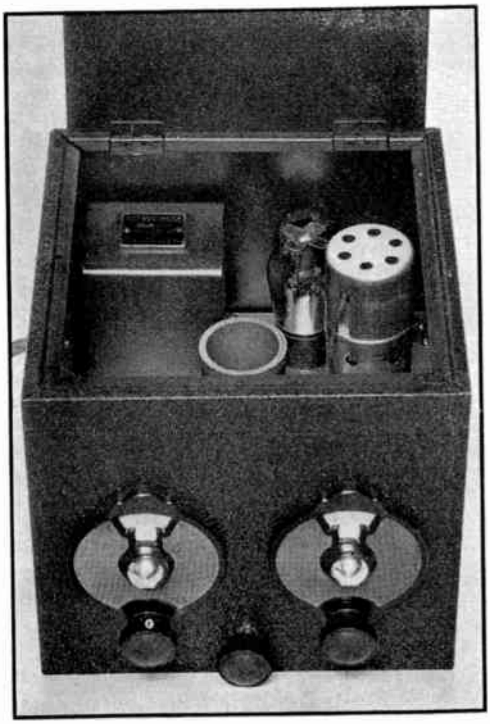


FIG. 702—THIS TWO-TUBE RECEIVER HAS A CONTINUOUS FREQUENCY RANGE OF 1450 TO 41,000 KILOCYCLES AND GIVES COMPLETE BAND-SPREAD ON FIVE AMATEUR BANDS

It can be used with either 2.5- or 6.3-volt tubes without change in the wiring. The right-hand dial gives general coverage and the left gives bandspread.

A table of drill sizes giving the proper numbered drill to use for passing a screw through a panel or for tapping to take a certain size of machine screw is included in the Appendix. Only the sizes most used in radio constructional work are given.

Soldering and Wiring

● In wiring different pieces of apparatus a neatly soldered job will repay the builder in good appearance and reliable operation. Good connections may be made without solder, but a well-soldered joint has low contact resistance.

Making good soldered joints is a quite simple matter. A few points should be kept in mind for best results. A hot well-tinned soldering iron, clean, bright surfaces, and a *small* amount of rosin-core solder will do the trick. Tinning the parts to be soldered before completing a joint will be helpful.

Soldering flux keeps the clean surface from becoming oxidized when heat is applied. Acid fluxes or soldering pastes are especially to be avoided. They are good for mending tin pans and gutter pipes but cause corrosion of electrical connections. The melted "paste" can cause a set to operate poorly or to become inoperative by adding leakage paths across coils and condensers. Use lump or powdered rosin that can be obtained for a dime from any drug store, or buy "rosin-core" solder.

"Tinning" the soldering iron is done by filing the point bright and clean and rubbing it in hot solder with a little flux until the point is covered with clean solder. Scrape connections with a knife or file before soldering, to save time and make a joint good electrically and mechanically. The soldering iron must be re-tinned occasionally if it becomes overheated. It should always be used when very hot, but not allowed to become red hot. A hot iron makes soldering easy.

Solder should not be carried to the work on the tip of the iron when using rosin-core solder; the prolonged heat of the iron ruins the flux, and an improperly soldered joint often results. Instead, the parts should first be tinned, then connected together to provide an adequate mechanical joint, and finally heated by the iron until the parts are hot enough to melt the solder and cause liquid solder to flow around the joint. Only in this way can permanent, uniform, resistance-free soldered connections be made.

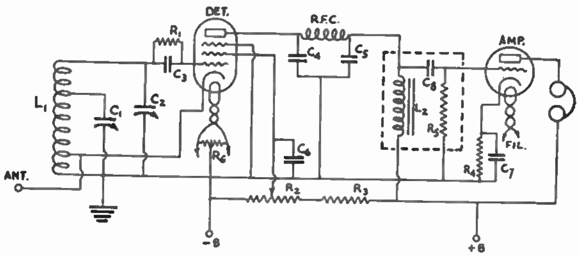


FIG. 704 — CIRCUIT DIAGRAM OF THE TWO-TUBE RECEIVER

For 2.5-volt a.c. filament operation, the 57 and 58 are recommended as detectors and the 56 as the audio amplifier. For storage battery operation suitable detectors are the 77, 78, 6C6, 6D6 and 6J7; audio amplifier, 76, 37 or 6C5. These tubes also can be operated from a 6.3-volt transformer.

C_1, C_2 — 100-μμfd. midget variable (Hammarlund MC-100-S).
C_3, C_4, C_5 — 100-μμfd. fixed mica condenser (Aerovox Type 1460).
C_6, C_7 — .5-μfd. or larger.
R_1 — 5 megohms.
R_2 — 50,000-ohm potentiometer (Frost) small size.
R_3 — 25,000 ohms, 10 watts (Ohmite).
R_4 — 2000 ohms, 1 watt.
R_6 — 75 ohms, center-tapped (Ohmite).
RFC — Universal wound short-wave choke (Hammarlund).
L_2, C_8, R_5 — Screen-grid coupler (National Type S-101). Suitable values are: L_2, 500 henrys; C_8, .01 μfd.; R_5, 0.5 megohm.

Coil Data

Frequency Range	*Total turns, L_1*	*Cathode Tap*	*Band-Spread Tap*
1450 to 3400 kc. (1.75)	*54½*	*3¼*	*29¾*
3050 to 7100 kc. (3.5)	*27½*	*1¼*	*11¾*
6100 to 14,200 kc. (7)	*13½*	*¾*	*4¼*
10,600 to 24,000 kc. (14)	*7½*	*½*	*1¼*
18,000 to 41,000 kc. (28)	*3½*	*⅓*	*⅓*

All coils are wound with No. 24 d.s.c. wire on 1½-inch diameter forms, the length of the coil being 1½ inches in all cases. The figure in parenthesis after each frequency range indicates the amateur band for which that coil is used. The taps are counted off from the lower or ground terminal. Assuming that the tuning dials have 100 divisions and that the 0 end of the scale represents maximum condenser capacity, the setting of C_2 to give amateur band coverage on C_1 will be approximately as follows, using appropriate coils: 1.75 mc., 44; 3.5 mc., 38; 7 mc., 28; 14 mc., 54; 28 mc., 78. See text on coil construction.

Many skillful constructors wire a receiver in the following order: First, all filament or heater connections are wired with twisted pair (in the case of a.c. circuits) placed, wherever possible, in the angles formed by the top and sides of the chassis, and away from other circuits. Second, all grid and plate connections are run as directly and with as short leads as possible from the tube socket or cap to the indicated part (preferably to the condenser, in a tuned circuit), but spaced from, or run at right angles to, other circuit elements. Finally, the plate and grid return circuits, with their various filter elements, are placed in a neat, orderly and non-conflicting array. Insofar as possible, a single common ground point should be used for each stage, by-pass condensers should be placed right at the socket terminal or by-passed element, choke coils should be mounted so that their fields do not mutually interact, and as much spacing between the parts in adjacent stages should be provided as the general design permits. If ordinary push-back wire is used for plate and grid connections in high-frequency sets, it should be kept away from the chassis or other parts, since the insulation at high frequencies is none too good. Spaghetti or varnished cambric insulation is satisfactory at the ordinary amateur frequencies.

The underlying thoughts to keep in mind in wiring the receiver are that damaging reactions between stages due to stray coupling between circuit elements should be avoided, that too much dependence must not be placed on ordinary forms of insulation in marshalling the elusive high frequency currents, and that the resistance introduced by a single improperly soldered connection can ruin the performance of the entire receiver.

A Two-Tube Pentode Receiver

● A two-tube receiver of advanced design and good performance is illustrated in Figs. 702 to 707, inclusive. A pentode regenerative detector and one stage of audio are employed, and the set is intended for headset reception. It is also adapted to either 2.5-volt or 6-volt a.c. or d.c. filament supply with heater-type tubes, or to 2-volt low-current filament supply with slight modifications.

The circuit diagram of the receiver is shown in Fig. 704 as intended for heater-type tubes and in Fig. 707 as modified for 2-volt filament-type tubes. Additional views demonstrating the constructional details are given in Figs. 703 and 705. The actual layout used is not particularly important except that, as always, it is desirable to have short leads in the r.f. circuit. Metal chassis construction is strongly recommended, since the shielding thus afforded is helpful in reducing capacity effects and in cutting out hum pickup from the induction fields which permeate most homes having a.c. wiring. For these same reasons a metal cabinet is advantageous, and since it is possible to purchase metal boxes for less than the cost of the aluminum that would go into making one of the same dimensions, the set was made to

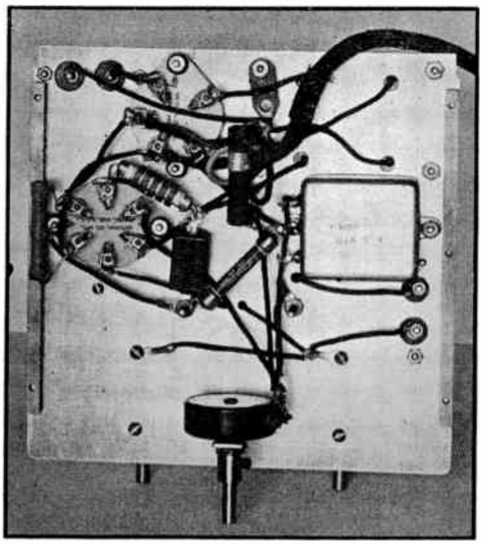


FIG. 705 — THIS UNDERNEATH VIEW SHOWS THE REGENERATION CONTROL RESISTOR AND THE VARIOUS BY-PASS CONDENSERS AND RESISTORS

The positive-"B" terminal is on a small piece of fibre which insulates it from the base. Each filament lead in the six-wire cable consists of two wires soldered together to lower the voltage drop. All ground connections from the tuning condenser and coil are bonded together.

fit such a box, in this case a National Type C-SRR. The aluminum base or chassis on which all the parts, including the tuning condensers and the regeneration control, are mounted measures 7½ by 7½ inches. Quarter-inch square brass rods, drilled and tapped for 6-32 screws, are fastened along two edges of the base to furnish a convenient means of securing it in place in the cabinet.

The two tuning condensers are mounted along the front edge of the base with their

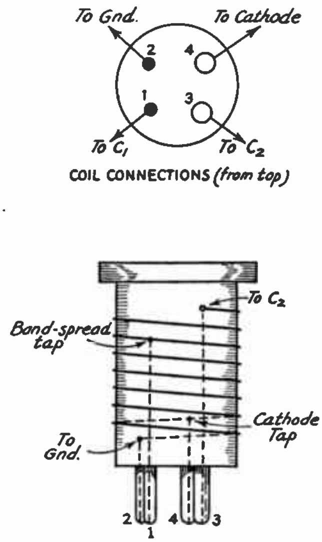


FIG. 706 — COIL SOCKET CONNECTIONS AND THE METHOD OF BRINGING OUT COIL TERMINALS

shafts projecting beyond the edge so the dials can be fastened to them when the set is put in the box. Behind the tuning condensers is the socket for the plug-in coils, an isolantite socket mounted on metal pillars so the socket prongs clear the base. The grid condenser and leak are just behind the right-hand tuning condenser, the far end of the condenser being supported from the base by a small piece of bakelite drilled and tapped to serve as a mounting.

To the rear of the grid condenser is the detector tube socket, and in the rear right-hand corner the binding posts for the phones. The audio tube socket is next, and occupying the rear left-hand corner is the audio coupler. The antenna and ground terminals are along the left edge of the base mounted on a bakelite strip.

The coil socket is mounted so that the leads to the tuning condensers are short and convenient. The rear right-hand socket terminal (No. 4) is connected to the cathode of the detector tube; the wire from the coil socket drops down through a hole in the base and runs underneath to the tube socket. A wire from this same prong also runs through another hole in the base to the antenna post. The connection to the ground terminal is similarly made to the rear left-hand terminal (No. 2) on the coil socket. The feedback coil — the part of the coil included between the cathode tap and ground — is thus made to serve as the antenna coupling coil as well. Experiment has shown that this method provides just about the right amount of coupling, keeping antenna effects

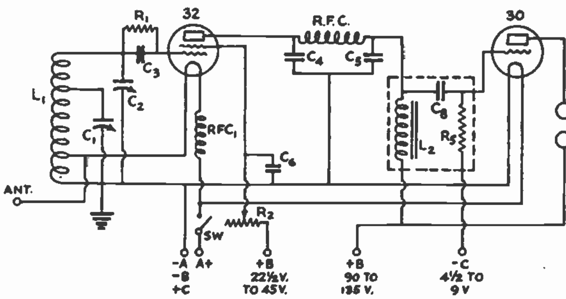


FIG. 707 — THE TWO-TUBE RECEIVER DIAGRAM ADAPTED FOR TWO-VOLT TUBES

Components have the same values as indicated in Fig. 704. The filament supply may be from an Air-Cell Battery or from two dry cells connected in series; in the latter case a 10-ohm rheostat should be connected in series with the "A" battery so the voltage applied to the filaments can be regulated to the proper value. The detector filament choke, RFC_1, is wound with No. 30 s.s.c. wire on a half-inch form to a length of two inches.

to a minimum while providing plenty of signal strength.

Parts mounted below the base include the regeneration control, the plate by-pass condensers and plate choke, and the screen and audio cathode by-pass condensers. This last is a double condenser having two sections of 0.5 μfd. each. Increasing each to 1 μfd. will reduce regeneration-control resistor noise and aid in amplification of the lower audio frequencies. The audio cathode resistor and the screen dropping resistor also are mounted underneath the base. The regeneration control resistor is mounted on a bracket made from half-inch brass strip, from which it must be insulated. An extension shaft gives the necessary length so that this resistor can be controlled from the panel.

Fitting the set to the box requires a little care, but presents no particular problems. The back and bottom of the box should be removed, after which the receiver can be pushed in from the rear. A space of about two inches between the bottom and the base will be sufficient; lines should be ruled along the inner sides of the box as guides so the chassis will be square with the box. Then the points at which the shafts of the tuning condensers and regeneration control go through the front should be marked and holes drilled to correspond. These may be made fairly large, and small inaccuracies will not matter. The next step is to drill small holes along the sides of the box for the screws which fit into the brass-rod mounting strips. Drilling and tapping of these rods for the side screws should be left until after the holes in the sides of the box have been drilled, so that their exact location can be easily spotted when the set is in its final position. The dials should not be fastened in place until all the other mechanical work has been finished; if dials similar to those shown (National Type B Midget) are used, the drilling template should be lined up with the condenser shafts after the receiver is securely mounted in the box. This will avoid the embarrassment of having condenser shafts and dials refuse to line up. The only precaution to be observed in connection with the regeneration-control shaft is to see that it does not touch the box as it comes through.

Fig. 706 shows how the connections are made on the coil forms, while the specifications are given under Fig. 704. In all cases the grid and ground ends of the coils come through the forms directly over their respective pins, and the tap specifications are given in turns and fractions of turns from the ground end. The length of the winding should be exactly 1½ inches on all coils, and on all but the 1.75-mc.

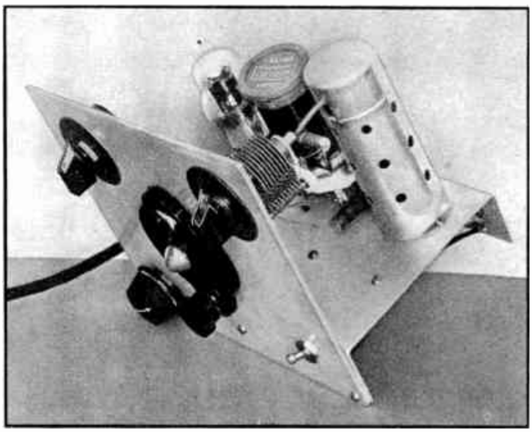


FIG. 708 — A TWO-TUBE RECEIVER HAVING THE EQUIVALENT OF THREE ORDINARY STAGES

Construction of the power pack, which is suitable for use with any of the regenerative receivers described in this chapter, is detailed in Chapter Fifteen.

coil the turns should be separated to give an even spacing throughout. The 1.75-mc. coil is close-wound with the wire specified. Different brands of wire vary a bit in insulation thickness, so if the completed close-wound 1½-inch coil has a turn or two more or less than indicated in the coil table it is quite in line with what would be expected. A small variation in the total number of turns on this coil is unimportant so long as the taps are counted off from the ground end as specified. The turn spacing on the 3.5-mc. coil is adjusted by putting another winding of the same size wire between the turns of the actual coil, the auxiliary winding being removed after the coil terminals are soldered in place. Spacing on the higher-frequency coils is adjusted by hand. Taps are made by drilling a hole through the form at the proper point, cutting off the wire and running it down to the proper pin. A new piece of wire with its end fastened in the same pin continues the winding. When finished, the windings should be given a coat of "dope".

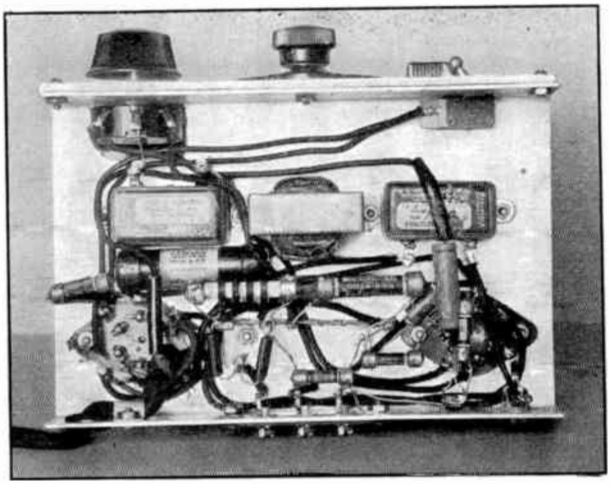


FIG. 710 — BOTTOM VIEW OF THE 6F7-41 TUBE RECEIVER CHASSIS

The audio coupling choke is visible in the center, flanked by the audio coupling and regeneration-control by-pass condensers. The antenna terminals are mounted on a bakelite plate at the back of the chassis, where also are mounted the headphone tip jacks.

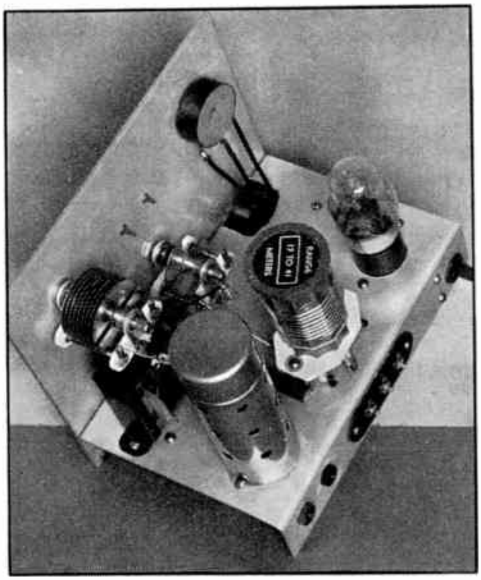


FIG. 709 — REAR VIEW OF THE MULTI-PURPOSE TUBE RECEIVER

With the coils specified, the band-spread is between 80 and 100 dial divisions on the band-spread condenser on all except the 3500-kc. coil. In this case the tap has been adjusted to spread the 400-kc. c.w. portion over the dial.

Any desired degree of spread can be obtained by changing the position of the tap. Moving the tap toward the ground end will increase the spread — decrease the frequency coverage — on C_1, while moving the tap toward the grid end will make C_1 cover a wider frequency range. Unfortunately the position of the tap for a pre-determined amount of band-spread cannot be readily calculated, and the work must be done experimentally.

Electrically, there are only two pitfalls to avoid. The first is to make sure that the part of the coil included between the cathode tap and ground end is as close to specifications as possible. It does not take much "tickler" in this circuit to provide all the needed feedback, and too much feedback not only reduces the sensitivity but also may lead to howls.

The second thing to avoid is the use of a make-shift audio coupler between the detector and amplifier. While audio transformers can be pressed into service as coupling impedances, a good many of them show a pronounced tendency to produce fringe howl. Trouble of this sort can be sidestepped by acquiring a coupler made especially for the job of coupling a screen-grid detector to an audio amplifier. There are several of them on the market.

The receiver can be used with either 2.5- or 6.3-volt tubes of the types enumerated under the circuit diagram, and is suitable for either a.c. or storage-battery operation of the filaments of 6.3-volt tubes. Plate voltage can come either from a "B" pack or batteries, with voltages from 90 to 250 volts being satisfactory. Somewhat greater signal strength will be obtained at the higher "B" voltages.

The set should first be tested with the an-

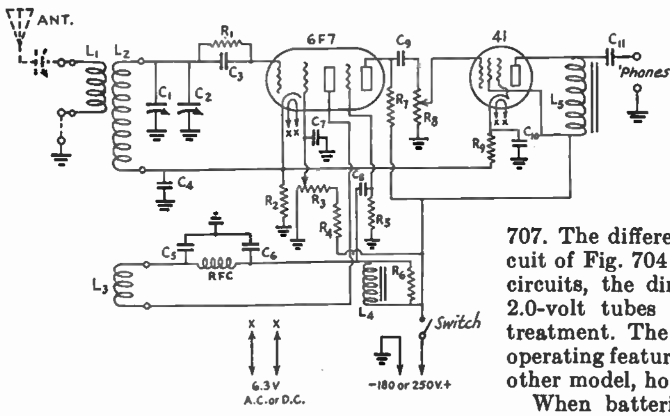


FIG. 711 — CIRCUIT DIAGRAM OF THE ADVANCED TWO-TUBE RECEIVER

The following parts, or their equivalents of different manufacture, are required:

L_1, L_2, L_3 — Three-winding coil kit (Hammarlund SWK-6).
L_4 — Screen-grid plate impedance, 1080-henry inductance at 0.5 ma. (Thordarson T-2927).
L_5 — Output coupling impedance, 30-henry inductance at 25 ma. (Kenyon KC-800).
C_1 — 140 μμfd. midget variable condenser (Hammarlund MC-140-S).
C_2 — 20 μμfd. Midget variable (Hammarlund MC-20-S).
C_3, C_5, C_6 — 100-μμfd. midget fixed mica condensers.
C_4 — 0.01 μfd. 200-volt tubular paper condenser.
C_7 — 0.5-μfd. 200-volt can-type paper condenser.
C_8, C_9 — 0.1-μfd. 400-volt tubular paper condenser.
C_{10} — 5-μfd. 35-volt tubular electrolytic condenser.
C_{11} — 0.5-μfd. 400-volt can-type paper condenser.
R_1 — 2-megohm ½-watt grid leak.
R_2 — 50-ohm 1-watt fixed resistor.
R_3 — 50,000-ohm midget potentiometer.
R_4 — 50,000-ohm 1-watt resistor.
R_5 — 1-megohm ½-watt resistor.
R_6 — 0.5-megohm ½-watt (0.1 meg. without L_4).
R_7 — 0.25-megohm ½-watt resistor.
R_8 — 0.5-megohm midget potentiometer.
R_9 — 1000-ohm ½-watt resistor.
RFC — Receiving-type short-wave r.f. choke (Hammarlund CHX).

If it is desired to build the coils, L_1, L_2, L_3, they can be wound with No. 30 double-silk-covered wire on standard 1½-inch plug-in forms, allowing about 1/16-inch between windings. L_1 should be wound at the top of the form, with the terminal marked "1" at top. The remaining windings and terminals follow progressively downward as shown. The turns-per-winding specifications are as follows:

	L_1	L_2	L_3	Frequency Band
No. 1	*70*	*20*	*10*	*1750-Kc.*
No. 2	*30*	*10*	*10*	*3500-Kc.*
No. 3	*11*	*7*	*5*	*7000-Kc.*
No. 4	*5*	*5*	*5*	*14,000-Kc.*

tenna disconnected to make sure that it goes into oscillation smoothly, and, incidentally, to make sure that the plate power-supply, if an eliminator, is free from tunable hums. If the receiver is quiet and stable throughout the entire range, the antenna may be connected. If hum and body capacity now appear at some part of the range, different antenna lengths should be tried. It should not be difficult to find a length which will permit stable operation in the amateur bands.

A circuit diagram of the receiver arranged for operation with battery-type 2.0-volt tubes is shown in Fig. 707. The differences between this and the circuit of Fig. 704 are principally in the filament circuits, the directly-heated filaments of the 2.0-volt tubes requiring somewhat different treatment. The mechanical construction and operating features remain unchanged from the other model, however.

When batteries are used for "B" supply with the heater-type tube model, a switch should be installed in the negative "B" lead so the batteries can be disconnected from the voltage divider when the receiver is not in use and thus avoid unnecessary drain on the batteries. In the 2.0-volt tube model the filament switch is all that is necessary, since the voltage divider is omitted from the receiver.

A Two-Tube Receiver With Multi-Purpose Tube

● The conventional form of two-tube receiver employs one tube as a regenerative detector and the other as an audio amplifier. However, with the multi-purpose tubes now available, in which two or more receiving tube functions are combined in one envelope, it is possible to build a two-tube receiver very nearly the equivalent of three stages.

A representative receiver of this type employs a 6F7 tube, which combines a triode and a pentode in the same envelope. While a number of different applications of this tube suggest themselves, undoubtedly the simplest and most trouble-free method of utilizing the two sections of the tube is to employ the pentode section as a regenerative detector with screen-grid regeneration control, and the triode as an audio amplifier stage, in which position it contributes a measured gain of 5.

The mechanical layout of the set is shown in Figs. 709 and 710. The chassis is made by taking a piece of 1/16-inch sheet aluminum 8 inches square, and bending down two 1½-inch sides. The panel is made of ⅛-inch sheet aluminum, 7 by 8 inches. Viewed from the front, the controls are: upper left, audio gain; upper right, band-settings; lower left, regeneration; and lower right, the send-receive switch. In the center, of course, is the main tuning control.

On top of the sub-panel can be seen the two tubes, the 6F7 being shielded, the tuning condensers, the coil and socket; and, beneath the band-setting condenser, the detector plate impedance. Underneath is the impedance which couples the headphones to the plate circuit of the final audio tube, a type 41 power pentode used as a voltage amplifier with a large bias in order to provide high gain, and the numerous fixed condensers and resistors required in the circuit.

The circuit diagram is given in Fig. 711. L_1, L_2 and L_3 are all wound on the same form. These coils are a commercially-manufactured kit; similar kits are supplied by a number of different manufacturers. Alternatively, home-wound coils can be used, as specified in the table with Fig. 711.

It will be noticed that the d.c. grid return of the 6F7 pentode section is to the cathode terminal of the socket. This is necessary in order to provide bias for the triode (audio) section of the tube, derived through R_3. The bias for the 41 is taken through this resistor, as well, in order to hold the 6F7 bias fairly constant despite the cathode current variation in that tube due to the plate current changes with detection. The two audio stages provide a large over-all gain, and it will be found necessary to retard the audio gain control for most headphone reception. A loudspeaker can be operated at moderate volume on strong signals.

The antenna connection is so arranged that a doublet receiving antenna or an ordinary single wire can be used at will. If an antenna of some length is used, it will be found that the loading of the antenna is so great the 6F7 may refuse to oscillate. In this event, a series condenser should be placed in the antenna lead. Any condenser that may be available will be satisfactory, provided it has a maximum capacity of 100 μfd. or more. It need be adjusted only once for each band.

The power supply requirements are 6.3 volts, a.c. or d.c., at 0.7 amp. for the heaters, and from 150 to 250 volts at 30 ma. for the plate supply.

A Tuned R.F. Regenerative Receiver

● The progressive amateur is rarely content to operate a receiver not fitted with at least one stage of radio-frequency amplification. The increase in sensitivity and the general improvement in performance made possible by a stage of r.f. amplification is usually well worth the additional apparatus and the added construction.

The three-tube receiver illustrated, and diagrammed in Fig. 713, has a tuned r.f. stage with controllable sensitivity. The circuit arrangement differs a little from those previously described, but the operating principles are the same. The band-spreading system will be recognized as the first of those outlined early in this chapter. It is used in this set because it is one of the easiest systems to get working when the tuning of two stages is to be ganged,

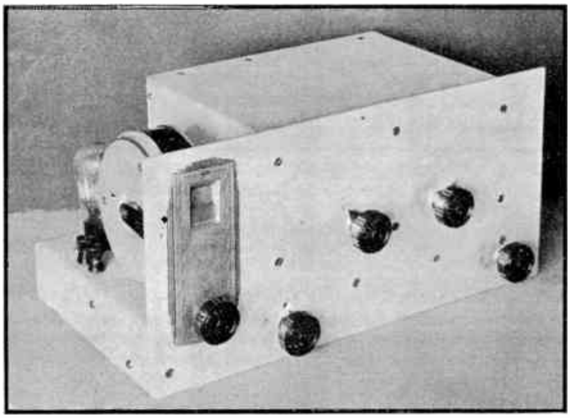


FIG. 712 — A MODERN THREE-TUBE TUNED R.F. AMATEUR BAND RECEIVER

It comprises a stage of t.r.f. amplification with controlled sensitivity, a stable regenerative detector and one-stage audio. It uses heater-type tubes for a.c. or 6-volt d.c. operation.

The tuning dial is placed at the left so the receiver can be operated without getting in the way of papers, log books, etc. To the right and below the dial is the regeneration control. The two upper knobs are the band-setting condensers. The sensitivity control is in the lower right-hand corner. The audio tube and the 'phone binding posts can be glimpsed behind the drum dial on the sub-base.

and because the relatively large capacity in the tuned circuits makes the detector oscillate more stably and thus prevents the signals from wavering should the "B" supply voltage change slightly.

The panel is of ⅛-inch aluminum and measures 7 by 14 inches. The sub-base is made of a single piece of 3/32-inch aluminum with the corners cut out and edges bent down in a vise so that the top surface is 13½ by 7½ inches and the vertical sides are two inches high. The two shield boxes are made of 1/16-inch aluminum, each measuring 4¾ inches high, 4¼ inches wide and 7 inches deep. The panel constitutes the front of both boxes. The pieces making up the sides of the boxes are fastened together by being screwed to vertical pieces of ¼-inch square brass rod which have been drilled and tapped to take small machine screws at appropriate points. Similar rods also are used to fasten the boxes to the panel.

It is important, in building up the chassis, to make certain that good contact is made between all metal parts. Loose panels in the shield boxes will result not only in poor shielding but will undoubtedly be the source of many noises.

The tuning condensers are Hammarlund midgets, mounted as shown in Fig. 714. To gang the two condensers the spring contacts which wipe on the shaft should be removed so that a flexible coupling can be slipped over the shaft. The connection to the rotor plates of the condenser so altered should be made through the *front* bearing when this is done, because the rear bearing may be noisy. The condensers and dial are connected together by means of pieces of quarter-inch shafting and small flexible couplings.

The detector circuit is designed to permit the use of 5-prong coil forms. Only three terminals are needed for the oscillating circuit, the other two being available for the coupling coil from the r.f. stage. As in the two-tube receiver, the tickler in this circuit comprises the portion of L_4 between cathode and ground, and is smaller than the tickler of more usual regenerative circuits.

A small audio transformer is used to couple the detector to the audio amplifier. A coupler such as the one used in the two-tube receiver can be substituted, provided changes are made in the mechanical arrangement of the set so it can be fitted in.

The wiring diagram, Fig. 713, is for operation from an a.c. power pack which will deliver 2.5 or 6.3 volts a.c. for the filaments and 200 volts d.c. for the plates. Voltages for the screen grids are obtained by means of voltage dividers and series resistors. If "B" batteries are to be used resistors R_5 and R_6 may be omitted and a separate lead brought out from R_{10} to the 45-volt tap on the "B" battery.

Resistor R_3 controls the amplification of the r.f. tube by varying the bias applied to its grid. The advantage of such a control is that it permits reducing the strength of strong signals and thus prevents the detector from "blocking" or "pulling in." A strong signal will occupy much more space on the dial than a weak one unless its strength can be reduced. The sensitivity control does this and thereby

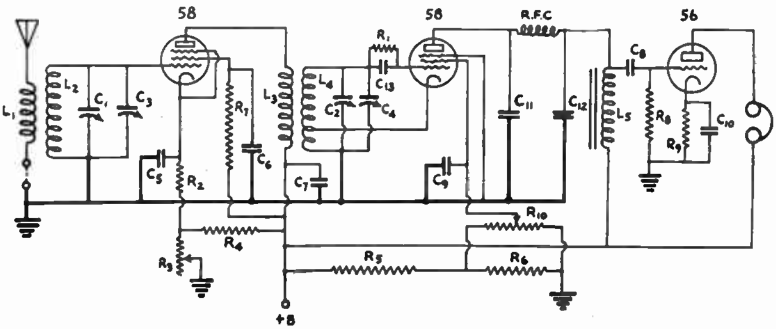


FIG. 713 — CIRCUIT DIAGRAM OF THE THREE-TUBE RECEIVER

The tube filaments (heaters) and the dial light are wired in parallel. The tubes indicated on the diagram, are for 2.5-volt a.c. operation. The 58's would be replaced by 78's or 6D6's, the 56 by a 37 or 76, and a 6-volt dial light should be used for 6-volt d.c. operation. With battery B supply resistors R_5 and R_6 should be omitted, and the positive terminal of the regeneration control R_{10} should be connected to the plus-45-volt battery tap; also, a d.p.s.t. switch should be included to cut off both sides of the B supply when the receiver is not in use, in addition to a switch in the filament circuit. The negative-B connection is made to the chassis (ground). Heavy lines indicate "ground" connections which should be made to a single common point on the chassis. Power-pack design for a.c. operation is given in Chapter Fifteen.

$C_{1,2}$ — 35-μμfd. midget condensers (Hammarlund MC-35-S). See text.
$C_{3,4}$ — 100-μμfd. midget condensers (Hammarlund MC-100-S).
$C_{5,6,7,8}$ — .01-μfd. mica condensers.
$C_{9,10}$ — 1-μfd. non-inductive paper condensers.
$C_{11,12}$ — 100-μμfd. fixed mica condensers.
C_{13} — 250-μμfd. mica condenser.
R_1 — 5-megohm resistor.
R_2 — 250 ohms, 2 watt.
R_3 — 10,000-ohm wire-wound potentiometer, tapered.
R_4 — 50,000 ohms, 2 watt.
R_5 — 14,000 ohms, wire-wound, 5 watt.
R_6 — 5000 ohms, wire-wound, 5 watt.
R_7 — 100,000 ohms, 1 watt.
R_8 — 1 megohm.
R_9 — 2000 ohms, 1 watt.
R_{10} — 50,000-ohm potentiometer.

Coil Data

L_1, L_2 on same form; L_3, L_4 ditto.

Band	L_1	L_2	L_3	L_4
1750	10	55	30	55 tapped at 3rd turn
3500	6	28	20	28 " " 1st "
7000	5	11	9	11 " " ½ "
14,000	3	5	5	5 " " ¼ "

All primaries (L_1 and L_3) are wound with No. 36 d.s.c. wire. The 3500-kc. grid coils are wound with No. 20 d.c.c.; 1750-kc. grid coils with No. 28 d.c.c.; both close-wound. The 7000- and 14,000-kc. grid coils are wound with No. 18 enamelled wire spaced to occupy a length of 1¼ inches. Tap turns are from the ground end of detector coils. National 5-prong coil forms (diameter 1½ inches) are used. Spacing between coils on each form is approximately ⅛ inch.

greatly increases the *effective* selectivity of the receiver.

The antenna input has been arranged so that a doublet antenna can be used with the receiver. With an ordinary antenna and ground, one of the antenna posts should be connected to the ground post to complete the circuit.

Should the set not work right at the first trial, check over the wiring and apply the tests outlined later in this chapter. These tests also apply to the two-tube receiver previously described.

A Metal-Tube T.R.F. Receiver

● The widespread publicity attending the introduction of metal tubes for use in commercial broadcast receivers has naturally generated corresponding interest on the part of amateur constructors concerning the applicability of these tubes to home-built sets. Metal tubes seem to possess several very definite advantages which indicate their increasing use and popularity, especially in short wave receivers. While these advantages are most apparent in superheterodyne design, it is possible to use the tubes with benefit in an ordinary regenerative receiver having tuned radio-frequency amplification.

The receiver to be described can be built to use either metal or glass tubes; it is not especially a "metal-tube" receiver. Conversely, it is possible to adapt almost any of the receivers thus far described to employ metal tubes, with only slight, if any, modification of circuit constants.

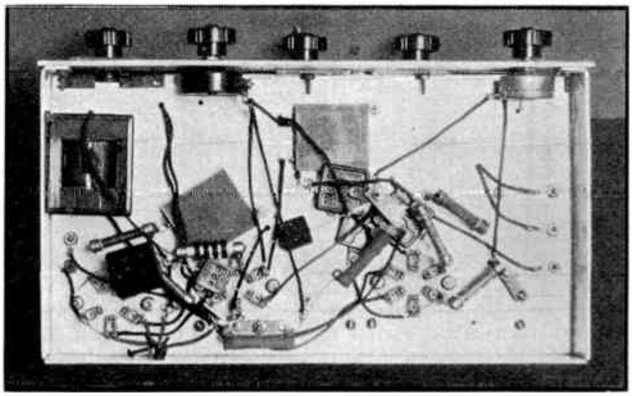


FIG. 715 — UNDER THE BASE OF THE THREE-TUBE RECEIVER

Resistors, by-pass condensers, chokes; all placed where most convenient. The only thing to keep in mind in this sub-base wiring is to make all the r.f. grounds at one point on the chassis. The audio coupler is mounted on the side at the left.

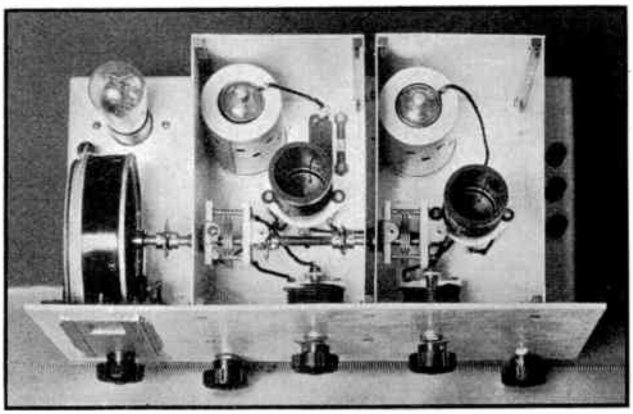


FIG. 714 — PLAN VIEW OF THE THREE-TUBE AUTODYNE WITH SHIELD COVER REMOVED

The detector stage is next to the drum dial. The ganged tuning condensers are mounted on the left-hand wall of each shield. The Isolantite coil sockets are mounted on small pieces of brass tubing which lift them far enough above the base to prevent grounding of the contacts. The detector grid condenser and leak are just behind the coil in the detector compartment. The tubes, also mounted in sub-panel sockets, have individual shields.

The construction can be seen in Figs. 718–720. The chassis is 12 inches long, 7 inches wide, and 2 inches high. It is made by bending two 2-inch sides down on an 11 by 12-inch sheet of 1/16-inch aluminum. The panel is of 1/8-inch aluminum, 8 by 12 inches. The dial and coil shields are mounted on the panel; all other parts, including the tuning condenser, are mounted on the sub-base. Mounted between the r.f. coil shields and the tuning condenser are the audio coupling impedances. The antenna terminal strip is located on the left side of the chassis. Headphone or speaker connections are made to tip jacks on the rear. Left to right, the controls along the bottom of the front panel are: r.f. gain, trimmer, regeneration, and send-receive switch.

While front-of-panel plug-in coils are employed, this feature can be dispensed with in the interests of economy, if desired, since its primary advantage is merely convenience. In this event, coils similar to those in the receiver just described can be used. The front-of-panel coils used are those supplied with the National pre-selector. No change is made in the r.f. coils, but some modification of the detector coils is necessary. In order to accomplish this,

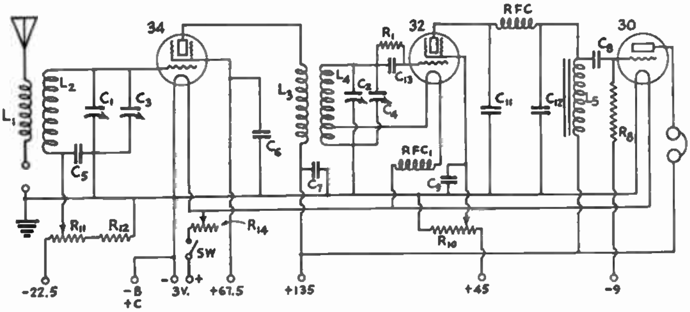


FIG. 716 — THE THREE-TUBE RECEIVER CIRCUIT MODIFIED FOR USE WITH TWO-VOLT TUBES

Components have the values given in Fig. 713 with the following additions: R_{11}, 50,000-ohm potentiometer; R_{12}, 5000 ohms, 1-watt rating; R_{14}, 10-ohm rheostat; RFC_1, same specifications as given in Fig. 707. R_{11} and R_{12} constitute the gain control circuit in the r.f. amplifier; R_{12} is used to make certain that a small amount of grid bias will be applied to the tube even though R_{11} is set at its minimum-bias end. Filament supply may be from an Air-Cell battery or from two dry cells connected in series.

To prevent "B" and "C" battery discharge through the voltage-dividers when the receiver is not in use, switches may be installed in series with the "−22.5" and "+45".

the fibre cylinder protecting the coil windings is first removed by twisting it on the form, so as to break the cement holding it in place. The coil handle is disassembled by taking out the mounting screws. The trimmer condenser is supported by its leads, soldered into the pins connected to the secondary winding; these must be removed while the new windings are being made, and then replaced.

First of all, new primary windings L_3 are required. These are inter-wound with the main windings on the coil form, and connected to the same pins on the form as the original antenna windings. The following number of turns will be required on the different coils, wound from the bottom end of each form:

1.75 mc.	— 42 turns No. 32 d.s.c.
3.5 mc.	— 22 " " 28 "
7 mc.	— 10 " " " "
14 mc.	— 4 " " " "

In addition, a cathode winding L_5 is also required on each detector coil. This winding has one end connected to the ground end of the tuned circuit winding, and is wound in the slot at the bottom of the form *in the opposite direction to the main winding,* as indicated on the circuit diagram. The cathode end is connected to the blank pin on the form. This cathode winding has the following number of turns on the respective coils:

1.75 mc.	— 6½ turns No. 28 d.s.c.
3.5 mc.	— 3½ " " " "
7 mc.	— 2 " " " "
14 mc.	— 1½ " " " "

The number of turns in the cathode winding is fairly critical and some readjustment may be necessary in individual receivers. If regeneration is not smooth over the entire range of each coil, further experimentation is indicated.

The same power supply can be used for this receiver as for the previous two-tube receiver, and described in detail in Chapter Fifteen. In common with nearly all regenerative receivers, a power pack incorporating an r.f. filter for the elimination of tunable hum is desirable.

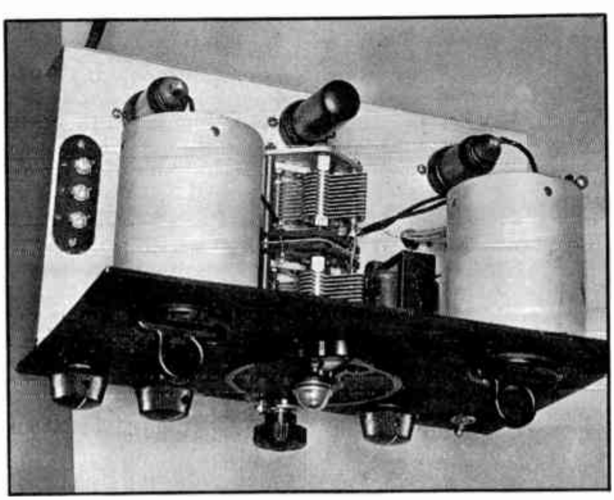


FIG. 717-718 — A METAL-TUBE T.R.F. RECEIVER

Such distinctive features as front-of-panel plug-in coils and metal tubes characterize this receiver design.

A Regenerative Single-Signal Superheterodyne

● While the simple regenerative receiver is the ideal beginner's set, and the tuned r.f. regenerative receiver is adequate for certain types of amateur operation, ideal operation under present-day conditions demands a receiver that is capable of considerably greater selectivity than is afforded by any of these simpler types. The superheterodyne receiver is the answer to this problem.

In even the simplest forms, a superheterodyne receiver is a relatively complex device, much more difficult to build and adjust than a regenerative set. For this reason, experience with the simpler forms is urged before the amateur constructor attempts the construction of a superhet. However, given careful construction and intelligent adjustment and operation, there is no reason why the typical amateur could not successfully build a satisfactory superheterodyne receiver; and the receivers to be described have all been built by amateurs and made to function. They represent, in this respect, as nearly troubleproof designs as can be devised.

The six-tube regenerative single-signal superheterodyne shown in Figs. 721, 722 and 724 is illustrative of the design and construction of amateur high-frequency superhets. It has a preselector stage, first detector with separate oscillator, a single stage of high-gain regenerative i.f., power second detector, and separate beat oscillator.

The photographs show the general arrangement and Fig. 723 gives the wiring diagram. The left-hand shield in Fig. 721 contains the high-frequency oscillator. Directly behind the drum dial is the 2A5 second detector. In the center compartment is the first detector and its tuning circuits, with the oscillator coupling condenser, while in the right-hand compartment is the r.f. preselector-amplifier.

On the back deck, at the extreme left, is the c.w. beat oscillator coil and condenser unit, T_3, with the beat control knob projecting at the top. Next is the c.w. beat oscillator tube. The center can contains the i.f. transformer assembly, T_2, with the i.f. amplifier tube to its right. At the extreme right is the regenerative i.f. transformer assembly, T_1.

Looking at the front of the panel, the upper row of knobs are, left to right: h.f. oscillator tank, C_5; first detector tank, C_4, and r.f. tuning condenser, C_1. At the bottom of the panel, the left-hand switch, SW_1, controls the high voltage supply to the receiver. Next is the c.w. beat oscillator "on-off" switch, SW_2, cutting the screen voltage. The knob below the illuminated dial is the main tuning control operating the ganged condensers C_2 and C_3, with the gain control, R_3, next. The knob at the right operates the i.f. selectivity control, the regeneration attenuator R_9.

Doublet antenna connections are made to insulated binding posts on the outside shield of the r.f. stage, with the ground binding post nearby on the main deck. With a conventional single-wire antenna connected to one insulated post, the other is connected to ground. Of course the doublet antenna should be used if possible, since it makes possible considerable additional gain.

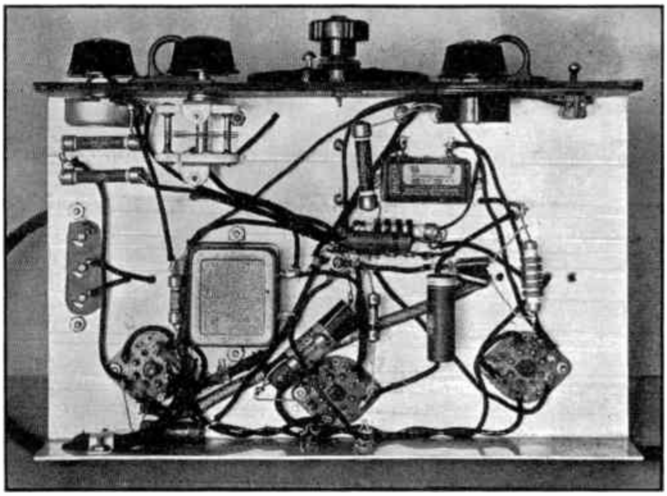


FIG. 719 — UNDERNEATH THE CHASSIS

All ground returns are brought to a central ground point in the middle of the chassis, to eliminate stray couplings; resistors and condensers are mounted wherever convenient, with all leads as short and direct as possible. The shielding on the long plate lead should have a diameter of 3/8-inch. The metal tubes require no individual shields.

Insulated 'phone tip jacks on the left end of the chassis provide connections for 'phones and speaker.

Once the tank condensers have been set for a given band, the selectivity adjusted to the desired degree, and the c.w. beat note fixed, the receiver is in effect single-dial tuning with operating controls for volume, frequency and c.w. note convenient for one position of the hand.

The structural part of the receiver is all of sheet aluminum. The chassis or main deck is made from a piece of 3/32-inch aluminum 21 inches by 12 inches. From two corners on one long side of this piece, 2-inch squares are cut out and then three sides are bent down at right angles so as to form the sides and back of a deck 17 by 10 inches and 2 inches high.

All of the inter-stage box shields are cut from 1/16-inch aluminum. The six sides are 7 inches long by 4¾ inches high, while the three ends are 4¼ inches wide by 4¾ inches high. The shields are held together at the corners by ¼-inch square brass rods drilled and tapped for 6/32 machine screws. The corner posts are fastened to the main deck by screws into their lower ends.

The front panel is of ⅛-inch thick aluminum, 18 inches long by 7 inches high. It is fastened by screws to the front posts of the shield boxes. A cover fitting over all the shields is a sheet of 1/16-inch aluminum 16 inches by 7 inches held in place by flat springs on its under side, pressing against the sides of the shield boxes.

The Isolantite five-prong coil sockets are mounted above-deck on pillars long enough to clear the contacts. Similar tube sockets (six-prong) are mounted below the base under their 1½-inch holes. With this arrangement a minimum of wires need pass through the base. Complete tube shields are provided for all tubes. A ½-inch length of ⅛-inch rubber tubing slipped over each grid wire, before soldering on the grid clip and afterwards pushed up on the clip, prevents any possible grounding of the grid on the grid-cap shield.

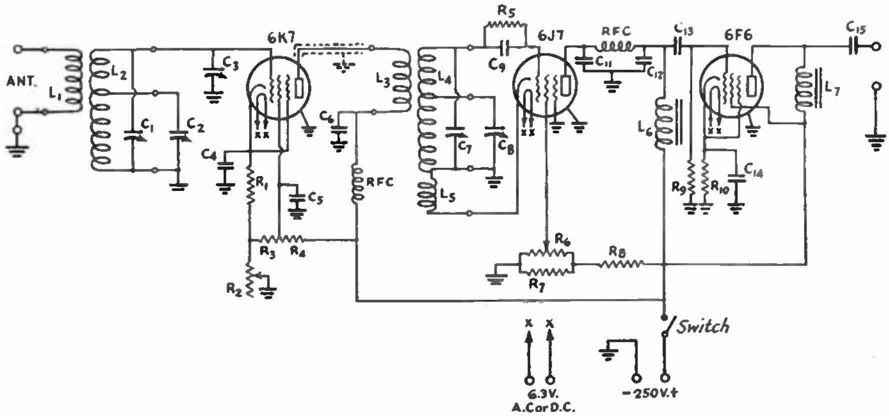


FIG. 720 — CIRCUIT DIAGRAM OF THE METAL-TUBE T.R.F. RECEIVER

L_1, L_2, L_3, L_4, L_5 — National Pre-Selector coils; see text.
L_6 — Detector coupling impedance, 1080-henry (Thordarson T-2927).
L_7 — Output coupling impedance, 22-henry at 35 ma. (Thordarson T-1892).
C_1, C_7 — Trimmer condensers mounted inside coil forms.
C_2, C_8 — 100-μμfd. gang condenser (National 2SE-100).
C_3 — 20-μμfd. midget variable (Hammarlund MC-20-S).
C_4 — 0.1-μfd. 200-volt tubular paper.
C_5, C_6 — 0.01-μfd. 400-volt tubular paper.
C_9, C_{11}, C_{12} — 100-μμfd. midget mica, fixed.
C_{10} — 0.5-μfd. 200-volt can-type paper.
C_{13} — 0.1-μfd. 400-volt tubular paper.
C_{14} — 5-μfd. 35-volt tubular electrolytic.
C_{15} — 2-μfd. 400-volt can-type paper.
R_1 — 300-ohm ½-watt.
R_2 — 5000-ohm variable resistor.
R_3, R_7 — 50,000-ohm ½-watt.
R_4, R_8 — 50,000-ohm 1-watt.
R_5 — 2-megohm ½-watt.
R_6 — 50,000-ohm potentiometer.
R_9 — 1-megohm ½-watt.
RFC — Receiving-type short-wave r.f. chokes.

The National 500-kc. i.f. transformers each require minor alterations to adapt them to the circuit, and they should be removed from their cans for this purpose. The first operation is on the regenerative i.f. transformer, T_1.

As supplied, the grid coil, L_7, is at the upper end of the dowel, nearest the condensers, and the plate coil at the bottom. In order to couple the tickler coil, L_8, to the grid coil, the external connections from the unit T_1 must be changed so that the grid coil is the lower one. This means that one of the wires that normally passes out through the bottom of the can should be brought out the top through a piece of shield braid; and the wire originally at the top is brought out through the bottom.

A one-inch length of ½-inch dowel is fastened by means of a wood screw to the end of the dowel carrying the coils in the unit. At the lower end of the new dowel, the tickler L_8 is bunch-wound with 25 turns of No. 30 d.s.c. wire. If this tickler is wound in the same direction as the other coils, the final connections from T_1 are as follows: Inside end of upper or plate coil L_6 to B+, outside to first detector plate through shield braid; inside end of middle or grid coil L_7 to ground, outside through shield braid from top of can to grid cap of i.f. amplifier; inside end of lower or tickler coil L_8 to i.f. suppressor, outside end through shielded lead to i.f. cathode. If the i.f. circuit cannot be made to oscillate with R_9 in the maximum resistance position or disconnected, then the tickler connections should be reversed at the coil terminals. If oscillation should fail with the tickler connected either way, the number of tickler turns should be increased a few at a time until oscillation is obtainable.

For T_2 the connection out of the top of the shield is removed and brought down inside to the detector grid condenser and leak which are placed within the can. Plate and grid leads from T_2 also should be shielded with flexible copper braid.

In the beat oscillator unit the grid condenser and leak are also mounted within the can. The only other operation required is to shield the grid lead from the top of the can to the oscillator tube.

The high-frequency oscillator coupling condenser C_1 is made of two brass angles, having faces about ¾ by ⅝ inch, mounted on a small piece of bakelite in the detector compartment with the faces spaced ⅛ inch. The connection from the plate of the h.f. oscillator to C_7 is in shielded braid but may be left unshielded.

The coils are wound on National 5-prong forms according to specifications given in the table. No attempt has been made to make the tuned circuits track exactly. The over-all gain of the receiver is high enough so that, by judicious use of the gain control, c.w. reception is possible throughout an entire amateur band without touching the tank condensers. Better tracking can be secured easily by removing a few turns of wire from the oscillator coils L_5. A further refinement would be to gang an additional condenser, similar to C_2 and C_3, for the r.f. amplifier.

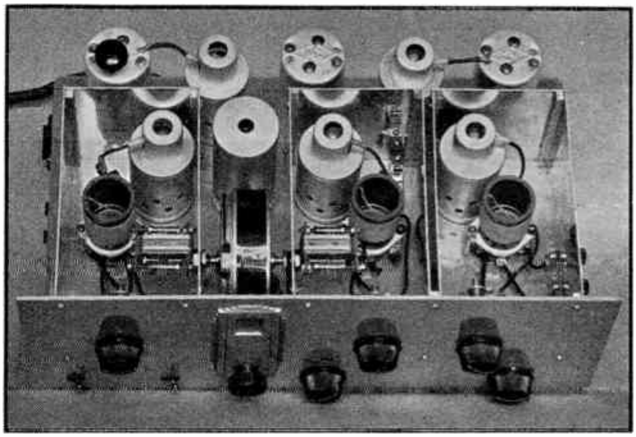


FIG. 721 — A SIX-TUBE REGENERATIVE SINGLE-SIGNAL SUPERHETERODYNE RECEIVER

A pre-selector stage, a separate high-frequency oscillator, and a high-gain i.f. stage with controllable regeneration make this receiver an outstanding performer. (W1EAO).

The power supply leads are brought in through a flexible cable in the rear. The B+ voltage is conveniently distributed from a terminal strip attached to SW_2. Although only four wires are essential to the power supply cable, cables with four wires having two which are of suitably low resistance for heater currents are not readily available. Accordingly, a standard 8-wire cable is used with three wires in parallel for each of the heater leads. By this means the filament voltage drop from power supply to set is kept to a value of less than 0.1 volt. Care must be taken, however, that all the paralleled wires are securely soldered to the terminal plug at the supply end of the cable.

The power supply may be of the type described in Chapter Fifteen. The filament winding of 2.5 volts should be capa-

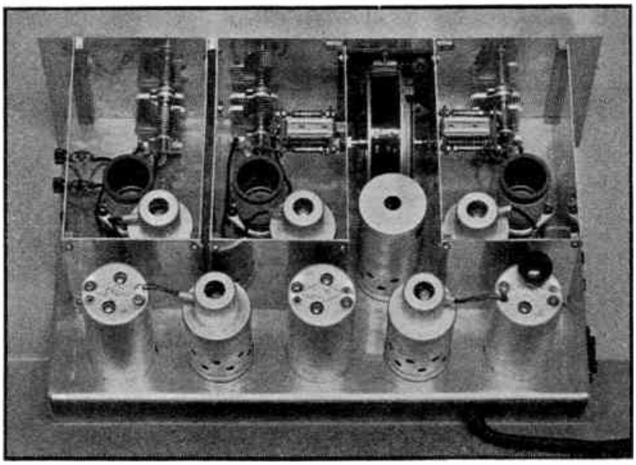


FIG. 722 — A REAR VIEW OF THE REGENERATIVE SINGLE-SIGNAL SUPERHETERODYNE

This supplements the front view of Fig. 721 and shows more clearly the construction of the intermediate-frequency amplifier.

ble of delivering the 8 amperes necessary for the tubes and dial light. High voltage under 50-ma. load should be approximately 180 volts.

To align the i.f. amplifier, set the selectivity control at minimum selectivity, and apply a 500-kc. signal to the grid of the i.f. tube. The *second* i.f. transformer is then adjusted to resonance as indicated by maximum second-detector output, an insulated socket wrench being used to tune the condensers C_6 at the top of the can. The oscillator is then coupled to the first detector grid and the same procedure is used to tune the *first* i.f. transformer. The beat oscillator may be isolated from the second-detector circuit and used as a signal source, but preferably a separate test oscillator should be

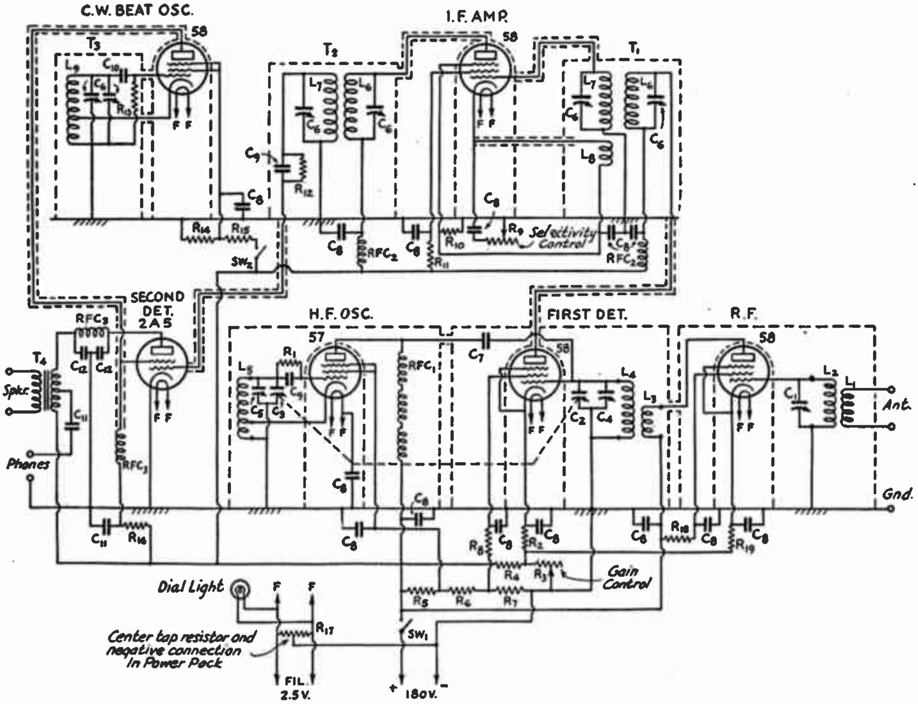


FIG. 723 — CIRCUIT OF THE SIX-TUBE REGENERATIVE S.S. RECEIVER
Dotted lines indicate shielded leads.

L_1, L_2, L_3, L_4 and L_5 — See coil table.
L_6 and L_7 — 500-kc. i.f. transformer windings.
L_8 — See text.
L_9 — 500-kc. beat oscillator coil. (See text.)
C_1 — 140-μμfd. midget condenser (Hammarlund MC-140M).
C_2, C_3 — 25-μμfd. midget condenser (National SE-50 cut down to 3 stator plates).
C_4, C_5 — 100-μμfd. midget condensers (Hammarlund MC-100M).
C_6 — 70-μμfd. midget condenser (in National i.f. units).
C_7 — H.f. oscillator coupling condenser. (See text.)
C_8 — 0.01-μfd. r.f. by-pass condensers, tubular paper.
C_9 and C_{10} — 250-μμfd. mica grid condensers.
C_{11} — 1-μfd. audio by-pass and coupling condensers.
C_{12} — 250-μμfd. plate by-pass condensers, tubular paper.
R_1 — 50,000-ohm 1-watt oscillator grid leak.
R_2 — 5,000-ohm 1-watt first detector cathode resistor.
R_3 — 12,000-ohm variable resistor, right-hand taper (Electrad).
R_4 — 100,000-ohm 1-watt.
R_5 — 10,000-ohm 5-watt.
R_6 — 7,000-ohm 2-watt.
R_7 — 3,000-ohm 2-watt.
R_8 — 50,000-ohm 1-watt.
R_9 — 2,000-ohm variable resistor, left-hand taper (Electrad).
R_{10} — 300-ohm 1-watt (i.f. amplifier cathode resistor).
R_{11} — 50,000-ohm 1-watt.
R_{12} — 1-megohm ½-watt second detector grid leak.
R_{13} — 50,000-ohm ½-watt beat oscillator grid leak (Integral with National oscillator unit).
R_{14} — 2,500-ohm 2-watt.
R_{15} — 50,000-ohm 2-watt.
R_{16} — 25,000-ohm 5-watt.
R_{17} — 20-ohm center-tap resistor (in power supply).
R_{18} — 50,000-ohm 1-watt.
R_{19} — 300-ohm 1-watt r.f. cathode resistor.
T_1 and T_2 — National 500-kc. air-tuned i.f. transformers. (See text.)
T_3 — National 500-kc. beat oscillator assembly.
T_4 — Universal push-pull output transformer (Kenyon).
RFC_1 — 2½-mh. sectional choke (National No. 100).
RFC_2 — 10-mh. single-section universal wound r.f. choke.
RFC_3 — 60-mh. single-section universal wound r.f. choke.
SW_1 and SW_2 — Single-pole panel switches.

used. If a modulated signal is used, the output can be judged by ear. For an unmodulated signal a 0–50 milliammeter should be placed in the plate circuit of the second detector, when resonance will be indicated by plate current dip to minimum.

After aligning the i.f., the high-frequency circuits are aligned, using an oscillator or frequency meter giving a signal in an amateur band. The three condensers C_1, C_2 and C_3 will have nearly the same settings, although the oscillator (being tuned 500 kc. higher than the detector) will have a somewhat lower capacity setting.

When everything is aligned the c.w. beat oscillator should be set so as to give about a 1000-cycle tone when heterodyning a signal tuned in "on the nose." Then the selectivity control should be brought up to just below oscillation, as indicated by the "ringing" sound. The signal will increase in intensity and, with tuning through zero beat, the audio image or "other side of zero beat" should be hardly audible. Careful manipulation of the alignment adjustments will bring out this desired single-signal feature to its fullest.

HIGH-FREQUENCY COIL DATA

Band Kc.	*L_1 Turns*	*L_3 Turns*	*L_2, L_4 and L_5 Turns*	*Tap on L_5—Turns from Ground End*
1,750	10	30	55, No. 28 d.c.c.[1]	18
3,500	6	20	28, No. 20 d.c.c.[1]	9
7,000	5	9	11, No. 18 enam.[2]	3
14,000	5	5	5, No. 18 enam.[2]	2

[1] Close-wound.
[2] Spaced to make coil length 1¼ inches.
L_1 and L_3 all close-wound with No. 36 d.s.c., spaced ⅛-inch from L_2 or L_4. Forms are National R-39, five-prong.

The value of the tickler L_3 has intentionally been left so that oscillation in the i.f. circuits can occur with the control resistor R_9 almost, but not quite, at its point of highest resistance. The receiver never should be operated with the i.f. self-oscillating.

Superheterodyne With Band-Switching

● Perhaps the major problem of amateur-band tuner design is that of providing tuning ranges covering all the amateur bands. As has been seen, it is impossible to tune over a range having a frequency ratio much greater than 3-to-1 with a single condenser; 2½-to-1, or even 2-to-1, is much nearer the average for all-wave coverage. This condition necessitates some method of coil changing. Two methods of accomplishing this are in common use. One consists of plug-in coils; this method has been exemplified in the receivers previously described in this chapter. Its major advantages are flexibility and good efficiency. Another system is that of coil-switching, with all the necessary coils permanently mounted in the tuner and selected at will by means of a multiple rotary switch; convenience is the major advantage, and so highly is this asset prized by amateurs that they are usually willing to sacrifice some flexibility and efficiency in its attainment.

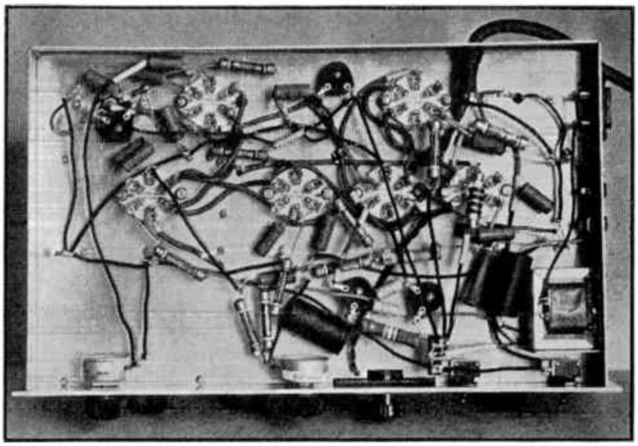


FIG. 724 — A BOTTOM VIEW OF THE SIX-TUBE SUPERHET

By-pass condensers and resistors are placed in the most convenient locations. The detector output transformer is mounted on the side wall of the chassis, and can be seen in the lower right-hand corner.

The superheterodyne receivers to be described in the balance of this chapter employ commercially-built band-changing units. While it might be possible for a skilled amateur to successfully design, construct and adjust a coil-switching system, covering the necessary frequency ranges, the labor and expense involved would exceed considerably the cost of ready-made units. The two units described are typical of current practice of manufacturers of similar equipment. Equivalent products of other manufacturers may be substituted, provided constants and quality are similar.

The seven-tube receiver contains a tuned r.f. pre-selector stage, an electron-coupled pentagrid mixer, a triode-connected pentode oscillator, a single i.f. stage with controllable regeneration, a duo-diode detector and high-mu a.f. amplifier in one envelope (one diode being used for rectification, and the other for automatic gain control and beat-frequency injection), and a pentode audio amplifier with capacity-inductance coupling to headphones or magnetic speaker, or, through a suitable output transformer, to a dynamic speaker.

The construction of the receiver is shown in Figs. 725–727, and the circuit in Fig. 728. Installation of the tuner unit is discussed in an

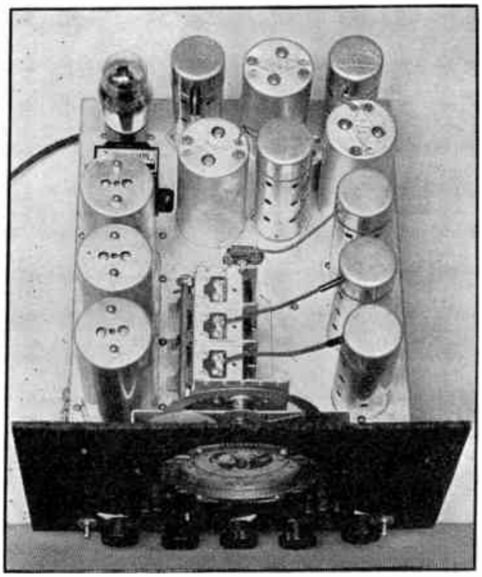


FIG. 725 — SEVEN-TUBE SUPERHETERODYNE WITH BAND-SWITCHING

To the left of the chassis appears the coil-switching unit: then, in order, the antenna, r.f., and oscillator coil shields. Directly to the rear is the output coupling choke and 42 output tube. From left to right, around the rear and right side, are the 42, 75 second detector and first a.f., second i.f.t., 6D6 i.f., first i.f.t., 6D6 oscillator (triode-connected), 6A7 mixer, 6D6 r.f. In the center is the beat-frequency oscillator tube, a 6D6, and associated tuned circuit, as well as the dual three-gang tuning condenser.

instruction sheet which accompanies the device; as will be seen by reference to the circuit diagram, which shows the tuner sections blocked off, four connections to each section are required. The wiring of the balance of the set follows no particular pattern, leads being run as directly as possible and at the builders' convenience. All parts are used as they come from the dealer's shelves, with the exception of the b.f.o. transformer T_4, which must be disassembled in order that a lead may be connected to the stator of the trimmer condenser for attachment to C_{28}, the b.f.o. panel control.

After all the parts have been mounted and the receiver has been wired it is advisable to check all circuits with an ohmmeter, in order to ascertain that all connections have been properly made and that no unintentional short-circuits, especially of the high-voltage circuits, exist. Following this, it is desirable to secure some sort of service oscillator which will provide modulated radio frequencies in the range 500–18,000 kc., for alignment purposes. The construction of a suitable home-built test oscillator is described in Chapter Seventeen. The circuit alignment procedure is as follows:

Set the modulated test oscillator at 507 kc., the intermediate frequency of the receiver. Remove the grid clip of the 6D6 i.f. tube, connect a 250,000-ohm resistor from the tube cap to ground, and connect the cap to the oscillator through a 250-$\mu\mu$fd. fixed condenser. Adjust the trimmer screws in the i.f. transformer, diode first and then plate, until maximum response is heard in the loudspeaker or until maximum deflection is observed on an output meter connected across the headphone terminals. Replace the 6D6 grid clip, remove the 6A7 grid clip, and repeat the procedure, touching up both transformers very carefully until peak response is obtained. Keep the output of the oscillator low, in order that the stages will not be overloaded, and set the r.f. gain control at maximum. When the i.f. stages have been aligned turn on the beat oscillator, set the panel control at mid-scale, and adjust the trimmer condenser in the shield can until a sharp whistle of moderate pitch is obtained with the modulation removed from the test oscillator. Finally, turn off the beat oscillator, set the regeneration control at maximum, and adjust the trimmer in T_3 until oscillation occurs and the sharp whistle is heard again. Back off the regeneration control until the oscillation stops and touch up the trimmer adjustment again, until oscillation occurs at the lowest point on the scale. In operation, oscillation is never allowed to occur, the control being advanced until the very point of oscillation, when regeneration, and consequently selectivity, is greatest. If oscillation occurs at too low a point on the scale a fixed resistor of suitable value can be shunted across the potentiometer, in order to lengthen the useful control range.

Ordinarily very little readjustment of the coil assembly will be required. To check its alignment, the output of the test oscillator should be connected to the antenna and ground posts. Setting the band switch to position 4 (on a left-to-right scale), set the test oscillator at 3,000 kc. Slowly adjust the antenna and r.f. trimmers until maximum response is obtained, keeping the output from the oscillator as low as possible. The padding condensers (at the rear of the unit) are adjusted by varying their settings slightly while rotating the tuning condenser, observing the point at which maximum response is obtained. The same procedure should be repeated on the other bands. Adjust antenna and r.f. trimmers first, at the high frequency end of the band. Then adjust the padders, setting the oscillator and tuning the set to the low-frequency end of the band.

After these adjustments have been completed the set is ready to use. Replace the test oscillator with the actual antenna and ground, and listen for signals. Rough tuning can be done with the right-hand knob, but band-spread tuning in the amateur bands should be done with the left-hand tuning knob. Any type of single-wire antenna can be used; if a doublet of one of the commercial varieties now on the market is used, the impedance-matching transformer at the set can be eliminated.

A Crystal-Filter S.S. Superhet

● The most advanced type of amateur superheterodyne for both c.w. and 'phone reception is the single-signal type with a variable selectivity crystal filter. A modern version of this variety of receiver is illustrated in the first figure of this chapter and will now be described in detail. The complete schematic diagram of the receiver circuit is given in Fig. 729. Employing a total of 12 metal tubes in the receiver proper, several effective operating advantages are obtained in addition to high selectivity and sensitivity. Principal of these is the independent a.v.c. action achieved by use of the separate a.v.c. amplifier and rectifier combination, as previously outlined in Chapter Six. The signal-meter arrangement used is also advantageous, being operative on all signals, whether the beat oscillator is on or off, and being adaptable to indicating audio signal level as well as r.f. carrier strength. As is readily apparent from the schematic diagram, the separate a.v.c. and signal-meter circuit can be dispensed with if the constructor desires.

The high-frequency end, comprising the r.f. amplifier stage, the mixer and separate oscillator, utilizes a coil-switching unit which tunes the 1.75-, 3.5-, 7- and 14-mc. amateur bands exclusively. As with the superhet previously described, other tuners of suitable design could be used instead. As shown in the plan view of Fig. 730, the tuner unit is centered in the chassis with the other components grouped to give a logical circuit sequence from antenna input to audio output. Referring to this plan view, progressing backward from the panel, the r.f., mixer and oscillator tubes are to the left of the tuner unit. At the extreme left, next to the panel, is the crystal-filter unit, with the first i.f. tube immediately behind it. The first i.f. transformer is at the rear, in line with the three high-frequency tubes. To the right of this transformer are the second i.f. amplifier tube (immediately behind the tuner), the second i.f. transformer T_3 and the second detector; while along the rear of the chassis in corresponding positions are the a.v.c. amplifier, its coupling transformer T_4 and the a.v.c. rectifier. In the extreme right-hand corner is the c.w. beat oscillator tuning unit T_5 and the oscillator tube. Progressing from this point toward the panel again are the first audio amplifier, the pentode output amplifier and the signal-meter tube.

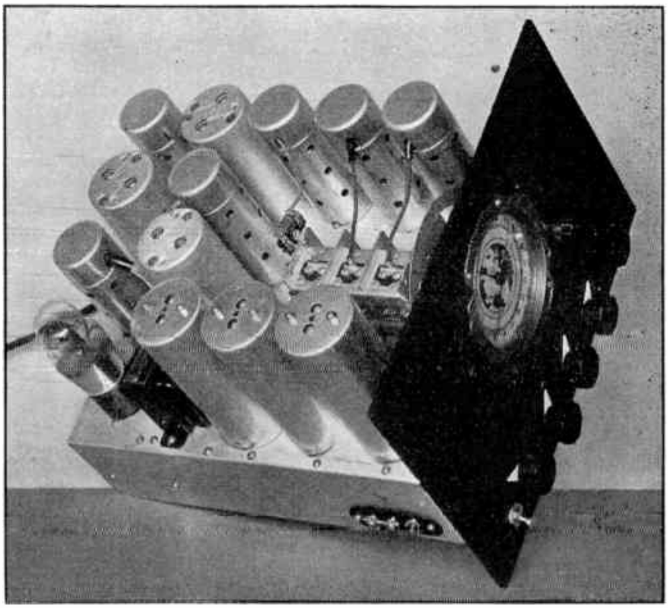


FIG. 726 — PANEL LAYOUT OF THE SEVEN-TUBE SUPERHET

Left to right, the controls along the bottom of the panel are: send-receive switch, band-change switch, audio-frequency volume control, beat-frequency oscillator control, radio-frequency gain control, regeneration control, and a.v.c.-b.f.o. switch (a.v.c. being used on 'phone, the b.f.o. for c.w.). To the left, above, is the bandspread tuning control, with the main control to the right. Individual drive mechanisms for each condenser unit are contained in the dial.

The controls are identified by reference to the panel view of Fig. 701. The main tuning control is the large knob immediately below the tuning scale in the center. The upper knob to the left of the tuning scale is the band-width control of the filter, with the rejection control below it. The control below the meter at the right is for the signal-meter adjustment. In the bottom row, from left to right, are the knobs for r.f. gain, a.v.c. limiter or delay, band switch (center), audio volume and beat-note. In line beneath these, also from left to right, are the B-supply switch, beat oscillator switch and 'phone jack.

The base is formed of aluminum sheet, the top being 17½ inches across and 12 inches from

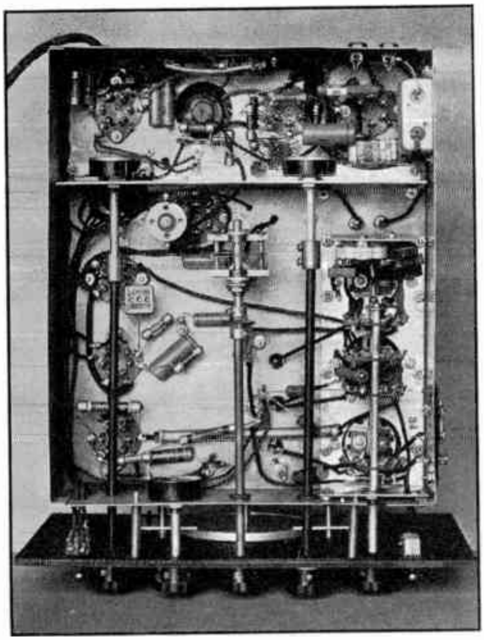


FIG. 727 — BOTTOM VIEW OF THE BAND-SWITCHING SUPERHETERODYNE

A key to the tube line-up and control order can be obtained by reference to Figs. 725 and 726. The baffle shield at the rear of the chassis, made of 1/16-inch aluminum 3 inches high, carries the a.f. gain and regeneration controls, as well as isolating the i.f. stage. In the right-hand rear corner can be seen the cathode by-pass and output coupling condensers. Care should be taken to mount the beat-frequency oscillator control condenser — as well as all other parts — solidly.

front to back. The ends are folded down to give a depth of 3 inches, the back being covered by a 3-inch wide piece of 1/16-inch thick stock screwed to ¼-inch square brass rods bolted in the two rear corners. The hole for the tuner will be cut to accommodate the particular type used. The front panel is also of aluminum 3/16-inch stock, 19 inches by 10½ inches high. The panel dimensions are made suitable for standard 19-inch relay-rack mounting. A standard base and panel could be used if one of suitable dimensions is obtainable. In the present instance, the 12-inch depth of the base, made necessary by the double row of components along the back, could not be met by the standard bases available.

The construction and wiring follow the same general practices as have been previously outlined. As shown in the bottom view, a baffle of thin aluminum sheet is placed around the a.v.c. amplifier-rectifier circuit to prevent undesirable coupling to the detector input circuit. Special precaution should be exercised to keep the signal from the beat oscillator from getting into the a.v.c. by stray coupling. The lead from the beat oscillator to the detector circuit is shielded, as shown in the schematic diagram. The lead from the crystal-filter unit to the first i.f. amplifier grid is also shielded with braid. The beat oscillator condenser and audio volume resistor are operated from the panel by quarter-inch bakelite shafts. These components are placed as near as possible to their associated circuits to eliminate long leads. The antenna terminal strip, with two connections for the doublet antenna and a third connection for ground, is on top of the base to the right of the first audio tube. The plate output terminals of the pentode power amplifier are tip jacks on the right side of the base. The power-supply cable is fitted with a standard four-prong plug for connecting to the socket in the power pack.

After proving the circuit connections, the first step in testing the receiver is to align the i.f. stages to the frequency of the filter crystal, which is 456 kc. This might be done with a test oscillator tuned to resonance with the crystal frequency. However, the more certain procedure is to use the crystal in a separate oscillator circuit temporarily rigged for the purpose. This oscillator may be a triode or screen grid tube in any of the standard circuit arrangements shown in Chapter Eight, the plate tank consisting of a 1-mh. or so i.f. coil and 100-$\mu\mu$fd. tuning condenser, or a broadcast-band coil and a 500-$\mu\mu$fd. tuning condenser. The a.v.c. circuit is first aligned. With all the tubes in place and the set switched on, the signal-meter potentiometer should be adjusted to give full-scale reading on the meter. Then the test oscillator should be coupled to the grid of the a.v.c amplifier tube by looping one end of an insulated wire around its grid tap and looping the other end of this insulated wire around the plate coil of the 456-kc. crystal oscillator. The crystal oscillator will first have been tested for oscillation, of course, by tuning for the dip of a milliammeter connected in its plate circuit.

Coupling transformer T_4 is tuned for maximum dip of the signal meter, the coupling to the oscillator being loosened if the meter dips to zero over a broad range of adjustment. The coupling is then transferred to the grid of the first i.f. tube and the primary and secondary of transformer T_2 are similarly adjusted for maximum dip of the meter. Then the coupling is transferred to the grid of the mixer tube, this grid being disconnected from the tuner. The output tuning of the crystal filter circuit, on top and toward the back of the filter unit, is also adjusted for maximum dip of the meter. For this adjustment it may be necessary to back off the r.f. gain control to get a sharp minimum reading for resonance. Following this the crystal should be replaced in the receiver. With the rejection condenser turned all the way to the left, which shorts out the crystal, a rough adjustment of the detector coupling transformer T_3 can be made. With the gain and volume controls full on, a peak of "hiss" should be noticeable by listening carefully with a headset or loud speaker connected to the appropriate output circuit. At the same

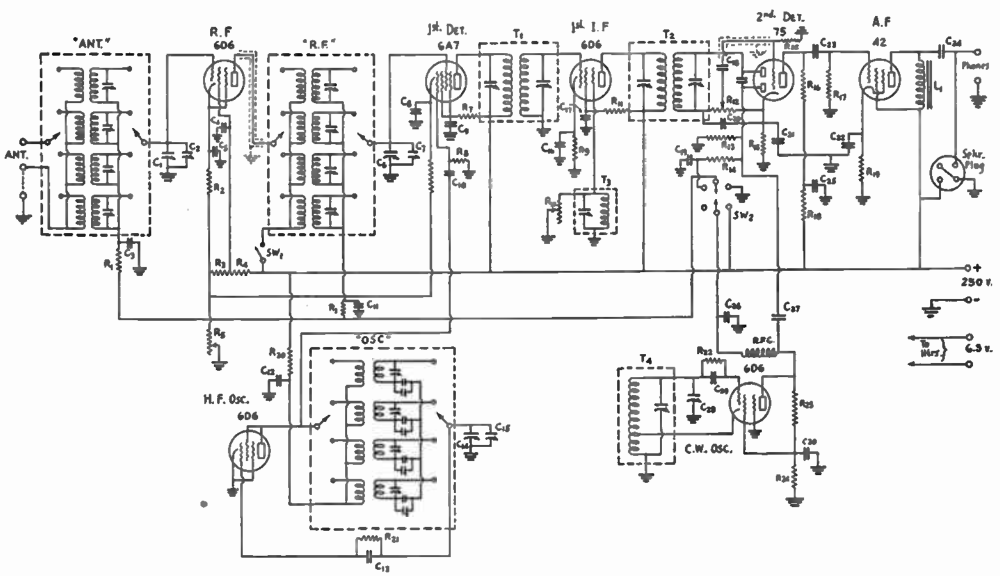


FIG. 728 — CIRCUIT DIAGRAM OF THE 7-TUBE SUPER

The sections marked "Ant", "R.F.", and "Osc" are contained in Gen-Ral coil assembly No. 34, 18 to 1.6 mc. See text for further details.

T_1 — National 500-kc. air-tuned i.f. transformer, interstage type.
T_2 — National 500-kc. air-tuned i.f. transformer, diode type.
T_3 — Sickles No. 801 456 kc. single-tuned i.f. unit in 1¼-inch can, with plate (untuned) winding removed.
T_4 — National 500 kc. beat-frequency oscillator unit, modified as described in text.
C_1-C_6-C_{14}, C_2-C_7-C_{15} — De Jong dual three-gang tuning condenser, 33 and 140 μμfd. per section respectively, supplied with dual tuning dial. Separate condenser gangs of proper capacity ranges and separate dials can be substituted.
C_3, C_4, C_5, C_8, C_{11}, C_{12}, C_{17}, C_{18}, C_{26}, C_{30} — 0.01-μfd. 400-volt tubular paper.
C_9, C_{16}, C_{19}, C_{23} — 0.1-μfd. 400-volt tubular paper.
C_{10} — 75-μμfd. midget mica.
C_{15}, C_{27} — 100-μμfd. midget mica.
C_{20} — 50-μμfd. midget mica.
C_{21}, C_{22} — Dual 10-μfd. 35-volt electrolytic.
C_{24} — 1-μfd. 400-volt can-type paper.
C_{25} — 4-μfd. 450-volt tubular electrolytic.
C_{28} — 20-μμfd. midget variable (Hammarlund MC-20-S).
C_{29} — Contained in T_4.
R_1, R_{14}, R_{16} — 250,000-ohm ½-watt.
R_2, R_9 — 500-ohm ½-watt.
R_3, R_4, R_{23}, R_{24} — 50,000-ohm 1-watt.
R_5 — 10,000-ohm variable.
R_6 — 300-ohm ½-watt.
R_7, R_{11} — 100,000-ohm ½-watt.
R_8, R_{15}, R_{21} — 50,000-ohm ½-watt.
R_{10} — 50,000-ohm variable.
R_{12} — 500,000-ohm variable pot.
R_{13}, R_{17}, R_{25} — 1-megohm ½-watt.
R_{18} — 5,000-ohm ½-watt.
R_{19} — 500-ohm 1-watt.
R_{20} — 5,000-ohm 1-watt.
R_{22} — Contained in T_4.
SW_1 — S.p.s.t. toggle, send-receive switch.
SW_2 — D.p.d.t. toggle, a.v.c.-b.f.o. switch.
L_1 — 22-henry 35-ma. choke (Thordarson T-6808).
RFC — 25-millihenry r.f. choke.

Field supply within the capabilities of the power pack is obtainable directly from the speaker plug (an ordinary speaker requires about 6 watts through 10,000 ohms, or 25 ma. at 250 volts; a "high-fidelity" type usually requires from 12 to 15 watts, or 50 ma. at 250 volts through 5000 ohms).

Shielding of the 6D6 r.f. stage plate lead and 75 grid lead should not be overlooked; at least ⅜-inch diameter shielding braid should be used, carefully grounded to chassis.

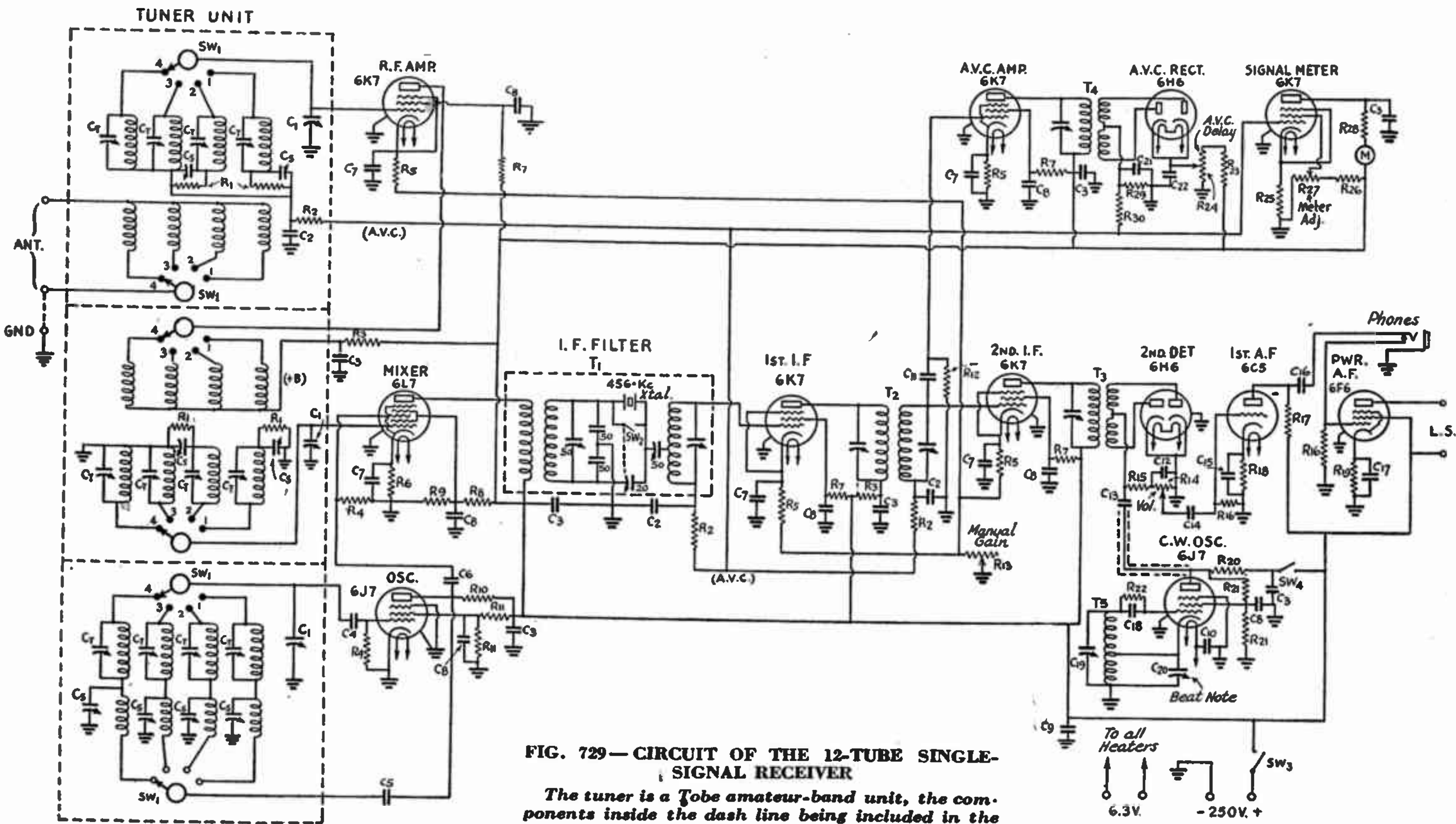


FIG. 729—CIRCUIT OF THE 12-TUBE SINGLE-SIGNAL RECEIVER

The tuner is a Tobe amateur-band unit, the components inside the dash line being included in the manufactured assembly.

CS *— Series band-spread and tracking condensers (in tuner).*
CT *— Parallel trimmer condensers (in tuner).*
C1 *— Triple-gang tuning condenser, approximately 30 μμfd per section (in tuner).*
C2 *— 0.01-μfd. grid by-pass condensers, 200-volt tubular.*
C3 *— 0.01- to 0.1-μfd. plate by-pass condensers, 400-volt tubular.*
C4 *— 50-μμfd. oscillator grid condenser, mica midget.*
C5 *— 100-μμfd. oscillator plate blocking condenser, mica midget.*
C6 *— 50-μμfd. osc. plate coupling condenser, mica midget.*
C7 *— 0.01- to 0.1-μfd. cathode by-pass condensers, 200-volt tubular.*
C8 *— 0.01- to 0.1-μfd. screen by-pass condensers, 400-volt tubular.*
C9 *— 0.25-μfd. main high-voltage by-pass, 600-volt tubular (may not be required).*
C10 *— 0.01- to 0.1-μfd. filament by-pass, 200-volt tubular.*
C11 *— 250-μμfd. a.v.c amp. coupling condenser, mica midget (inside shield of T2).*
C12 *— 50-μμfd. detector load by-pass, mica midget (may be omitted).*

C_{13} — 50-μμfd. beat osc. coupling condenser, mica midget.
C_{14} — 0.1-μfd. detector output coupling condenser, 200-volt tubular.
C_{15} — 5-μfd. cathode by-pass, 25-volt electrolytic.
C_{16} — 0.1-μfd. audio coupling condenser, 400-volt tubular.
C_{17} — 25-μfd. cathode by-pass, 50-volt electrolytic.
C_{18} — 0.001-μfd. beat osc. grid condenser (in T_5).
C_{19} — Beat osc. tank cond. (2 midgets in parallel inside T_5).
C_{20} — 20-μμfd. midget variable, 3-plate (beat-note control).
C_{21} — A.v.c. rectifier load by-pass, 100-μμfd. or larger, depending on time constant wanted. See Chapter Six.
C_{22} — 0.1-μfd. 200-volt tubular, delay circuit by-pass.

Unless otherwise noted, fixed resistors may be ½-watt type or higher rating.

R_1 — 10,000-ohm grid resistors (in tuner).
R_2 — 100,000-ohm grid decoupling resistors (higher resistance may be used to increase time constant of a.v.c.).
R_3 — 2000-ohm 1-watt plate decoupling resistors.
R_4 — 50,000-ohm grid leaks.
R_5 — 350-ohm cathode resistors.
R_6 — 500-ohm cathode resistor.
R_7 — 100,000-ohm screen grid dropping resistors.
R_8 — 10,000-ohm 1-watt.
R_9 — 75,000-ohm 1-watt (These two resistors make up voltage divider for mixer screen).
R_{10} — 10,000-ohm osc. plate load resistor.
R_{11} — 50,000-ohm osc. screen-voltage divider resistors.
R_{12} — 1-meg. a.v.c. amp. grid resistor (inside T_3).
R_{13} — 5000-ohm manual r.f. gain control, volume-control type.
R_{14} — 1-megohm volume control.
R_{15} — 50,000-ohm c.w. osc. coupling resistor.
R_{16} — 1-megohm audio-coupling grid resistors.
R_{17} — 100,000-ohm audio plate resistor.
R_{18} — 5000-ohm audio cathode resistor.
R_{19} — 450-ohm pentode cathode resistor.
R_{20} — 100,000-ohm beat osc. plate drop resistor.
R_{21} — 50,000-ohm b.f.o. screen divider resistors.
R_{23} — 50,000-ohm beat osc. leak (in T_5).
R_{22} — 20,000-ohm 1-watt.
R_{24} — 5000-ohm potentiometer for a.v.c. delay control.
R_{25} — 2000-ohm signal-tube cathode resistor.
R_{26} — 100,000-ohm.
R_{27} — 50,000-ohm potentiometer for meter setting.
R_{28} — 50,000-ohm meter limiting resistor (lower value for higher range meter).
R_{29} — 100,000-ohm a.v.c. rectifier load resistor.
R_{30} — 100,000-ohm a.v.c. filtering resistor (higher res. for larger time constant).
T_1 — Variable band-width crystal filter (National Type HRO).

Capacitance values in μμfd. are indicated by figures on diagram.

T_2 — Double air-tuned i.f. transformer (Hammarlund ATT-465).
T_3 — Single air-tuned full-wave diode coupling transformer (Sickles 456-kc.).
T_4 — Same as T_3.
T_5 — Beat oscillator unit, 456-kc. (National BFO).
M — 0-1 d.c. milliammeter. A 0-5 meter may be used.
SW_1 — Coil switch (in tuner unit).
SW_2 — S.p.s.t. crystal switch (ganged with phasing or rejection control in unit).
SW_3 — S.p.s.t. B-supply toggle switch.
SW_4 — S.p.s.t. b.f.o. toggle switch.

The power pack should be capable of furnishing 4 amps at 6.3 volts and approximately 100 ma. at 225 to 250 volts.

time, the selectivity or band-width control of the filter should be tuned for maximum noise output.

The next step is to check the alignment of the high-frequency tuner circuits. This procedure is covered in detail in the instruction sheets which go with the particular tuner used. The general procedure, preferably using a test oscillator, is to adjust the r.f. and detector input circuits for maximum response, first by making careful adjustment of the parallel trimming condensers with the tuning at the high-frequency end of each band. Adjustment of the series condensers with the tuning control at the low-frequency end of each band also will be necessary on the r.f. and first detector input circuits for the two higher-frequency ranges (7 and 14 mc.) with the Tobe amateur-band tuner. The oscillator trimming and tracking condensers will not need adjustment unless the band coverage is not properly placed on the tuning scale.

With these adjustments completed, the final alignment of the i.f. circuit to exact resonance with the series peak of the crystal is necessary. To do this, a steady signal from a test oscillator or from an amateur-band crystal oscillator should be used. This signal is tuned in with the filter crystal in its series connection, the phasing and band-width controls being set at approximately mid-scale with this particular filter unit. Peak resonance with the crystal will be indicated by bottom dip of the signal meter. Keeping the signal tuned in "right on the nose" and adjusting the gain control for a suitable dip deflection, the tuning adjustments of T_4, T_3 and the filter unit should be made for peak resonance in all circuits. The adjustments are likely to be slightly different from those obtained in the first alignment, with the crystal in a separate oscillator, because the frequency at which a crystal oscillates in the usual circuit is not the same as its frequency as a series resonator, as has been previously explained in Chapter Four.

When these adjustments have been completed, the beat oscillator should be switched on and its tank circuit set to give zero beat with the test signal on crystal resonance, the panel beat-note control being turned all the way to the right. These tank adjustments are at the top of the beat-oscillator shield can. A beat-note range from zero beat to several thousand cycles then should be obtainable by adjustment of the panel control. The final adjustment for resonance of T_3 is most conveniently made by listening for maximum volume from a modulated signal or adjusting for maximum indication on an output meter connected across the speaker circuit.

Throughout these adjustments the a.v.c.

delay control will have been set for full a.v.c. action (no positive bias between the a.v.c. rectifier cathode and ground). In operation, this control may be set to suit the type of signal and the receiving condition. As the cathode is made more positive with respect to ground, the initial signal level at which the a.v.c. action begins is raised. With this control turned to give maximum positive bias (all the way to the left) the a.v.c. is practically switched off. For 'phone reception, it will be usual to operate with the a.v.c. full on, while for c.w. it will be found more satisfactory to use an intermediate setting such that the a.v.c. becomes operative only on strong signal peaks. The manual r.f. gain control, as well as the audio volume control, can be independently set to suit conditions.

The user of a Single-Signal receiver of this type should become thoroughly acquainted with the operation of the crystal filter control so that he may realize the full benefit of this useful feature. The selectivity control (the upper one) governs the band-width of the crystal filter, as previously described. With the crystal in circuit, minimum selectivity (maximum band width) will occur with this control at approximately mid-scale. Either side of this point, the selectivity increases as evidenced by a reduction in noise level and a tendency to "ringing" pitch of noise crashes and strong signals. The mid-setting is the one to use for 'phone. The rejection control is operated in conjunction with the selectivity control for the particular purpose of eliminating heterodyne interference caused by signals within a kilocycle or so of the desired signal. This adjustment normally will also be set near mid-scale. When heterodyne interference occurs, this rejection control should be adjusted carefully for the point at which the heterodyne beat-note is minimum in strength or disappears entirely.

It is advisable to check over the alignment of the receiver occasionally, once a month or so, to make sure that none of the adjustments have drifted or have been jarred from their proper values. This applies particularly to the high-frequency tuning circuits.

Servicing Receivers

● The most useful instruments for locating faults in a defective receiver are a multi-range ohmmeter and a high-resistance d.c. voltmeter. A simple combination ohmmeter and d.c. voltmeter suitable for general receiver testing is shown in Chapter Seventeen. The ohmmeter 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 made. Lacking such an instrument, rough checks for circuit continuity (indicated by audible clicks) can be made with a pair of 'phones and a "B"-battery in series, connected across the circuit under check; or with a low-range d.c. voltmeter and battery in series. An a.c. voltmeter should be used for checking the line and filament voltages in a.c. operated sets.

If the tubes do not light, check the filament supply (transformer or battery) and connections. Zero voltage across the primary will result with a blown fuse in the primary of an a.c. supply. Check the voltage at the socket terminals of a single tube that fails to light when others come on. If voltage checks OK, the tube may be burned out or there may be a defective contact in the socket.

Unreasonable hum in an a.c. receiver usually indicates either an open filament center-tap resistor or a tube with low resistance (leakage) between heater and cathode. Such a tube should be replaced. Less likely causes of excessive hum are an open filter or by-pass condenser in the supply circuits, or a defective rectifier tube. An open receiving tube grid circuit also may cause bad hum, usually accom-

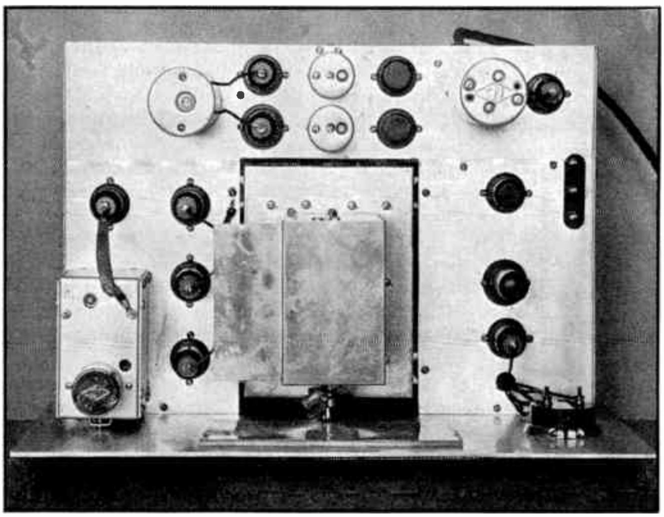


FIG. 730 — PLAN VIEW OF THE 12-TUBE S.S. SUPERHET DESCRIBED IN THE TEXT

A panel view of the same receiver is given in Fig. 701 at the beginning of this chapter. Locations are described in the text.

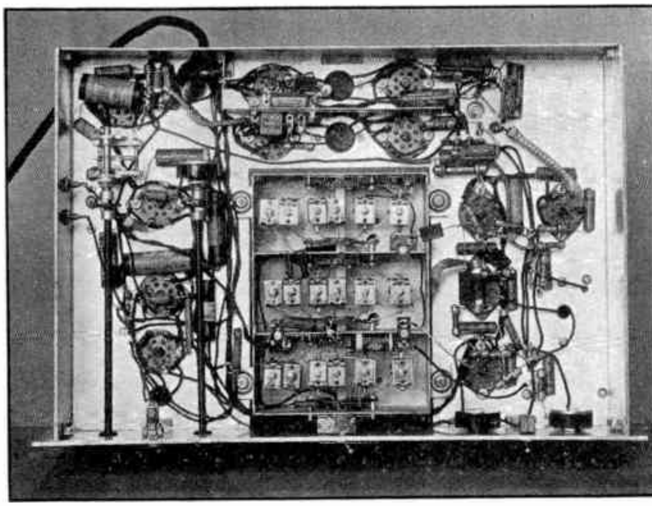


FIG. 731—THE UNDER-CHASSIS ASSEMBLY OF THE RECEIVER

The location of the components can be readily checked by referring to the plan view and the text.

panied by low output and serious distortion. Periodic clicking accompanied by poor sensitivity in a regenerative receiver may indicate an open detector grid leak or one of excessively high resistance. Replace the leak, using one of lower resistance if necessary.

If the filaments light but there is no output (set "dead"), first check the B-supply voltage and connections to the output stage. Even with no signal coming through there should be strong clicks when the headset or speaker is connected and disconnected. If the output circuit checks OK, clip a pair of 'phones across the output of each preceding audio stage, including the detector, until the signal is picked up, thus locating the circuit in which the fault lies. Check the tube, resistors, bypass and coupling condensers, etc., in the defective stage, both for shorts and opens, using an ohmmeter or its equivalent.

If strong clicks result when the grid of a regenerative detector is touched, but there is no signal or only very weak signal output, it is likely that the fault is in a r.f. circuit ahead of the detector. Check the r.f. tube or tubes and the plate circuits of preceding stages for opens and shorts. An open secondary circuit or grid coil may cause periodic clicking like that resulting from a defective detector grid leak, in which case the grid circuit should be tested for open circuit with an ohmmeter or 'phones and battery. If a circuit should test neither shorted nor open but does not "tune," look for a defective connection between coil and tuning condenser.

Noticeably weak signal response will result with an open antenna coupling coil or open connection in the antenna-ground circuit. A shorted grid condenser, either in a detector circuit or an r.f. amplifier using capacitive coupling, will have the same effect. This may be checked by removing the grid resistor, which should cause the periodic clicking sound in the output. Shorts of this kind can be caused by a blown condenser or by soldering paste smeared between the terminals. Needless to say all soldered connections should be thoroughly wiped with a clean cloth to prevent such leakages.

A regenerative receiver may "howl" just as the detector starts to oscillate. This "fringe howl" is most likely to result with transformer or impedance-coupled detector output and the best precaution against it is to use an audio transformer or choke of the better grade rather than one of the cheaper type with inadequate primary windings. If it does occur with the transformer that must be used, however, it can be reduced or eliminated by connecting a resistor across the secondary of the audio transformer. In most cases a resistance of 100,000 ohms will be sufficiently low. A grid leak of lower value also may help in some cases. These expedients reduce the receiver output, of course, and must be considered as less desirable than the substitution of an audio coupler having better characteristics.

"Stringy quality" or poor base-note response usually can be traced to an open or inadequate bypass capacitance in a detector or audio amplifier circuit. Too-small capacitance across a cathode resistor is a common source. An open or too-small grid condenser in a grid-leak detector also may be the cause of this trouble.

Servicing Superheterodyne Receivers

● In addition to the general receiver servicing suggestions given in the preceding section, 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. 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 bypass capacitance is a very common cause of such oscillation. Additional bypass capacitance, 0.1 to 0.25 μfd., usually will remedy this type of oscillation. The same applies to screen-grid bypasses 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. If the latter, replace with a new resistor, using one of lower resistance if necessary.

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, of course, as a result of the i.f. noise components beating with the carrier it furnishes in the second detector. The oscillator input to the second detector should be just enough to cause a noticeable change in second detector plate current. (About 0.05 ma. increase in the case of a self-biased triode second detector, for instance.)

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. They are not likely to occur with the circuits shown in the receivers of this chapter, and are prevented by the design precautions which have been given. Other "birdies" which show up in the operation of the receiver are most 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 somewhat similar motorboating effect can occur with a crystal-filter receiver operating at high selectivity when a strong signal is tuned a few cycles off crystal resonance. Under such a condition, the crystal is shocked into excitation at its own frequency, slightly off the i.f. signal frequency, and a slow beat between the two frequencies results. This constitutes overload of the crystal and is entirely normal. It is avoided by precise tuning and by keeping the input to the crystal circuit at a reasonable level by proper setting of the r.f. gain.

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 through a large capacitance, 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 output with the first detector (mixer) input shorted would indicate that the first detector tube 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. Alternatively, a "Variac" can be connected in the a.c. supply circuit and the line supply voltage varied approximately 10 percent plus and minus normal (say from 100 to 130 volts). The beat note should remain similarly steady. A change of a kilocycle or more would indicate poor stability. 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 2½-inch diameter). Calibration spread of 10 kc. or less per scale division is satisfactory for reset and logging purposes.

CHAPTER EIGHT

Principles of Transmitter Design and Operation

OSCILLATORS — AMPLIFIERS — NEUTRALIZATION AND TUNING — FREQUENCY MULTIPLICATION — TROUBLE SHOOTING

PRESENT-DAY amateur transmitters are of two general types: those which employ "self-controlled" oscillators and those in which a crystal-controlled oscillator is used. The first of these types is called "self-controlled" because the frequency of the oscillations generated in the transmitter depends on the constants of the circuit. In the second type a piezo-electric crystal determines the frequency on which the transmitter operates.

When an oscillator of either type is used to feed the antenna directly, the transmitter is said to be "self-excited." If, however, the oscillator drives one or more amplifier tubes which in turn feed the antenna, the arrangement is known as an "oscillator-amplifier" transmitter. One may have either a self-controlled or a crystal-controlled oscillator-amplifier transmitter.

Transmitting Tubes

● An excellent variety of power tubes is available to the amateur contemplating the construction of a high-frequency transmitter. The large number of tubes is, in fact, often a source of confusion to the beginner because it is difficult for him to decide upon the type best suited to his particular purpose. Broadly speaking, however, tubes may be classified according to the power output to be expected from them. Thus, a group of small tubes for use in low-power transmitters show power outputs of the order of 10 to 25 watts; a group of medium-power tubes is rated at 35 to 50 watts output; a third group carries a nominal rating of 100 watts, and so on. Obviously, then, the first decision the amateur has to make in the choice of a transmitting tube is that of the power output he wants. The tables of transmitting tubes in Chapter Five give the important characteristics and operating ratings of the tubes most suitable for use as radio-frequency oscillators and power amplifiers.

The tubes are listed in two classifications, triodes or three-element tubes comprising the first. They are useful as oscillators or power amplifiers. All are capable of working well on the four lower-frequency amateur bands which carry the bulk of amateur communication — the 1.75-, 3.5-, 7- and 14-mc. bands. The types marked with an asterisk (*) are especially designed for very high frequency work, and in addition to giving excellent performance on the four bands just mentioned, also will be found to be well suited to work on 28 and 56 megacycles.

The tetrodes and pentodes listed in the second classification are intended particularly to be used as radio-frequency power amplifiers. They are of the screen-grid type and can be used without neutralization (see later section). They are also useful in certain types of oscillator circuits.

In addition to the tubes designed especially for transmitting, practically all of the power-amplifier type receiving tubes have been adapted by amateurs to use in transmitters. Popular types include the 45, 46, 59, 47, 2A5, 53 and 42. The pentodes are widely used as crystal-oscillator tubes, while both triodes and pentodes are in general use as buffers and doublers, and even as final stages in low-power transmitters. With plate voltages of about 400, all these tubes are capable of outputs of five or ten watts.

Self-Controlled Oscillator Circuits

● There are two general divisions of self-controlled oscillator circuits; those employing capacitive coupling to feed back energy from the plate to the grid circuit, and those using inductive coupling for the same purpose. All circuits are modifications of these two general classes.

The operation of the vacuum tube as an oscillator has been explained in Chapter Five. The maximum amplitude to which oscillations will build up depends upon the characteristics of the tube, the circuit constants, the grid bias and the plate voltage. The frequency of oscillation will be determined principally by the inductance and capacity values in the tuned circuit — called the "tank" circuit because it acts as a reservoir of radio-frequency energy — although other circuit constants such as the interelectrode capacitances of the tube also will affect the frequency.

The circuits in most general use are the Hartley, Armstrong or tuned-grid tuned-plate, Colpitts and ultraudion. They are shown schematically in Fig. 801.

The Hartley Oscillator

● In the Hartley oscillator, shown in Fig. 801, the tuned circuit has its ends 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. In this way the coil is divided into two sections, one in the grid circuit and one in the plate circuit. Oscillations are maintained because of the inductive coupling between these two sections.

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 feedback 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.

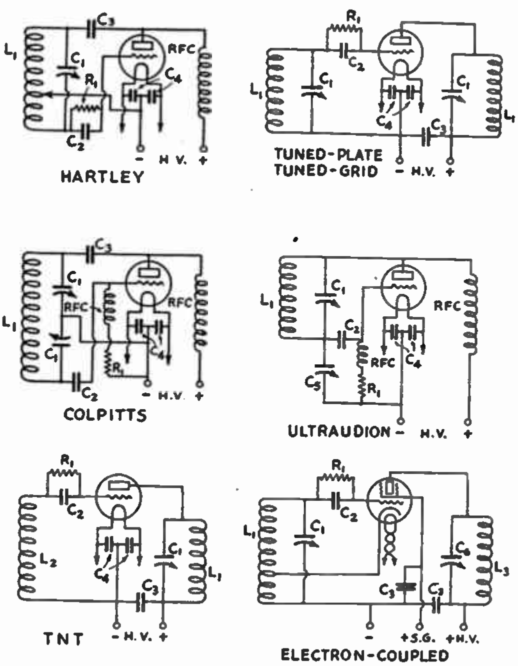


FIG. 801 — SELF-CONTROLLED OSCILLATOR CIRCUITS

All are capable of giving good frequency stability and efficiency with careful design and adjustment. For the benefit of the experimenter, the following suggestions are given for circuit constants: L_1, C_1, depending upon frequency band to be used; consult coil table for inductances, using a 500-μμfd. condenser at C_1. The grid condenser, C_2, may be from 100 to 250 μμfd. in all circuits; its value is not generally critical. The plate blocking condenser, C_3, should be .002 μfd. or larger. Filament bypass condensers, C_4, may be .002 μfd. or larger. For value of grid leak, R_1, consult tube table in Chapter Five. In the ultraudion circuit the excitation control condenser, C_5, should have a maximum capacity of 100 to 250 μμfd. The output tank circuit, L_3, C_6, in the electron coupled circuit should be designed for low-C operation; use a 250- or 100-μμfd. condenser for C_6 and corresponding inductance from the coil table for the frequency in use.

In the circuits using parallel feed, the r.f. choke coils shown should not be omitted.

Blocking and Bypass Condenser Functions

● The plate blocking condenser, C_3, is used to provide a low-impedance path for r.f. currents while preventing the d.c. plate voltage from being short-circuited to the filament center-tap through L_1. Its value is not critical. C_2, the grid condenser, similarly insulates the grid from filament center-tap to permit the bias voltage to develop in the grid leak, R_1. The filament by-pass condensers, C_4, are used to provide an r.f. center-tap for the filament so that radio-frequency currents flowing in that circuit will divide equally between the two halves of the filament. Grid and plate blocking or bypass condensers and filament bypass condensers have the same general function in all the oscillator circuits shown.

Tuned-Plate Tuned-Grid and "TNT" Oscillators

● The tuned-grid tuned-plate circuit has two tank circuits, one connected between the grid and the filament of the tube and the other between the plate and filament. These two circuits 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, although the grid tank affects the frequency to a lesser extent. The chief function of the grid tank is that of controlling the feed-back or excitation. It should be set to a slightly lower frequency than the plate tank in normal operation.

A variant of the t.p.t.g. circuit is the so-called "TNT" circuit, also shown in Fig. 801. In the TNT, the grid tank is replaced by a coil which, with its own distributed capacity and the capacity of tube and wiring connected across it, is broadly resonant at the operating frequency. Its chief advantages are its economy and the fact that it is a very simple circuit to tune once the proper size for the grid coil has been determined.

Colpitts and Ultraudion

● The Colpitts circuit is arranged so that the filament is connected to the junction of two condensers which are in series across the coil. In this way the grid and plate circuits share the voltage drop across the condensers.

Excitation with the Colpitts circuit is controlled by varying the capacity ratio of the two tuning condensers, the total capacity of the two in series being maintained constant to retain the same frequency of oscillation. The larger the capacity of the condenser between grid and filament compared to that between grid and plate, the lower is the excitation voltage, and vice versa. With most tubes the "grid" condenser will have about twice the capacity of the "plate" condenser for normal operation.

The ultraudion circuit, a member of the Colpitts group, is seldom used except at the ultra-high frequencies. Excitation is controlled by C_5; the larger the capacity of C_5, the lower the excitation. The division of r.f. voltage across the tube elements is secured through the interelectrode capacities of the tube and the method of connecting the tank circuit.

The Electron-Coupled Circuit

● The electron-coupled circuit is a development from the fundamental circuits already discussed, made possible by the screen-grid tube. This circuit gives in one tube some of the beneficial effects of the oscillator-amplifier arrangement. The control-grid, cathode and screen-grid, the latter being used as a plate, are combined in a conventional triode oscillating circuit with the screen at ground potential for r.f. voltage. The output of the oscillator is taken from the regular 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 Hartley circuit is used in the oscillator portion of the circuit shown in Fig. 801, although the Colpitts could be substituted if desired. Excitation is controlled in the same way as in the ordinary Hartley circuit.

With suitable care in design and operation, electron-coupled oscillators will provide a high order of frequency stability. The plate or output circuit may be tuned to a harmonic of the oscillator circuit as well as to the same frequency. The output usually drops off rapidly on harmonics above the second, however.

"Grounds" and Ground Potential

● Throughout this chapter reference frequently will be made to "ground" or the "grounded" part of the circuit. In many instances this does not mean that an actual ground connection is necessary, but simply refers to the part of the circuit which is at the same radio-frequency potential as the earth, and which therefore *could* be connected to earth without in any way disturbing the operation of the circuit. The "grounded" part of the circuit nearly always will be the part which is connected to the negative terminal of the high-voltage power supply. Parts of the circuit at ground potential usually are connected together with direct wire connections or through bypass condensers, the latter being used when the two parts so connected are at the same r.f. potential but have different d.c. or a.c. voltages on them. For instance, the condenser C_3 in the electron-coupled circuit of Fig. 801 connects the end of the tank coil opposite the plate to the filament center-tap, thus bringing the lower end of the tank coil to the same potential as the filament.

Oscillator Bias

If the rectified grid current is made to flow through a resistor connected in the d.c. circuit between grid and filament, there will be a voltage drop in the resistor which can be utilized as grid bias, since the direction of current flow is such that the end of the resistor or grid leak nearest the grid is negative with respect to the end connected to the filament. The bias voltage developed in the grid leak will be equal to the product of the leak resistance in ohms by the d.c. grid current in amperes. If the grid current through a 5000-ohm leak is 10 milliamperes, for example, the bias will be 5000×0.010, or 50 volts.

The bias on an oscillator is a function of the excitation and grid-leak resistance. Oscillator bias is self-regulating, adjusting itself to meet varying conditions of excitation. In general, grid leak values are not critical. A resistance of 10,000 ohms is suitable for most tubes working as self-controlled oscillators, although tubes having very low amplification factors may require 25,000 or 50,000 ohms, while tubes with very high μ's may operate best with values of 5000 ohms or lower.

Series and Parallel Feed

● In the Hartley oscillator circuit of Fig. 801, the positive d.c. plate voltage lead is shown connected to the plate through a radio-frequency choke coil, *RFC*. The tank circuit is then connected to the plate through the blocking condenser, C_3. This method of supplying d.c. power to the plate is known as "parallel feed" because the r.f. and d.c. plate-filament circuits are in parallel. Parallel feed requires the use of an r.f. choke having high impedance at the operating frequency so that none of the r.f. power generated by the tube can leak back to the power supply instead of going to the tank circuit where it belongs.

D.c. plate power for the t.p.t.g. oscillator is shown fed through the plate tank coil to the plate, a bypass condenser, C_3, being connected across the positive and negative high-voltage terminals. The d.c. and r.f. plate circuits are thus in series, and this method of supplying d.c. power to the tube is known as "series feed." With parallel feed, the plate power is fed in at a point of high r.f. potential; with series feed, the feed point is at low r.f. potential.

Series feed is usually to be preferred from the standpoint of circuit efficiency because it is not necessary to depend upon an r.f. choke to prevent leakage. With an effective choke, however, there will be negligible loss with parallel feed. With series plate feed, the shaft of the plate tank condenser usually is at d.c. plate potential above ground so that with high plate voltages there is an element of danger to the operator of the transmitter unless the condenser shaft is adequately insulated from the control knob. With parallel feed there is no d.c. voltage on the condenser shaft.

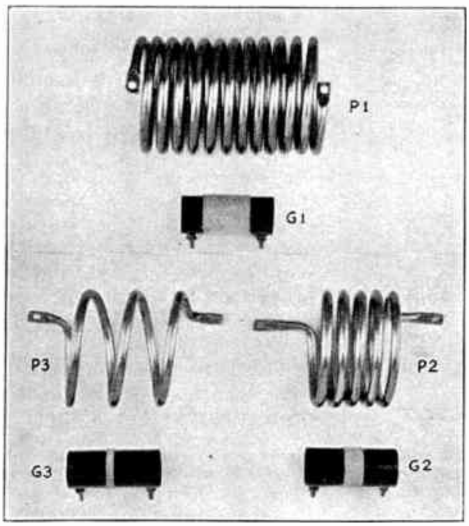


FIG. 802 — TYPICAL HIGH-C COILS FOR THE SELF-CONTROLLED OSCILLATOR

The copper-tubing coils, P_1, P_2 and P_3, are for the 3.5-, 7- and 14-mc. bands, respectively. They will be satisfactory for any of the circuits shown in Fig. 801. The smaller coils are of the type often used for the resonant grid coil in TNT oscillators.

Series and parallel feed may be used in other circuits than the plate as well. For example, the grid bias for the t.p.t.g. circuit is series fed, while the grid bias for the Colpitts circuit is parallel fed. In some cases series feed may be quite difficult, if not impossible, to attain. This is the case of the grid feed for the Colpitts circuit; the grid leak cannot be connected across the grid condenser to give series feed because there is no d.c. path from the grid condenser to filament.

Frequency Stability

The causes of frequency instability can be roughly divided into two groups, those which are "mechanical" in nature and those which are "dynamic." Mechanical instability results from variations in the circuit constants due to mechanical vibration and thermal effects. Mechanical vibration will cause rapid fluctuations in frequency by varying the spacing between condenser plates, the separation between coil turns or the distance between the tube elements. These are avoided largely by rigid construction, by reducing the vibration and by mechanically isolating the oscillator.

Frequency fluctuation ("creeping") due to thermal effects results from variation in spacing of the tube elements (variation in inter-element capacity) or circuit components with changes in temperature. Creeping can be minimized by keeping the power dissipated in the tube at or below its normal rating, by choosing tubes having internal construction particularly intended to reduce frequency-creeping (low internal capacities), and by using circuits which have large capacities in parallel with the tube's input and output capacities. Such circuits are popularly known as "High-*C*" circuits. The use of a large shunting capacity in the plate circuit is particularly effective.

"Dynamic" instability is caused by anything which affects the tube's characteristics, especially its plate impedance, during operation. A variation in plate impedance will cause a change in frequency. The principal cause of dynamic frequency instability — sometimes called "frequency flutter" — is the variation in plate voltage which results when a poorly-filtered plate supply is used. The variations in plate voltage under these conditions take place at an audible rate, causing the oscillator frequency to vary or be modulated at the same rate. The result is a broad, rough signal, unpleasant to the ear and illegal under the amateur regulations.

To prevent dynamic instability it is essential that the plate supply be the best "pure d.c." obtainable and that the grid bias — or grid leak — be sufficiently high in value. Moreover, too much care cannot be exercised in adjusting the grid excitation. Dynamic instability can be reduced by careful circuit design; the use of a High-*C* plate tank is especially effective. Such a tank circuit is capable of reducing the amplitude of frequency fluctuations with variations in plate impedance.

High-C Tank Circuits

● For low-power transmitters a circuit is sufficiently high-C if the actual condenser capacity in use is approximately 400 to 450 μμfd. at 3500 and 1750 kc., 250 to 300 μμfd. at 7000 kc., and 200 to 250 μμfd. at 14,000 kc. Typical tank coils for high-C circuits of low-power transmitters are shown in Fig. 802. They are made of quarter-inch copper tubing for the sake of rigidity and also because the circulating currents in high-C circuits are quite large, even with low power, hence considerable current carrying capacity is needed. The smaller coils illustrate the way in which grid coils for the TNT circuit can be made; they can be wound with fine wire because of the low current flowing in the low-C grid circuit.

Push-Pull Oscillator Circuits

● Push-pull oscillator circuits are developed from the single-tube circuits already described. Several push-pull circuits are given in Fig. 803. Their similarity to the fundamental circuits from which they are derived will be recognized after inspection. The push-pull Colpitts requires two tuning condensers (or a split-stator condenser) and provides no means of excitation control except through variable grid condensers. The push-pull Hartley is seldom used because the large number of taps on the coil makes a cumbersome mechanical job with the small coils used in high-C circuits.

The unity-coupled circuit resembles the Hartley except that separate coils, very closely coupled, are provided for the grid and plate circuits. In actual practice the grid coils are similar to the copper-tubing coils shown in Fig. 802, while the plate coil is made of small, well-insulated wire run through the center of the tubing. A hole is drilled in the center turn of the copper-tubing coil to allow a connection to be made to the center of the plate coil inside. Where a large number of turns is required, as for a 1750-kc. coil, the two coils may be wound of No. 14 wire on an insulating form, one coil being wound between the turns of the other.

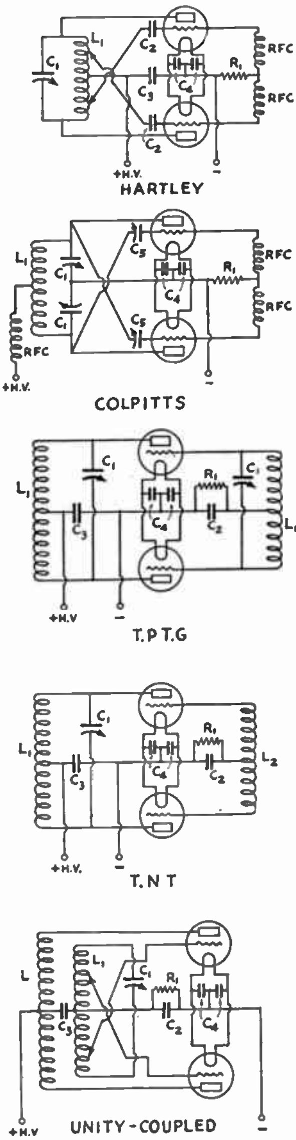


FIG. 803 — PUSH-PULL SELF-CONTROLLED OSCILLATOR CIRCUITS

Circuit constants are much the same as those for the single-tube circuits given in Fig. 801. Tank tuning condensers, C_1, should have a maximum capacity of 250 to 500 μμfd. Specifications for L_1 may be taken from the coil table, or coils similar to the copper-tubing coils shown in Fig. 802 may be used. Since the two tubes are in series in a push-pull circuit, a somewhat higher LC ratio than is generally recommended for single-tube circuits can be used without detriment to the dynamic stability. The actual condenser capacity in use should be approximately 250 μμfd. at the operating frequency, and coils may be proportioned accordingly. Grid condensers, C_2, may be 100 to 250 μμfd., except in the Colpitts circuit, where variable condensers (C_5) having a maximum capacity of 50 μμfd. should be used, the correct operating value being determined by experiment. Plate blocking and filament bypass condensers, C_3 and C_4, should be .002 μfd. or larger, although the values are not critical.

The resistance of the grid leak, R_1, will in general be half that recommended in the tube table for a single tube. Slightly higher values may be found to give better efficiency and a better note.

Crystal-Controlled Oscillators

● Although closely resembling the self-controlled oscillator in principles of operation, the control of frequency in the crystal oscillator is, as the name implies, lodged in a specially-ground slab of piezo-electric crystal, usually quartz. The piezo-electric crystal and its properties have already been discussed briefly in Chapter Four.

The piezo-electric crystal, because of its electro-mechanical properties, will oscillate at a frequency determined almost entirely by its dimensions. When it is properly connected in the controlling oscillator circuit, the line voltage can vary, the antenna can swing, and the tubes may heat without seriously affecting the output frequency of the transmitter. A ripple in the plate-supply voltage will cause amplitude modulation of the output of such an oscillator but can cause practically no frequency flutter.

Crystal Cuts

● A quartz crystal has three major axes, designated *X*, *Y* and *Z*. The *Z* axis is the optic axis. The *Y* axis is the mechanical axis. The *X* axis is the electric axis and is the one used as a reference in designating the cut of the plates used in oscillators. A plate cut with its major surfaces perpendicular to an *X* axis is known as an X-cut plate. This cut is also referred to as the "perpendicular" and "Curie" cut. Plates cut with their major surfaces parallel to an *X* axis are known as "Y," "parallel," and "30-degree" cuts. The most accepted terms for these two cuts are X-cut and Y-cut. In Fig. 804 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. These cuts demand extreme accuracy in cutting and grinding if the special characteristics are to be obtained. The exact way in which some of the cuts are taken from the crystal are known only to the manufacturers.

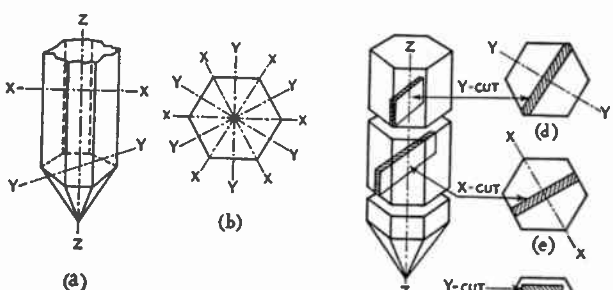


FIG. 804—DRAWING OF AN IDEAL QUARTZ CRYSTAL SHOWING LOCATION OF AXES AND ORIENTATION OF "X" AND "Y" CUTS

Crystal Grinding

● Reliable crystals are available at reasonable prices, so that the ordinary amateur does not attempt to cut and grind his own crystals. Cutting crystals requires special equipment and an accurate means for locating the crystal axes; because of the complications amateurs seldom attempt to cut crystal blanks from raw quartz. However, unfinished X- and Y-cut blanks (slices of quartz which can be ground into oscillating crystals) can be purchased cheaply, and some experimenters like to finish them into crystals which will oscillate at a desired frequency. Again, 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.

When an unground blank is purchased, a statement of the cut should be obtained from the seller, because the grinding cannot be done so easily if the ratio of thickness to frequency is not known. Fig. 805 gives the frequency-thickness relationships. 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. The best crystals are usually about 1" square, perfectly flat, and the two major surfaces are parallel.

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. It is better to have the crystal stuck to a perfectly flat piece of thin brass or a glass microscope slide than to bear down on the surface of the crystal with the fingers. Even pressure over the whole area of the crystal is essential for flat grinding. The crystal will stick to the flat brass plate or slide if the top of the crystal is moistened with kerosene. The crystal should be frequently tested for oscillation in a test circuit such as one of those shown in Fig. 807. If the crystal 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 17. 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

● In Chapter Four it was pointed out that the piezo-electric crystal is a mechanical vibrator. As a result of molecular friction when the quartz plate is vibrating at the tremendous rate required for the production of radio-frequency oscillations, heat is developed. This heating of the crystal causes it to change its characteristics slightly so that the frequency varies with the temperature. The rate of frequency change with temperature depends upon the type of cut, the precision with which the crystal was cut and ground, its size and shape, and individual characteristics of the quartz used.

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 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.

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. The vibration of a quartz crystal is extremely complex; in addition to vibrations of the type wanted for frequency control, there may also be present vibrations of other types which contribute to the heating and produce mechanical stresses in the crystal. When the vibration amplitude is high these stresses may be great enough to shatter the crystal, hence the power-handling capabilities of the crystal are limited. Secondary vibrations are always present in X- and Y-cut crystals; the AT-cut crystal is almost free from them, hence is capable of handling more power than either the X- or Y-cut.

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 simpler to construct and is generally used by amateurs. It is essential that the surfaces of the metal plates in contact with the crystal be perfectly flat. Satisfactory mountings can be purchased from most dealers in crystals or can be made up by the amateur.

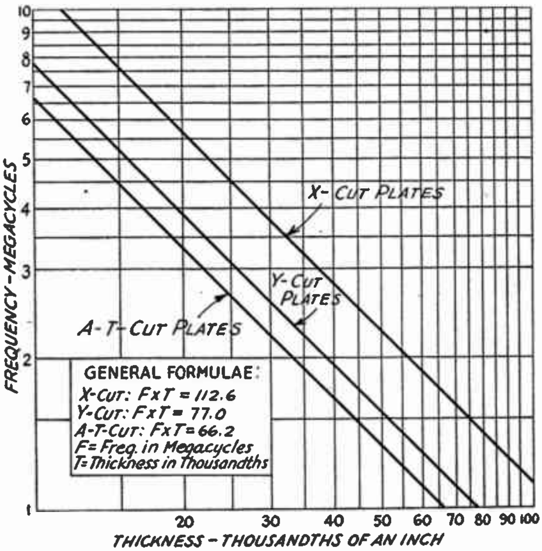


FIG. 805 — FREQUENCY-THICKNESS RELATIONSHIPS OF X-, Y- AND AT-CUT PLATES

Grit or an oily film on the surface of a crystal will affect its operation and will sometimes prevent oscillation. The crystal should be cleaned whenever erratic behavior or stoppage of oscillation gives evidence of a dirty condition. Carbon tetrachloride (Carbona) or alcohol are the best cleaning fluids. Plain 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. With Y-cut plates it is often possible to cause the crystal frequency to "jump" simply by changing the pressure of the top plate or by moving it about on the crystal. The present tendency with manufactured crystals is to sell them in individual holders to insure retaining calibration and to protect the crystal from dust and dirt.

Triode Crystal Oscillators

● The simplest crystal oscillator circuit is the triode circuit shown in Fig. 807. 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 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 vibration of the crystal, or more precisely, the amplitude of the r.f. voltage developed as a result of the mechanical vibration, as we have seen.

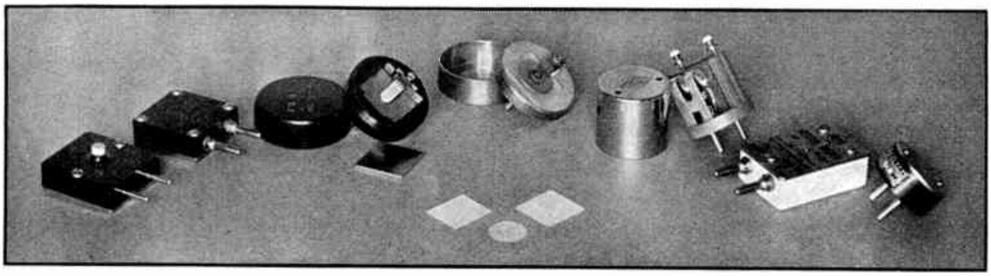


FIG. 806—CRYSTALS AND CRYSTAL HOLDERS

Several manufactured types of crystal holders are shown. The circular crystal in the foreground is a 20-meter plate.

In the simple triode oscillator circuit of Fig. 807, the limit of plate voltage that can be used without endangering the crystal is about 250 volts for X- and Y-cut crystals, although this figure will vary with the crystal itself, its mounting, and the type of tube used. Tubes with low amplification factors — the 45, for instance — should be operated at lower plate voltage than tubes with medium or high μ's, because low-μ tubes require a relatively large exciting grid voltage for a given output.

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, the power output obtainable from triode crystal oscillators is about five watts. The simple triode oscillator has been generally superseded by more suitable types.

The 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 of the crystal, obviously the greatest power output can be secured without danger to the crystal by choosing a tube of high power sensitivity (see Chapter Five). The power pentode is such a tube, hence we find that pentodes are widely used as crystal oscillators in amateur transmitters. Along with high power-sensitivity, the presence of the screen grid in the pentode 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 crystal oscillators can be operated at higher plate voltages than triodes.

The pentode tubes designed for audio power work, such as the 47, 2A5, 41, 42, and 59 (with proper element connections), are excellent crystal oscillator tubes. For a given plate voltage the crystal heating will be less with a pentode than a triode as the oscillator tube; alternatively, for the same amplitude of crystal vibration, higher plate voltages can be used with the pentodes, resulting in greater power output. A typical pentode oscillator circuit is shown in Fig. 807. It has been found best to operate the screen grid at approximately 100 volts; plate voltages up to 500 may be used without danger to the crystal. Power outputs of ten to fifteen watts can be obtained quite readily with 400 to 500 volts on the plate.

High-Power Pentode Oscillators

● Transmitting pentodes also can be used as crystal oscillator tubes, the larger tubes giving large outputs. Since these tubes have quite thorough screening, it may be necessary in some cases to provide additional feedback between plate and grid to ensure oscillation. This feedback can be secured by bringing a wire from the plate of the tube close to a similar wire connected to the grid of the tube to form a very low-capacity condenser, or by connecting a variable condenser of the type used to neutralize low-capacity triodes (such as the neutralizing condensers illustrated in Figs. 923 and 924 in the next chapter) between control grid and plate.

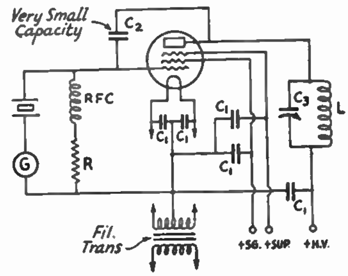


FIG. 808 — CIRCUIT FOR A HIGH-POWER PENTODE OSCILLATOR WITH EXTERNAL FEEDBACK

This circuit is suitable for use with RK20, RK28 and 803 tubes. Suitable values for C_1 are .001 or .002 μfd., C_2 as in text, and C_3, 100 μμfd. The grid leak, R, should be about 15,000 ohms, while L is wound to be resonant, in conjunction with C_3, at the frequency of the crystal used. The r.f. crystal current should not exceed the safe value for the type of crystal used.

Push-Pull Crystal Oscillators

● Two tubes may be connected in push-pull in the crystal oscillator, if desired; likewise, tubes may be connected in parallel. Just as with self-controlled oscillators, parallel operation entails no circuit changes other than tying all identical tube elements together. In the push-pull circuit, the crystal is connected between the grids of the tubes, as shown in the typical push-pull pentode circuit of Fig. 807.

Push-pull oscillators are useful for exciting a following push-pull amplifier on the same frequency. Since push-pull amplifiers are not suited to frequency doubling, however, the push-pull crystal oscillator is seldom used in multi-stage amateur transmitters.

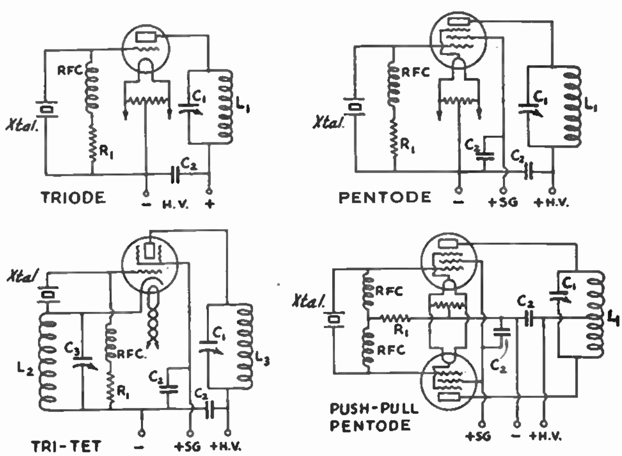


FIG. 807 — CRYSTAL OSCILLATOR CIRCUITS

In crystal oscillator output tank circuits it is generally advisable to use a fairly high LC ratio for best output and efficiency. The plate tuning condensers, C_1, may have a maximum capacity of 50 to 100 μμfd., with tank coils, L_1, having suitable inductance to make the circuit resonant at the crystal frequency. Coil specifications can be taken from the coil table. The cathode tank circuit, C_3L_2, in the Tri-tet oscillator is adjusted as described in the text; the output circuit, C_1L_3, will be similar to the output circuits used in the other crystal oscillators. Plate and screen bypass condensers, C_2, may be .002 μfd. or larger. The resistance of the grid leak, R_1, should be 5000 or 10,000 ohms except in the Tri-tet circuit, where a leak of 25,000 to 50,000 ohms will be found advisable, especially if the output circuit is tuned to a harmonic.

Crystal Oscillator Circuit Constants

● Triode and pentode crystal oscillator circuits are practically identical except for the screen supply in the pentode circuit. The screen, however, plays no part in the operation of the circuit except to perform its usual function of accelerating electron flow to the plate; it is bypassed to the cathode through a condenser of low reactance at the operating frequency and therefore has the same r.f. potential as the cathode.

Since quartz is an excellent insulator, parallel feed (see earlier section) must be used in the grid circuit to provide a path for the flow of d.c. grid current. In all circuits shown a grid leak furnishes the operating bias when the tube is oscillating; the r.f. choke in series prevents r.f. current from flowing through the leak. Occasionally the r.f. choke is omitted in cases where a high-resistance leak is called for — if the oscillator tube is a 45, for example — but it is usually good practice to include the choke. The choke should never be omitted except when a non-inductive grid leak is used, and then only when the leak resistance is of the order of 20,000 ohms or higher. Lower values place a considerable load on the crystal and may reduce the power output or even prevent the crystal from oscillating. With the receiving-type pentodes previously mentioned, a leak resistance of 5000 to 10,000 ohms is generally satisfactory. A power rating of one or two watts is sufficient.

In the pentode circuits using small tubes, the screen voltage may be supplied from a separate source of about 100 to 150 volts, from a voltage divider across the plate supply, or through a series resistor from the positive side of the plate supply. With the latter method, a resistance of 50,000 ohms, two- to five-watt rating, is commonly used.

It is unnecessary to use a high-C tank circuit in the crystal oscillator for the sake of stability, since the stability is determined almost solely by the crystal itself. Greater ease of oscillation, better efficiency and higher harmonic output are usually secured when the tank has a high L-C ratio, all of which are desirable in the case of the crystal oscillator. A tank condenser, C_1, having a maximum capacity of 50 to 100 $\mu\mu$fd. is large enough. A receiving-type midget condenser has ample plate spacing.

The inductance of the tank coil, L_1, 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 with a high L-C ratio when handling the amount of power developed by the usual crystal oscillator.

Tuning Adjustments

● A crystal oscillator is quite easy to adjust, since there is little the operator can do to change the frequency or to have an adverse effect on the frequency stability. Tuning therefore becomes chiefly a matter of obtaining the optimum amount of power from the oscillator.

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

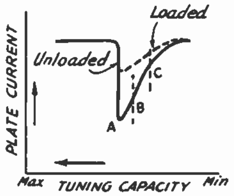


FIG. 809 — D.C. PLATE CURRENT VS. PLATE TUNING CAPACITY WITH THE TRIODE OR PENTODE CRYSTAL OSCILLATOR

Solid line, oscillator unloaded; dashed line, loaded.

will dip when the plate condenser is tuned through resonance at the crystal frequency. Fig. 809 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 when 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*.

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. The r.f. crystal current also is less when the tuning is in the region *B-C*, Fig. 809, than at *A*, furnishing an additional reason for slight detuning on the high-frequency (or low-capacity) side of resonance.

Harmonic Generation — The Tri-Tet

● Since the crystal is a single-frequency device, 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. 807, arranged for use with a screen-grid tube having an indirectly-heated cathode, such as the 24-A. 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 well-screened tube such as the 24-A must be used, otherwise the tube may oscillate as a t.p.t.g. oscillator. For harmonic generation only, the 59, 2A5 or equivalent tubes will deliver good output, but are not sufficiently well screened for fundamental operation. Because of the way in which the circuit operates, a relatively large r.f. voltage appears across the crystal under some conditions. This will cause heating of the crystal if certain operating precautions are not observed. The cathode tank circuit, L_2C_3, should not be tuned to the frequency of the crystal, as might be expected, but to a considerably higher frequency. For example, L_2C_3 will be tuned to approximately 5000 kc. when working with a 3500-kc. crystal, and the circuit constants should be proportioned accordingly. A circuit designed to be high-C at the crystal frequency will give best results. Tuning off in this manner not only reduces crystal strain but usually also increases the output on harmonics. The second factor affecting crystal heating is the voltage on the screen grid, which must be kept at the correct operating value for the type of tube in use. The screen voltage should not exceed 125 volts with tubes of the 59, 89, and similar types. Plate voltages up to 350 may be used.

With pentode-type tubes having separate suppressor connections, the suppressor may be tied directly to the screen or may be operated at about 50 volts positive. The latter method will give somewhat higher output than with the suppressor connected to ground or the cathode. More than 50 volts usually does not increase the output perceptibly.

Tri-Tet Circuit Constants and Tuning

● The importance of using a high-C (for the crystal frequency) cathode tank circuit in the Tri-tet oscillator has been emphasized in the preceding section. The constants of the plate tank circuit, C_1L_3, will resemble those of ordinary crystal oscillators; that is, the circuit will have a high *L-C* ratio. For harmonic generation, the tuning condenser need not have a maximum capacity of more than 50 μμfd., the inductance being proportioned accordingly for the frequency used.

The tuning procedure is as follows: With C_1 at a random setting, turn C_3 downwards from maximum capacity until there is a sudden change in plate current. Reduce the capacity a bit more, then turn C_1 until there is a sharp dip

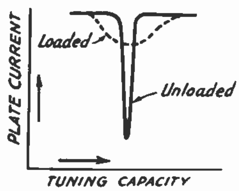


FIG. 810 — D.C. PLATE CURRENT VS. PLATE TUNING CAPACITY WITH THE TRI-TET OSCILLATOR

in the plate current, indicating that the plate circuit is in resonance. Set C_1 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_1 when the load is coupled to bring the plate current to a new minimum. Fig. 810 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_3 should be readjusted to obtain optimum power output. The setting of C_3 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. Consequently higher harmonics than the second are seldom used.

High-Power Tri-Tet Oscillators

● Transmitting pentodes of high power sensitivity such as the RK-20, RK-28 and 803 are suitable for use with the Tri-tet circuit at a quite high power level. From experimental work with the tubes it has been found that plate voltages as high as 1000 volts can be used without danger to the crystal provided the instructions in the preceding section with regard to cathode tuning are rigorously followed.

R.F. Power-Amplifiers

● Amplifiers intended for operation on the same frequency as the exciting source are of two types — triode and screen-grid. When a triode is used as a straight amplifier provision must be made in the circuit for cancelling out the effect of feedback to the grid circuit through the grid-plate capacity of the tube. This process is called "neutralization." If the tube is not neutralized, it will oscillate as a tuned-plate tuned-grid oscillator because its output tank circuit and the tank circuit of the preceding stage — the *driving stage* or *driver* — to which the amplifier's grid circuit is coupled, are tuned to the same frequency.

Screen-grid tubes (either tetrode or pentode type) do not require neutralization because of the action of the screen in reducing grid-plate capacity, as described in Chapter Five. To prevent self-oscillation, however, it is essential that there be no coupling, either magnetic or through stray capacities, between the grid and plate circuits. This often calls for the use of shielding.

Amplifier Operating Requirements

● The usual object of adjustment of an r.f. amplifier is that of obtaining maximum r.f. power output consistent with tube ratings and requirements as to purity of emissions imposed by the amateur regulations. Assuming fixed filament and plate voltages, the adjustments which affect the output are those of grid bias, excitation voltage, and plate loading. These three are all interrelated, a change in one requiring a change in the other two for optimum results.

Tank-Circuit Impedance

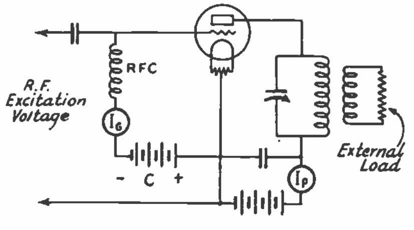


FIG. 811 — A SIMPLIFIED AMPLIFIER CIRCUIT

The resistor connected across the coupling coil represents the load to which the amplifier is delivering power; it may be an antenna or a following amplifier stage.

A simplified amplifier circuit, including only essentials and neglecting the necessity for neutralization, is shown in Fig. 811. The discussion centered about it will apply equally well to screen-grid tubes, since the screen (and suppressor, if the tube is a pentode) are at ground potential and hence have no effect on the r.f. operation of the circuit aside from establishing the tube characteristics. The tuned tank circuit in series with the plate of the tube constitutes the load for the tube. When tuned to resonance it is practically equivalent to a pure resistance, as explained in Chapter Four. The value of equivalent resistance represented by the tank is dependent upon the ratio of inductance to capacity and the resistance inherent in the tank itself, and upon the effective resistance coupled into the tank from the external load circuit, which may be an antenna or a following amplifier tube grid circuit. The tank resistance or impedance decreases as the coupling to the external circuit is increased, and also decreases as the ratio of capacity to inductance is increased.

For every condition of bias and excitation voltage there is an optimum value of load resistance or impedance which will give best output and efficiency.

Measurement of Excitation

● Since measurement of r.f. excitation voltage is rather difficult without special apparatus such as a vacuum-tube voltmeter, 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 in the value of d.c. grid current for the same excitation voltage, so that readings taken under different operating conditions are not comparable.

Effect of Excitation

● The value of excitation voltage has a marked effect on the operation of the amplifier. A typical set of performance curves, showing behavior of power output, power amplification ratio, and efficiency as a function of d.c. grid current are shown in Fig. 812. Fixed values of load resistance and grid bias are assumed. Inspection of the curves shows 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 exciter, is dissipated in the grid-filament circuit of the tube, appearing

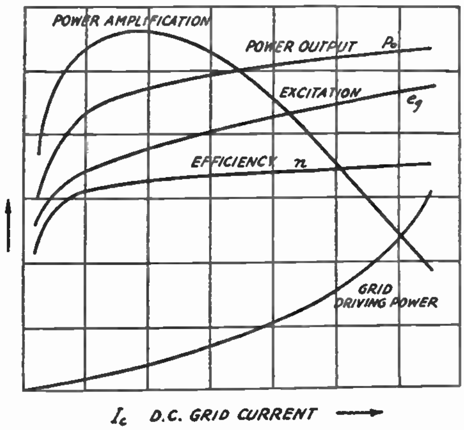


FIG. 812—EFFECT OF GRID EXCITATION ON POWER AMPLIFIER PERFORMANCE

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.

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 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 ratings, 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. 812, 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 normal, 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 power output at lower plate efficiency.

Most tubes are designed for operation as r.f. power amplifiers under average conditions, where the plate efficiency is in the vicinity of 70%. This corresponds to the optimum point on the curves of Fig. 812. They will deliver their rated power output at moderate plate voltages, considering the size of the tube, and with fairly low values of driving power. A few tubes available to amateurs, however, can be operated at relatively high plate voltages and are provided with oversize filaments to stand up under high-voltage operation. They can be operated at moderate plate voltages with normal efficiency or can be used by the experienced amateur for obtaining large power outputs at high plate efficiency.

Tank Circuits — L-C Ratios

● As we have said, for a given set of operating conditions there is a value of plate load resistance which will give highest efficiency. So far as the plate efficiency of the tube itself is concerned, it does not matter how this load resist-

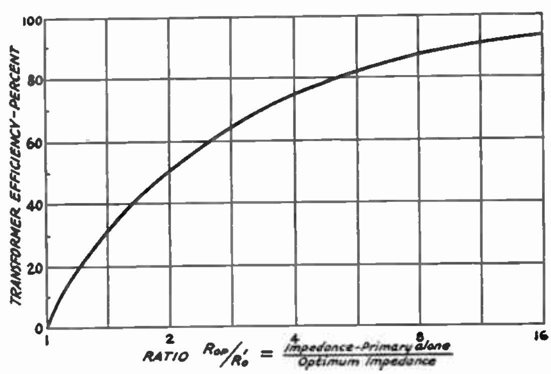


FIG. 813.— VARIATION OF COUPLING TRANSFORMER EFFICIENCY WITH TUNED CIRCUIT IMPEDANCE

This curve and those of Fig. 812 are from data by H. A. Robinson, W3LW.

ance 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. Since power consumed in the tank circuit is a loss, this is the same thing as saying that the efficiency of the tank circuit in delivering power from the tube to the external circuit is affected by the unloaded tank impedance.

The impedance of the tank circuit at resonance is equal to L/CR, where L is the inductance, C the capacity, and R the resistance. The higher the tank impedance, the greater the transfer efficiency; the relationship is shown by the curve of Fig. 813. It is evident that the impedance of the tank alone should be at least ten times the optimum load impedance for high transfer efficiency. The tank impedance can be raised 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 raise the tank impedance by increasing the *L-C* ratio than by attempting to reduce the resistance.

Under normal conditions of operation, with efficiencies of the order of 70% and a fairly low value of optimum load impedance, a satisfactory *L-C* ratio results when the tank capacity actually in use is approximately 200 μμfd. at 3.5 mc., 100 μμfd. at 7 mc., 50 μμfd. at 14 mc., and proportionate values on the other bands. For this type of operation higher *L-C* ratios will give a comparatively slight increase in transfer efficiency.

Tank Impedance and Harmonic Output

● When a high-impedance tank circuit is used, combined 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, although contributing to the plate efficiency, is not useful for signalling purposes and often is inadvertently 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.

Push-Pull and Parallel Operation

Other things being equal, the power output from two tubes will be the same regardless of whether they are connected in parallel or push-pull. The same is true of the power required from the driver. However, there are certain practical considerations which may make one method of connection preferable to the other.

Although the excitation power required is the same with either method of connection, for the balanced circuit the r.f. voltage must be twice as high as with parallel operation. This may require a relatively high *L-C* ratio in the tank circuit connected to the grids of the tubes. Fortunately the reduction in effective tube capacity with push-pull favors the use of a sufficiently high *L-C* ratio so that this requirement usually can be met without difficulty. In either parallel or push-pull operation the d.c. grid current for the two tubes should be twice that drawn by one tube alone.

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 — up to 14 mc., at least — tubes designed for high-frequency work (the types marked with an asterisk in the triode tables of Chapter Five) can be paralleled without particular difficulty.

Plate efficiency is favored to some extent by parallel operation as contrasted to push-pull. The optimum load impedance for two tubes in parallel is just half the value for one tube alone, since the total plate resistance of the two tubes is half that of either by itself. A tank having a given *L-C* ratio therefore will have greater transfer efficiency with two tubes in parallel than with one alone. Conversely, the *L-C* ratio can be halved for the same transfer efficiency, with a corresponding reduction in relative harmonic output.

The opposite is true with tubes in push-pull. The balanced circuit makes it necessary that each plate-cathode circuit be connected across only half the tank; the impedance into which each tube is working is only one-quarter that of the whole tank circuit with this method of connection. So far as the tube is concerned, this is equivalent to a 4-to-1 reduction in *L-C* ratio. Since the impedance of the part of the tank across which one tube is connected reaches the optimum value with looser coupling than is the case when the tube is connected across the whole tank, the power output will be less, which means a reduction in efficiency. To bring the efficiency back to a value comparable with the single tube, the *L-C* ratio must be quadrupled — that is, the capacity should be halved and the inductance doubled. On the basis of the optimum values previously given for normal operation, the total tank capacity in use with tubes in push-pull should be 100 μμfd. at 3.5 mc., 50 μμfd. at 7 mc., and 25 μμfd. at 14 mc., with proportional values at other frequencies.

The higher effective impedance of the tank circuit with push-pull operation does not have an appreciable effect on the harmonic output because the even harmonics are balanced out as an inherent property of the push-pull connection. 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 may be advantageous from the harmonic standpoint even though higher *L-C* ratios are used.

Push-pull is usually to be preferred to parallel operation because a balanced circuit is often found easier to handle than a single-ended or unbalanced circuit, especially at high frequencies. This is especially true in the case of neutralized amplifiers.

Interstage Coupling Methods

● With any amplifier tube, some means must be provided for feeding into its grid circuit the r.f. power generated by the preceding oscillator or driver. To do this effectively many types of inter-stage coupling have been devised. 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, and from push-pull to single tube. Tubes in parallel can be considered to be equivalent to one tube so far as drawing the circuit is concerned; in actual practice, however, 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. 814. The circuit at *A* is widely used; coupling is through condenser *C* 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 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

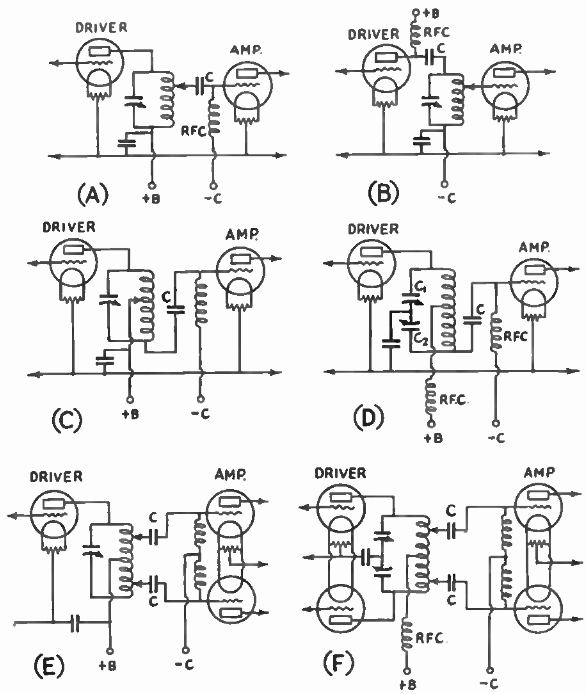


FIG. 814 — DIRECT OR CAPACITY-COUPLED DRIVER AND AMPLIFIER STAGES

Coupling condenser capacity may be from 250 μμfd. to .002 μfd., not critical, except under conditions described in the text.

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.

Circuit B is practically equivalent to Circuit A; the coupling condenser has been 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

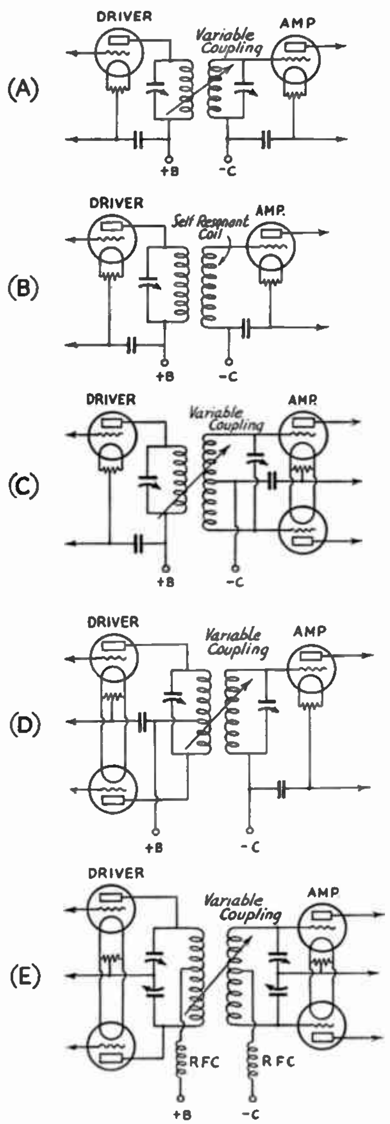


FIG. 815—INDUCTIVE INTERSTAGE COUPLING

interelectrode capacities, such as the 852, 800, 50T, 150T, RK18 and others with comparable capacities. The variable tap for regulating excitation is sometimes responsible for parasitic oscillation in the amplifier, a condition which is harmful to the efficiency.

The effect of paralleling the input and output capacities of driver and amplifier tubes can be avoided by using circuits like those of Fig. 814-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 also can be used for coupling to a following push-pull amplifier, as shown in Fig. 814-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. 814-F. The taps are equidistant from the center in this circuit also.

Capacity-Coupling Considerations

● When an r.f. amplifier is operated at high efficiency its grid or input circuit consumes power, which must be furnished by the driver. Since power is consumed, 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 without much difficulty, 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 (discussed in a later section) which impair the operation of the amplifier. 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.

Inductive Coupling

● Many of the disadvantages of capacity coupling can be overcome by the use of inductive coupling between stages, several typical circuits being shown in Fig. 815. Inductive coupling requires separate tank circuits for the plate of the driver and grid of the amplifier and also a means for varying the coupling between them. The two circuits are tuned to the same frequency, regardless of whether the amplifier is a straight amplifier or doubler.

Excitation can be adjusted by varying the coupling between the two tank coils, the circuits being kept tuned to resonance as the coupling is varied.

For simplification a self-resonant coil may be used in the grid circuit of the amplifier. When this is done, the grid coil usually is wound on the same form as the driver tank coil, the coupling thus being fixed. The number of turns is then adjusted to give maximum power transfer to the amplifier grid circuit. The coil should resonate at a frequency somewhat lower than the operating frequency if very close coupling is used. The self-resonant or untuned grid coil will work over a fair range of frequency without readjustment, although there is likely to be some loss of excitation if one coil is used to cover a band as wide as the 3500–4000 kc. band.

Inductive circuits for coupling single-ended to push-pull amplifiers and vice versa, as well as push-pull to push-pull, also are shown. The

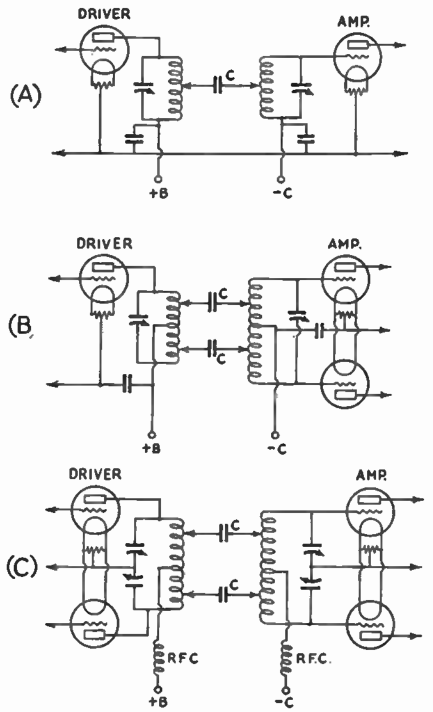


FIG. 816 — TRANSMISSION-LINE OR "MATCHED IMPEDANCE" COUPLING

untuned grid coil arrangement also may be used in these circuits. The operating principles and method of adjusting excitation are the same.

Inductive coupling provides smooth adjustment of excitation and driver loading and is an excellent system for use at the higher amateur frequencies. The chief disadvantage is the necessity for providing a mechanical means for varying the coupling between plate and grid tank circuits.

Transmission Line or Link Coupling

● The advantages of separately-tuned plate and grid tanks for driver and amplifier can be retained without the necessity for providing inductive coupling between the stages by the use of a transmission line terminating at the two tanks. 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. This is a highly convenient feature if, as in some layouts, the amplifier must be located at a distance from the driver.

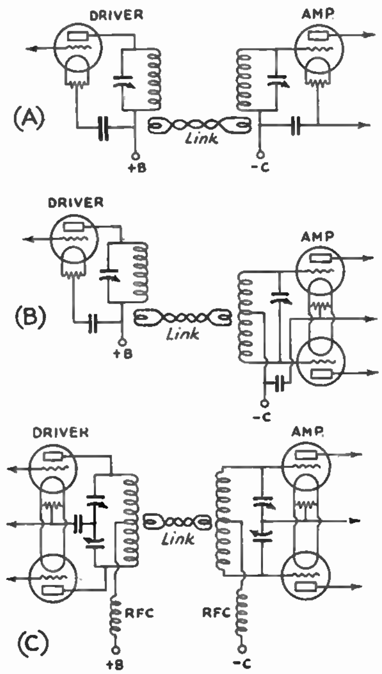


FIG. 817 — LINK COUPLING, USING A LOW-IMPEDANCE TRANSMISSION LINE

These circuits belong to the same family as those of Fig. 816.

Several forms of transmission-line coupling are shown in Figs. 816 and 817. In the direct-coupled circuits of Fig. 816 the excitation is adjusted by varying the positions of the taps on the two tank coils, the object being to obtain the maximum r.f. power at the grid of the amplifier without overloading the driver. The farther the taps from the ground ends of the coils the greater the loading on the driver. Moving the taps up from ground also will increase the excitation until the limit of driver output is reached.

In the circuit of Fig. 816-A, one side of the coupling line is the cathode connection between the two stages. For this reason the distance between stages should not be too great because there is an r.f. drop in the line, thus putting the cathode circuits of the two stages at different r.f. potentials. In circuits B and C the length of line is immaterial, since two wires are used and no current flows in the common cathode connection. The condensers marked *C* are for insulation purposes; their capacity is not critical but should be of the order of .002 μfd.

If a balanced line of the type shown in Fig. 816-B and C is run for a distance of more than a foot or two, it should be uniformly spaced throughout its entire length.

Link-Coupled Circuits

● Circuits for a low-impedance line, usually twisted pair, are shown in Fig. 817. The principle of operation is the same as with the direct-coupled lines except that inductive coupling usually is provided between the line and the tuned circuits. This 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 usually 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 a single turn 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.

Properly-adjusted transmission line coupling causes no increase in the capacities shunting the tank circuits. This type of coupling is therefore especially advantageous at the higher frequencies.

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. The process of 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 value.

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 may be called "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.

A neutralizing circuit is actually a form of bridge circuit, the grid-plate capacity of the tube and the neutralizing condenser forming two capacitive arms, while the halves of the balanced tank circuit form the other two arms.

Plate-Neutralizing Circuits

● Several plate-neutralizing circuits are given in Fig. 818. 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 preferable in that it tends to keep a better voltage balance over a range of frequencies. The only reason for using the circuit of A is to get as high impedance as possible in the part of the tank circuit included between the filament return and plate for the sake of efficiency.

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. 818-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 push-pull neutralizing circuits shown at

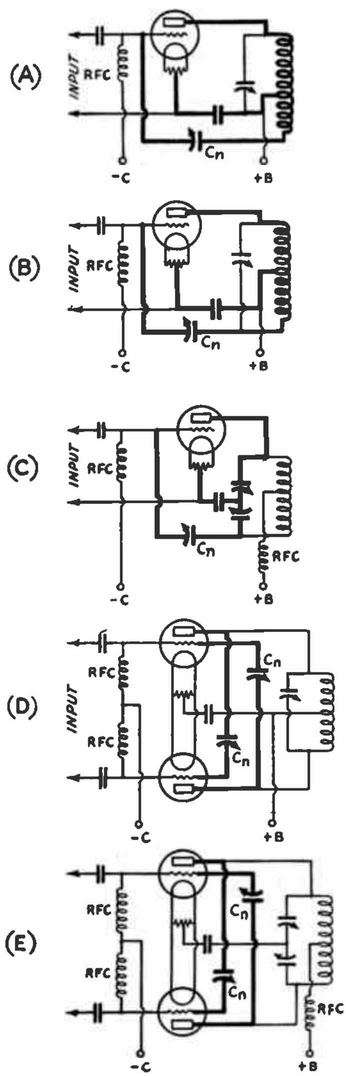


FIG. 818 — PLATE NEUTRALIZING CIRCUITS

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. 819. 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.

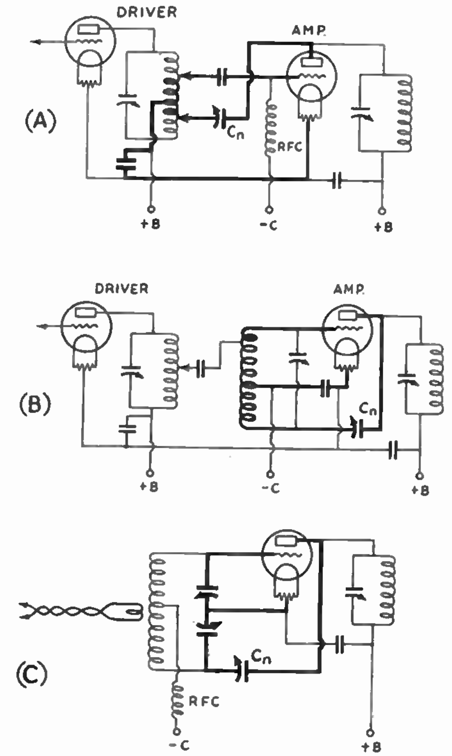


FIG. 819—GRID NEUTRALIZING CIRCUITS

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. An advantage of the grid-neutralizing systems is the fact that the single-ended plate tank circuit has higher impedance, and hence gives greater plate efficiency, than a balanced plate tank in which the plate-cathode circuit is connected across only half the turns or half the capacity.

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.

The paragraph above should make it clear that the neutralizing capacity required at C_n will depend upon the type of tube and the choice of circuit. For those tubes having grid and plate connections brought out through the bulb, such as the 800, 852, 50T, 150T and a few others, a condenser having at about half scale 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. For most small triodes, a condenser having a minimum of about 5 μμfd. and a maximum of approximately 20 μμfd. will suffice. Such condensers are readily obtainable in the midget sizes.

When two or more tubes are connected in parallel, the neutralizing capacity required will be in proportion to the number of tubes.

Neutralizing Adjustments

● The procedure in neutralizing is the same regardless of the tube or circuit used. To do the job satisfactorily it is essential that some form of fairly sensitive r.f. indicator be available; a flashlight lamp with its terminals connected to a loop of wire, a neon bulb, or a thermo-galvanometer connected to a wire loop are suitable.

The first step in neutralizing is to disconnect the plate-voltage from the tube. Its filament should be lighted, however, and the excitation from the preceding stage should be fed to its grid circuit. Couple the r.f. indicator 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.

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 tube is neutralized.

The aim of neutralizing adjustments is to find the setting of the neutralizing condenser which eliminates r.f. in the plate circuit when the plate circuit is tuned to resonance. It is not at all difficult to neutralize a tube 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 of the neutralizing condenser 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 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 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.

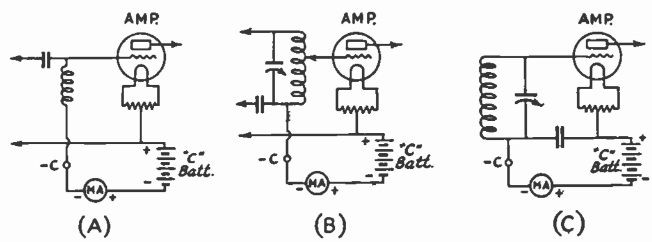


FIG. 820 — METHODS OF CONNECTING A MILLIAMMETER IN THE GRID RETURN LEAD TO MEASURE RECTIFIED GRID CURRENT

Tuning an Amplifier

Amplifier tuning is quite simple, and the adjustments are similar regardless of the type of circuit used. It is also immaterial whether the tube is a neutralized triode or a screen-grid tube requiring no neutralization. In describing the process, however, it will be assumed that the neutralizing, if required, has been carried through to a satisfactory conclusion. A tube which is not properly neutralized is likely to behave erratically when plate voltage is applied.

Before applying plate voltage to the amplifier, the plate circuit of the preceding stage should be tuned to give maximum output. Perhaps the most satisfactory indicator of the excitation power delivered by the driver stage is a d.c. milliammeter connected in series with the grid return circuit of the amplifier. The higher the rectified grid current indicated by such a meter, the greater is the excitation. The method of connecting the meter will depend upon the type of grid circuit used; Fig. 820 gives some examples. The connections at A would be used with amplifier grid circuits like those in Fig. 814-A, C, D, E and F; those at B with Fig. 814-B; and those at C with Figs. 815, 816 and 817. The method of connecting the grid meter in the push-pull circuits is obvious from inspection of Fig. 820. The plus and minus signs indicate the proper way to connect the meter in the circuit.

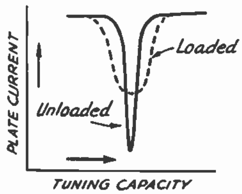


FIG. 821 — TYPICAL BEHAVIOR OF D.C. PLATE CURRENT WITH TUNING OF AN AMPLIFIER

The first step is to adjust the driver stage tuning for maximum amplifier grid current. Then the coupling between the stages should be adjusted to give a further increase, if possible. Methods of varying the coupling have been indicated in the discussion of the various coupling systems. The driver circuit should be retuned to resonance every time the coupling is changed, no matter what the coupling system used, since a change in coupling is likely to throw the tank circuit slightly off tune. If there is a tank circuit in the grid of the amplifier, as in Figs. 815, 816 and 817, it too should be retuned for the same reason. A few minutes spent in changing coupling and readjusting tuning should show quickly the optimum coupling for maximum grid current.

Once the proper grid-coupling adjustment has been found, the amplifier plate tank condenser should be set approximately at resonance. With the excitation connected, the plate voltage may then be applied and the plate tank circuit tuned to resonance, which will be indicated by a very pronounced dip in plate current. This adjustment should be made quickly, since the tube filament will be damaged by continued application of plate voltage with the tank circuit tuned off resonance. (In preliminary adjustments it is a good idea to use low plate voltage until the amplifier is properly tuned.) The off-resonance plate current usually will be considerably higher than the rated plate current for the tube — sometimes several times as great — but at resonance should drop to ten or twenty percent of the rated value. The higher the excitation power, the greater will be the dip in plate current at resonance. If the dip in plate current is not very pronounced, the excitation may be low or the tube may not be properly neutralized, if a triode.

When the tuning process has been carried this far, the output load circuit may be connected to the amplifier. This load circuit may be the antenna itself, through the coupling apparatus, or the grid circuit of a following amplifier. When the load is connected the amplifier plate current will rise. The plate tank circuit should be retuned for minimum plate current — this "minimum," however, will no longer be the low value obtained at no load but a new value nearer the rated plate current of the tube — since connecting the load probably will detune the tank circuit to some extent. The coupling to the load circuit should be adjusted so that the new minimum plate current value is approximately the rated plate current of the tube. Fig. 821 shows typical behavior of plate current with tank tuning and loading. If the load is an antenna circuit, the methods of adjusting coupling outlined later in this chapter should be followed; if another amplifier, the coupling may be adjusted as already described. In the preliminary tuning of an amplifier it is often desirable to use a lamp bulb of suitable power rating, connected across a few turns of the plate tank coil, as a dummy load. The lamp will give some indication of the actual power output of the amplifier.

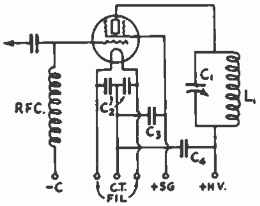
Screen-Grid Amplifiers

● The general principles of amplifier operation apply equally well to screen grid tubes as to triodes. Since neutralization is not required, the circuits of screen-grid amplifiers are relatively simple. Typical circuits for tetrodes and pentodes are given in Fig. 822.

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. Although the tubes are shielded from internal feedback, self-oscillation through feedback external to the tube is possible if these two circuits are not isolated from each other.

Complete shielding is advisable, although not always absolutely necessary, with the screen-grid amplifier.

Tuning adjustments are carried out in the same way as with triodes. The power output is considerably affected by the d.c. potentials on screen and suppressor; adjustment of these voltages after the circuit has been tuned may result in a further increase in power output. Care should be taken, however, to see that the rated screen dissipation, listed in the table in Chapter Five, is not exceeded.



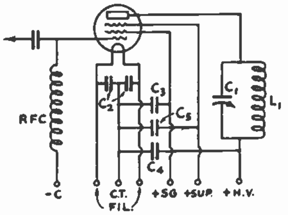


FIG. 822 — TYPICAL SCREEN-GRID AMPLIFIER CIRCUITS

The upper diagram is used with filament-type screen-grid power tubes such as the 865, 860, 282-A, 850, 254-A and 254-B. Important points to observe in the operation of the screen-grid amplifier are that the screen bypass 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 feedback. Bypass 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.

Screen-grid pentodes have high power sensitivity and usually require much less grid driving power for full output than does a triode of comparable ratings.

Frequency Multipliers

● Since at the present time the most satisfactory crystals are those ground for the lower amateur frequencies — 1.75, 3.5 and 7 megacycles — it becomes necessary to resort to other means than straight amplification to obtain crystal-controlled output on the higher-frequency bands. Many amateurs make a practice of operating in three or more bands with only one crystal, usually one having a frequency toward the lower end of the 3.5-mc. band so that its harmonics will fall in the higher-frequency bands. To do this it is necessary to use harmonic generators or *frequency multipliers*. The frequency multiplier is simply a straight amplifier whose plate circuit is tuned to a multiple of the driving frequency, operated under conditions which produce relatively high harmonic output. Since its input and output circuits are not tuned to the same frequency it cannot self-oscillate, hence a triode frequency multiplier does not need neutralization. The plate efficiency of a frequency multiplier is considerably less than that of a straight amplifier, and decreases rapidly when the plate circuit is tuned to a harmonic higher than the second. For this reason most frequency multipliers are designed to give output only on the second harmonic; since the frequency is doubled the tube is appropriately called a "doubler."

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. Tubes such as the 46 and 59 with Class-B connections, the 841, RK18, 800, 838 and 203-A are most suitable. Other types, such as the 10, 801 and 830, will work satisfactorily but require higher bias and greater excitation voltage than the high-μ tubes.

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. 818 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.

Almost any single-ended amplifier — single tube, or tubes in parallel — will operate as a doubler if the plate circuit is tuned to the second harmonic of the driver frequency. The bias voltage should be raised either by adding more battery voltage or by using a higher resistance grid leak. 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. A properly-operated doubler can give a power gain of about five, provided the tube is capable of handling the power. A small tube excited by one of similar ratings usually cannot give such a gain. At the higher frequencies — 14 and 28 mc. — small tubes used as doublers often do not give any power gain at all; the output on the second harmonic may be just about the same as the output of the driver tube, or even less. This may be no particular disadvantage in some transmitter designs, as will be explained later.

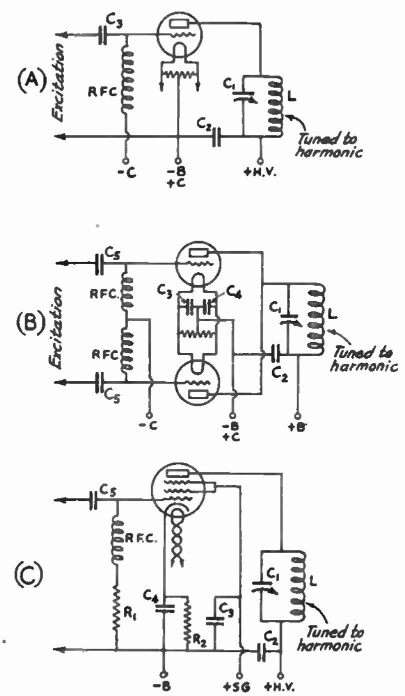


FIG. 823 — FREQUENCY MULTIPLYING CIRCUITS

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 μμfd. at the lower amateur frequencies and 25 μμfd. at 14 mc. and higher. C_2 is a plate bypass condenser having a capacity of about .002 μfd. The capacity C_3, the grid coupling condenser, depends upon the type of tube; see the discussion on interstage coupling. 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.

In the circuit at (C) tank circuit values should be the same as recommended above. C_2 and C_3 are the usual .002-μfd. bypass condensers. C_4, which controls the regenerative effect, usually should be approximately 100 μμfd.; so also should C_5 with the tubes most likely to be used in this circuit, the 59, 2A5, and their 6-volt equivalents. Grid leak, R_1, should be 50,000 ohms and cathode resistor, R_2, 1000 ohms.

Suitable coil specifications for the capacity in use at C_1 can be found by referring to the coil table.

Push-pull amplifiers cannot be used as doublers because the second and other even harmonics are cancelled in the output of such amplifiers. 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 both efficiency and output are low, and because the frequency relations of the amateur bands are such that even-harmonic output is necessary.

Doubler Circuits

● The simple doubler circuit is shown in Fig. 823-A. Neutralized circuits such as those in Fig. 818 also can be used. Special circuits for frequency doubling also have been employed. One which is often used is shown in Fig. 823-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 regenerative circuit, especially suitable for indirectly-heated cathode tubes such as the 59, 2A5, etc., is shown at Fig. 823-C. It is really a controlled oscillator, its characteristics being such that it readily "locks in" with the frequency of the driving source when the plate circuit is tuned to the harmonic. The circuit may not actually oscillate at the lower frequencies, but enough regeneration is supplied to increase both the output and efficiency of the doubler.

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. Since the optimum value will depend upon the type of tube used and the excitation available, it is not possible to give very definite specifications along these lines.

Locked Oscillators

● If two oscillators operating on frequencies differing by only a small percentage are coupled together, they will tend to synchronize, or both oscillate at the same frequency. In such a case the less stable oscillator of the two will be pulled into step with the more stable one. This phenomenon is generally called "locking." Advantage can be taken of it to make a fairly powerful oscillator operate under the frequency control of a relatively weak crystal oscillator and thereby secure the stability of crystal control without having to build up the output of the crystal oscillator in successive stages of amplification. Since the locked oscillator or "amplifier" supplies its own grid losses, relatively little crystal-controlled power is needed for high output.

A typical locked amplifier circuit is shown in Fig. 824. The oscillating amplifier circuit will be recognized as the TNT, a circuit which is readily put to this use. The crystal oscillator may be any of the types previously described; the Tri-tet (Fig. 807) is especially suitable since it is capable of locking the amplifier on two bands with any one crystal. A short transmission line (lamp cord is satisfactory) with a turn or two at each end provides a simple and effective way of coupling the two oscillators.

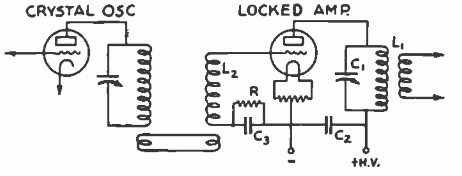


FIG. 824 — TYPICAL LOCKED AMPLIFIER CIRCUIT

The oscillating amplifier circuit is the TNT. Circuit constants will be the same as those recommended in the section on self-controlled oscillators. L_1 and C_1 are the usual tank inductance and capacity. C_2 and C_3 are the plate and grid condensers, respectively; L_2 is the untuned grid coil and R the grid leak.

Sources of Grid Bias

It is necessary to make provision in the circuit for the application of proper negative grid bias voltage to the grid of the amplifier or doubler tube. The transmitting tube tables in Chapter Five indicate the value of grid bias which should be used under representative operating conditions for normal plate voltage. If the tube is operated at a plate voltage other than that indicated, the grid bias should be increased or decreased accordingly.

Battery Bias

● Batteries have the advantage of giving practically constant voltage under all conditions of excitation or lack of it, although the grid current flow does have a charging effect which tends to raise the battery voltage. This effect increases as the batteries age and their internal resistance increases.

Besides the constant-voltage feature with varying grid currents, battery bias also protects the amplifier tube or tubes in case of excitation failure. This advantage is common to all fixed bias (as contrasted with biasing systems which depend upon the flow of grid current) systems. Should excitation stop with plate voltage applied, the plate current will drop to zero or a low value, depending upon whether the amplifier is biased beyond or near cut-off.

Grid-Leak Bias

● Grid-leak bias is economical, since no expenditure for batteries is necessary, and has the desirable feature that the bias regulates itself in accordance with the amount of excitation available, thereby tending to give optimum amplifier operation under varying conditions of excitation. When there is no excitation at all, however, there is also no grid bias, and in the case of tubes operating at fairly high voltages, especially those having low and medium values of amplification factor, a large plate current will flow if the excitation should for any reason fail or be removed while the plate voltage is connected to the tube. This may seriously damage the tube and possibly ruin it if not corrected in time.

The advantages of battery and grid-leak bias can be secured and their disadvantages eliminated by using a combination of both.

Many amateurs use just enough battery bias to reduce the amplifier plate current to a safe value should excitation fail, and connect in series with the battery a grid leak to obtain the additional bias needed under operating conditions. In general, the leak values recommended in the tube table may be used without change

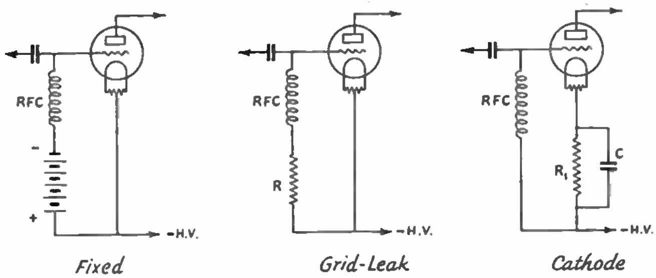


FIG. 825 — AMPLIFIER BIASING METHODS

A "B" eliminator or "C" power pack can be substituted for the battery provided its bleeder resistance is not too high. See Chapter Fifteen for information on the design of "C" power packs.

when used in conjunction with a small amount of "safeguarding" battery bias. The bias power pack, when properly designed, offers the advantages of a battery grid-leak combination.

When grid-leak bias is used the bias under operating conditions may be calculated by multiplying the leak resistance by the grid current in amperes (ma. ÷ 1000). If a battery is in series with the leak, the battery voltage should be added to the voltage obtained by the calculation.

Cathode Biasing

● Transmitting tubes also may be biased by the method universally used in receivers — by inserting a resistor of suitable value in series with the cathode or filament and using the voltage drop resulting from the flow of plate current through the resistor as bias. Correctly applied, this method of biasing combines the self-adjusting features of grid leak bias with some measure of protection to the tube in case of excitation failure. The voltage drop in the biasing resistor causes a reduction in plate voltage by the same amount, however, so that the plate supply should be designed to have a terminal voltage equal to the desired operating plate voltage plus the grid bias voltage. For a tube intended to be operated with 1000 volts on the plate and 200 volts negative bias, for example, the plate supply voltage should be 1200 volts.

The value of the biasing resistor, R_1 in Fig. 825, should be calculated for normal operation. For example, if the tube is rated to draw 130 ma. plate current and 20 ma. grid current, and requires 150 volts grid bias, the resistance required will be

$$R = \frac{E}{I} = \frac{150}{0.15} = 1000 \text{ ohms.}$$

The plate current that will flow with no excitation can be found by cut-and-try methods from the tube's characteristic curves. Assume some value of plate current, calculate the bias resulting, and then check with the curves to see if that particular bias value will cause the assumed plate current to flow, keeping in mind the reduction in plate voltage due to bias. A few trials should give an approximate result. The power input should then be figured to make sure it is below the safe plate dissipation rating of the tube.

Other Methods

● Power amplifier bias may also be obtained from the plate supply used for low power stages when conditions permit. A diagram showing the essentials is given in Fig. 826. The low-voltage and high-voltage supplies are not connected together at negative, as is usually the case, but the positive terminal of the low-voltage supply goes to negative high-voltage. Since this places the filament of the power amplifier and the filaments of the low-voltage tubes at opposite terminals of the low-voltage supply, a separate well-insulated transformer winding must be used for the amplifier filament. The tapped resistor, used to permit varying the bias, may be the regular bleeder on the low-voltage supply.

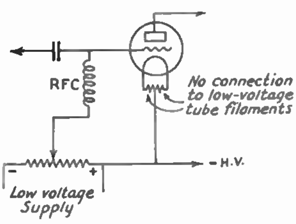


FIG. 826 — USING THE LOW-VOLTAGE PLATE SUPPLY FOR BIASING THE POWER AMPLIFIER

Circuit Values in Amplifiers

● The values of circuit components other than those already discussed (tank constants and coupling condensers) are seldom critical. By-pass condensers, for example, are used simply to provide a low-impedance path for the flow of r.f. current, and so long as the reactance of the condenser is low compared to the impedance of the part of the circuit across which the condenser is connected, this requirement will be met. The question is therefore simply one of getting a condenser large enough. Values from .001 to .01 μfd. are regularly used.

In the larger sizes, .01 μfd. and up, condensers often will exhibit some inductance as well as capacity, introducing the possibility that the condenser may be self-resonant at some high frequency. A condenser having such resonance will cause the circuit to work poorly at frequencies near the condenser's natural period. It is advisable to use mica or glass condensers in high-frequency circuits, although non-inductively wound paper condensers will give good service.

In the diagrams given in this chapter the filament return circuit has been shown with a center-tapped resistor, the plate and grid returns being brought to the center-tap. The purpose of the center-tap is to prevent hum-modulation of the tube's output by balancing the voltages on both sides of the filament with respect to the grid return. In practical transmitters this balancing may be done either by a resistor, as generally shown, or by a center-tap on the filament-supply winding. The results are the same with either method. If a non-inductive center-tapped resistor is used, it may be mounted close to the filament terminals on the tube socket and used as an r.f. return as well. However, filament bypass condensers usually replace the resistor for the r.f. return in all but low-power circuits using 2.5-volt tubes, and in all circuits where the center-tapped resistor or filament transformer has to be located at some distance from the tube. The resistor shown in these drawings is simply a convention, used to represent either a resistor or bypass condensers or both; in other words, it is a diagrammatic "short-hand" for the complete filament circuit.

Filament bypass condensers usually have a capacity of .002 μfd. or more. The larger the condensers the better (if they are non-inductive) since they are called upon to bypass a low-impedance part of the circuit.

Coupling to the Antenna

● To some extent the choice of an antenna coupling system is dictated by the type of antenna (and feeder system) to be used. There is also a factor of legality involved, since certain types of antenna-coupling arrangements are prohibited by the amateur regulations.

As with other radio-frequency circuits, there are three possible types of coupling — direct, inductive and capacitive, together with their variations. A good antenna coupling system should transfer power with the least possible loss, and should discriminate against harmonics to prevent off-frequency radiations.

Impedance Relations

● As we have seen, there is a load impedance value for the r.f. power amplifier which, for any particular set of operating conditions, will give optimum results. The impedance offered by the antenna or feeder system at the point at which power is to be fed into it may be widely different from this optimum value. The optimum load impedance value may be anything from 1000 up to several thousand ohms, depending upon the operating conditions; the higher values accompany high-voltage, high-efficiency operation. This value also is secondarily dependent upon the type of tube used, although two tubes of widely different characteristics will take approximately the same load impedance if both are operated at the same plate voltage and current and are driven to saturation. The antenna or feeder impedance at the feed point, on the other hand, may vary from a few ohms to a few thousand ohms. It is the function of the antenna coupling system to match these impedances. The general theory of impedance matching has been discussed in Chapter Five.

Direct Coupling

● Direct coupling methods for single- and two-wire feeders are shown in Fig. 827. Direct coupling between tank and antenna is prohibited by the regulations, but may be used when a non-radiating transmission line is used to feed the antenna. It is ordinarily used only with untuned-type transmission lines, the other methods being preferred for tuned lines.

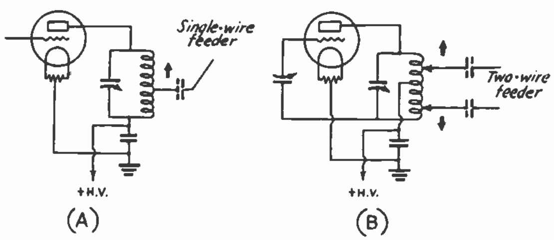


FIG. 827 — DIRECT COUPLING TO THE ANTENNA OR FEEDERS

The blocking condenser indicated by dotted lines is desirable for keeping the plate voltage off the antenna system when series feed is used; its value may be .001 or .002 μfd.

Adjustment is quite simple. The tap is moved along the tank coil to change the coupling, increasing coupling being indicated by the direction of the heavy arrow. The single-wire feeder can be coupled on either side of the ground point with balanced tank circuits. While the two wire line can be coupled to a single-ended tank circuit by connecting one wire to the ground end of the tank, the inductive coupling system shown at Fig. 828-D is preferable in such a case.

Push-pull amplifiers can be used with direct coupling; the connections are the same as those already discussed.

Low-impedance lines usually will be tapped on the coil close to the ground end, while high-impedance lines will find the optimum coupling point nearer the plate end of the tank coil.

Inductive Coupling

● Inductive coupling circuits are shown in Fig. 828. Inductive coupling is widely used with tuned transmission lines and also for working directly into the antenna itself without a feeder system. They are fairly easy to adjust and are readily adaptable to quite wide range of impedance matching.

The circuit of Fig. 828-A is used for coupling to a low-impedance point on the antenna system (series tuning), while B is used for coupling to a high-impedance point (parallel tuning). Coupling increases in the direction of the arrow. The coupling with series tuning is usually fairly close and a relatively small coil is required. With parallel tuning, the coupling usually will be quite loose and a large coil with small tuning capacity should be used in the coupling system.

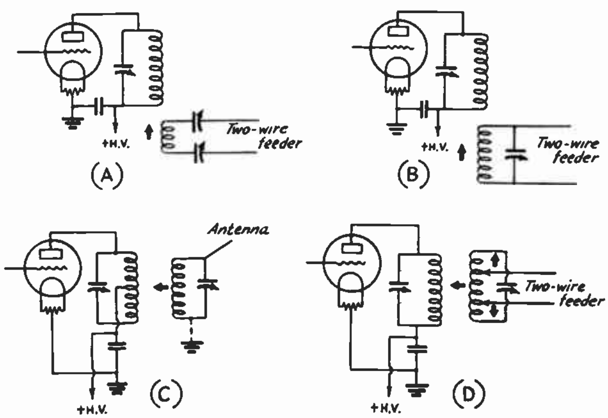


FIG. 828 — INDUCTIVE ANTENNA-COUPLING CIRCUITS

The arrangement of Fig. 828-C, used to couple a transmitter to an end-fed antenna, is also parallel tuning (high-impedance feed point). The coupling tank may be grounded as shown by the dotted lines, provided a short ground lead can be obtained.

The circuit of Fig. 828-D can be used to couple a single-ended tank circuit to a balanced two-wire untuned feeder. The degree of coupling can be changed by moving the coupling coil in relation to the tank coil and also by changing the feeder taps on the coupling coil.

The same general procedure is followed in the adjustment of all inductively-coupled systems. Starting with very loose coupling between the coils, the plate tank should be set at resonance and the antenna condenser (or condensers, if two are used) tuned to cause a rise in plate current. The coupling is then slightly increased and both tank and antenna-coupling circuit retuned to resonance, the plate tank for minimum plate current and the coupling circuit for maximum plate current. This process is continued until the rated plate current for the tube is reached, or until the output, if an r.f. indicating means is available, is maximum. If the coupling is made too tight it will be found that a slight readjustment of the antenna tuning condenser will cause a "jump" in the tuning of the tank condenser, resonance being found at two places. This "two-point" tuning should be avoided. Always use the loosest coupling which gives the desired plate current or optimum output.

If coupling is to a low-impedance point on the antenna system the r.f. current will be quite high and may be measured by an r.f. ammeter of suitable range. Such an ammeter makes an excellent indicator of r.f. output.

Low-Pass Filters

● A third type of antenna coupling arrangement is the low-pass filter, two forms of which are shown in Fig. 829. The function of impedance matching is provided for in the ratios of the capacities of the two condensers, C_1 and C_2, which are variable over a range sufficient to take care of most transmitting tubes and antenna-feeder systems. Two types of filter are used, one for those antenna systems which involve bringing but a single wire into the station, and one for balanced or two-wire systems.

Adjustment is as follows: With the filter disconnected, tune the amplifier or oscillator to resonance — the point of plate current minimum. Set the taps on L_1 (and L_2, if used) approximately as indicated under the circuit diagram for the band in use. Connect the filter to the tank circuit, placing the taps about midway between the ground point and the end of the coil. Apply plate voltage and rotate C_1 rapidly to find the point of plate current dip. This dip will not be to the no-load plate current value but probably will be to a value nearer the rated plate current of the tube. If the minimum plate current is too high, decrease the capacity of C_2 and retune C_1 to resonance; if the plate current is too low, reverse the procedure. The amplifier or oscillator tank condenser should not be touched during these adjustments.

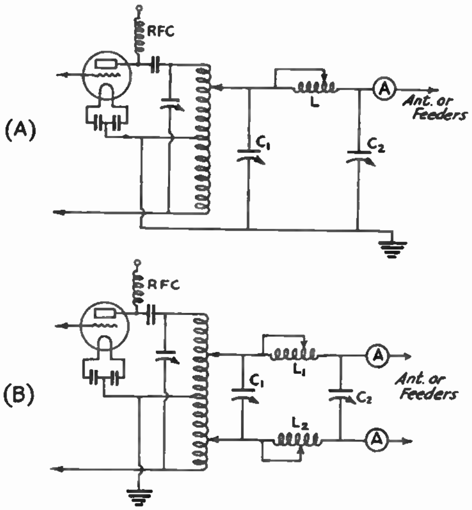


FIG. 829 — ANTENNA-COUPLING FILTERS

Their use and adjustment is explained in the text. Condensers C_1 and C_2 should have a maximum capacity of 250 μμfd. or more, with plate spacing sufficient to withstand the r.f. voltages developed by the transmitter. For powers up to 50 watts, receiving-condenser spacing will be satisfactory; for higher power, transmitting-type condensers should be used.

For operation from 1.75 to 14 mc., the inductance should be 30 turns wound to a 2½-inch diameter and 5½ inches long, tapped every five turns. Approximate settings are 30 turns for 1.75 mc., 15 turns for 3.5 mc., 10 turns for 7 mc., and 5 turns for 15 mc. L_1 and L_2 should have half the turns specified for L. The coils may be wound with No. 12 or No. 14 wire.

In making these adjustments to the antenna filter *the amplifier tank condenser should not be touched.* When the filter is properly adjusted it will present a pure resistance load to the tube's tank circuit, hence the latter will not require retuning. Should retuning the tank give a new minimum plate current point, the filter is not correctly adjusted.

Should it be impossible to make the tube draw normal plate current at any setting of C_2 (with C_1 set for minimum plate current) the tap or taps on the plate tank coil must be moved. The filter is designed for approximately 600 ohms input impedance, hence the same proportionate number of turns between tap and ground will not hold for all types of operation because of differences in optimum load impedance for different operating conditions and types of tubes. Moving the tap toward the plate end will increase the load on the tube, while moving it in the other direction will decrease it. Hence if the minimum plate current is too low, the tap or taps should be moved toward the plate end and if too high, toward the ground point. In the balanced circuit, the taps should be maintained equidistant from ground.

Antenna current will be indicated by the ammeter *A*. The object of adjustment is to obtain the highest antenna current with the lowest plate current to the tube or tubes. Varying the inductance of L_1 and L_2 probably will help in attaining this result, although the inductance values usually are not critical.

Link-Coupled Antenna Tuning Unit

● A modification of inductive coupling resembling the link line used in interstage coupling circuits is shown in Fig. 830. This system is particularly useful where tuned feeders are to be used and their length does not permit running right to the transmitter. The twisted line may be any reasonable length, so that the transmitter and antenna-tuning apparatus can be some distance apart.

The antenna tuning unit indicated is arranged for either series or parallel tuning, as described in Chapter Sixteen. To adjust the system, the plate tank is first tuned to resonance. The line is then coupled to the tank (a turn or two usually will be enough), and the antenna tuning adjusted to bring the plate current to maximum. Coupling can be changed by increasing the spread between the taps on the antenna coil or by increasing the number of turns in the link coil at the transmitter end.

As a variation, a link turn can be used at the antenna tuning-unit end with the taps on the plate tank coil, or inductively-coupled links can be used at both ends.

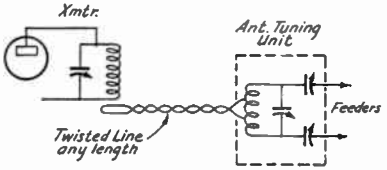


FIG. 830 — LINK COUPLING BETWEEN THE TRANSMITTER AND ANTENNA TUNING APPARATUS

This system eliminates variable inductive coupling and permits placing the antenna tuning apparatus at any convenient point.

Band-Switching

● For the sake of convenience in changing bands many amateurs are turning to band-switching in transmitters. This not only is an operating convenience, but also avoids the necessity for having a large number of plug-in coils on hand.

The chief requirement of a good band-changing scheme is that the plate circuit shall be switched to the proper band without the introduction of undue losses in the tank circuit. Two practicable methods are shown in Fig. 831. At A, a separate tank circuit is used for each band to be covered; the switch simply selects the one desired. If the switch has low capacity between points, this system will give good efficiency, since each tank circuit can be designed for optimum results. The chief disadvantage is the necessity for providing a separate tank condenser and coil for each band, which may be a considerable expense in a high-power stage. If the amplifier is an output stage, separate coupling coils, if used, can be coupled to each tank and switched in similar fashion, or coupling taps on the various tank coils can be selected.

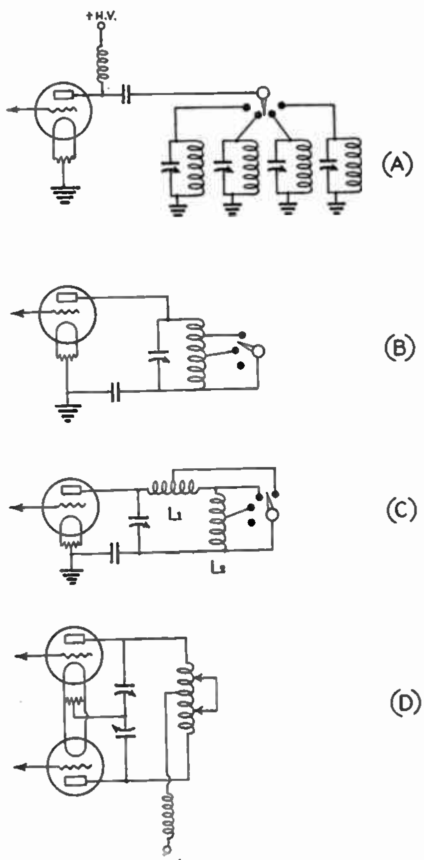


FIG. 831 — METHODS OF SWITCHING THE AMPLIFIER PLATE TANK CIRCUIT FOR CHANGING BANDS

Band-switching methods are most suited to screen-grid or pentode amplifiers because the complications involved in switching neutralized circuits are avoided.

In the system shown at B, the inductance of the tank coil is changed to a suitable value for each band by shorting out a portion of the coil. Thus only one tuning condenser is needed. The coil should be designed for the lowest-frequency band to be covered, the positions of the taps for the higher frequencies being found by experiment.

Since the shorted-out portion of the coil is very closely coupled to the active section, the voltage induced in the shorted section is considerable and an r.f. current of some magnitude will flow. If the resistance of the shorted section is low, the losses caused by this circulating current will likewise be low. It is necessary also to use a switch or other shorting device having low contact resistance to keep down the losses.

If more than three bands are to be covered, it is better to arrange the coil in two sections, as shown in Fig. 831-C. In this case the coil L_1 is designed for optimum inductance at the second from highest-frequency band to be covered; the inductance of L_2 is then made such that the two in series will give optimum inductance for the lowest-frequency band. For example, if the amplifier is to cover the four bands 3.5, 7, 14 and 28 mc., L_1 would be designed for 14 mc., while L_2 plus L_1 would give optimum inductance at 3.5 mc. The taps then can be set for the other two bands. The two coils should be arranged so that there is no inductive coupling between them, thus avoiding the loss that would be introduced at the higher frequencies if all shorting were done on a single coil.

The method shown at 831-C also can be used for covering five bands if L_2 is made large enough to resonate with the tank condenser to 1.75 mc. The 3.5- and 7-mc. taps would be on L_2; L_1 and its tap would cover 14 and 28 mc.

Turns may be shorted by using copper clips of low resistance and large contact surface with the wiring or tubing composing the inductances. Special switches designed for the purpose also are available. In making a band-swithing amplifier it is important that the switch leads be as short as possible and that the capacity to ground or the transmitter chassis be small.

Push-pull circuits may be switched by the method shown at Fig. 831-D, shorting outward from the center. The taps should be equidistant from the center-tap or ground point. Three bands can readily be covered by this method without appreciable loss of power at the highest frequency.

Harmonic Suppression

● Because operating a power oscillator or amplifier at high efficiency results in a plate output having a greatly-distorted wave form, harmonics are present in considerable strength in the output. Since harmonics often will fall outside the frequency bands assigned to amateurs, there is danger of off-frequency operation. The amateur regulations require that the transmissions shall be as free from harmonics as the state of the art permits.

The use of an output tank circuit having a relatively large capacity-to-inductance ratio (high-*C*) will reduce harmonics. While this is quite usual practice in self-controlled transmitters, the use of low-*C* tank circuits in oscillator-amplifier transmitters is general because the efficiency is higher with low-*C*. Nevertheless, slightly lower efficiency with high-*C* is preferable to off-frequency operation. Loosening the antenna coupling also will reduce harmonic radiation.

The push-pull amplifier possesses the characteristic of suppressing the even harmonics in its output circuit, although odd harmonics will be present to the same degree as in single-tube amplifiers of equivalent power output. Since the second harmonic is the most serious offender, however, the use of push-pull will do much to eliminate harmonic radiation. Those circuits utilizing a grounded-rotor split-stator tuning condenser — see Fig. 818-E — are more effective in eliminating harmonics than the type shown in 818-D.

Aside from those steps which can be taken to reduce harmonics in the plate circuit of the final amplifier stage, beneficial results can be secured by using certain types of antenna coupling and feeder systems. Inductive coupling to the feeder is preferable to direct coupling, from the standpoint of harmonic elimination. Likewise, the coupling coil should be coupled to the tank at a point of low r.f. potential — at the filament end in output systems which are not balanced with respect to ground; at the center of the coil in balanced systems — to prevent electrostatic coupling between the tank and feeder circuits. Feeder systems having a current loop at the coupling apparatus will discriminate against even harmonics; a quarter-wave Zepp feeder is an example of this type of feeder system. Directly-coupled feeders will do little to prevent the radiation of harmonics; the directly-coupled single-wire fed antenna is practically as good a radiator at harmonics as at the fundamental frequency.

As for the antennas themselves, those systems which are center-fed through a low-impedance untuned transmission line will discriminate against even harmonics; an end-fed antenna or one fed through a high-impedance line such as the single-wire system and the doublet with fanned feeders will not, practically speaking. Grounded antennas (Marconi type) and center-fed antennas without transmission lines (sometimes called antenna and counterpoise) also are poor radiators of even harmonics.

The antenna-coupling filter previously described is effective in preventing harmonic radiation. Because of the properties of the filter, frequencies higher than the fundamental are practically short-circuited and do not reach the antenna.

To check for harmonic radiation it is necessary to enlist the coöperation of another amateur station a few miles distant from the transmitter. Have the other operator listen for the harmonics to check their strength relative to that of the fundamental frequency. If a strong harmonic is detected, steps should be taken to reduce its strength. The discussion above should be of assistance.

If it is inconvenient to make major changes to the apparatus or antenna and feeder system, harmonics often can be brought to satisfactorily low strength by the use of tuned trap circuits. One method which has proved successful in a number of cases is shown in Fig. 832. The trap circuits are tuned to the frequency of the harmonic to be eliminated; a simple unilateral connection is used between the trap and the antenna or feeder. Best results will be secured by listening to the harmonic in the monitor while the trap condenser is slowly varied; the minimum point should be quite clearly defined. The tuning can be checked by having another station listen while the trap is tuned. A low-*C* trap seems to be most effective. The trap will not affect the fundamental output of the transmitter.

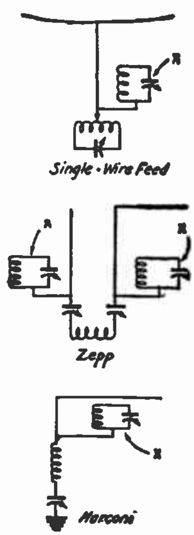


FIG. 832 — TUNED TRAP CIRCUITS TO REDUCE HARMONIC RADIATION

Designing the Transmitter

● Although all the foregoing discussion has dealt principally with parts of circuits and methods of accomplishing some particular end desired in building a transmitter, the reader who has followed the discussion closely will have a fair knowledge of some of the considerations underlying complete transmitter design. The advantages and disadvantages of various types of interstage coupling, of neutralizing circuits, of different antenna-coupling methods and the like have been considered in detail.

The power to be delivered by the transmitter determines to a considerable extent the types of tubes to be selected, the number of exciting stages to be used, and the choice of circuits and components. The frequency or frequencies on which the transmitter is to be worked likewise exerts its influence on these same factors.

Driving Stages

● The number of driving stages will be dependent upon the grid requirements of the final stage, the type of oscillator used, and the number of bands to be covered. Assuming that a crystal oscillator having an output of a few watts is to be used — almost universal practice — it becomes necessary to provide enough intermediate stages, straight amplifiers and doublers, to build up the power output of the oscillator to a value sufficient to drive the final stage. There are numberless ways of going about solving this problem. In general, there are two methods; one is to build an "exciter unit," whose purpose is to deliver approximately the same output, usually a few watts — about the same as could be obtained from the crystal oscillator — on a number of frequency bands, following the exciter unit by straight amplifiers. The second is to use as few tubes and circuits as possible, getting the greatest possible power gain in each stage, including the doublers. Both methods have their advantages, the former in wide frequency range and convenience in operation, the latter in economy of tubes, circuit components and power supply apparatus.

If a number of bands is to be covered, the number of intermediate stages will depend not only on the power gain needed but also on the oscillator frequency. For 14-mc. work, for instance, it is possible to start out with a crystal oscillator on 1.75 mc.; three multiplications of frequency and possibly additional straight amplification will be required. Two of the doublers can be eliminated if the oscillator uses a 7-mc. crystal, thus considerably simplifying the design. It may therefore be greater economy to purchase two or three crystals in different frequency bands rather than to use one crystal of low frequency followed by a large number of doubler and amplifier stages. Too, the smaller the number of stages the fewer the troubles likely to be encountered in construction and operation.

In planning the driving layout, it is better to err on the side of having too much excitation rather than too little. At the higher frequencies, especially, more driving power is required for a given output, not only because the tube losses increase but also because the circuit losses go up considerably. The efficiency of a doubler, for instance, is noticeably less in going from 7 to 14 mc. than from 3.5 to 7 mc., and is still poorer when doubling from 14 mc. to the 28-mc. band. For this reason it is always well to allow something for unexpected losses at the higher frequencies. If a tube is rated at say 20 watts as a straight amplifier it is best not to calculate on more than 10 watts of useful output from it as a 7-mc. doubler, perhaps 7 watts as a 14-mc. doubler and 5 watts as a 28-mc. doubler. This reduction in frequency-multiplying efficiency at the higher frequencies must be taken into account in deciding on the number and type of driving tubes. Also, since a doubler requires more exciting power than a straight amplifier, the driving power values given in the tube tables must be increased if the tube is to be used as a doubler.

The general method of design is to use the grid driving power required for the final stage as a starting point, selecting a tube which will deliver that power for the next-to-the-last stage. This tube may be either a straight amplifier or doubler, depending upon the conditions and the amount of power required. The third-from-last stage may then be chosen to deliver the grid power necessary for the driver, and so on, working back to the oscillator, its expected power output and frequency.

The field of choice is so wide that it is difficult to be more specific. The examples of transmitters in Chapter Nine illustrate different designs; a study of them should enable the builder to plan a layout which will meet his particular conditions satisfactorily.

Transmitter Troubles

It is often the case that when the building of a transmitter is completed, at first trials its behavior and power output are not what were expected or hoped. Erratic or unsatisfactory performance can be accounted for in many ways. One common fault is lack of sufficient grid excitation for the final stage, occasioned either through some circuit defect or because of "skimpy" design. If the tube layout is not one that will give the requisite power gain at the desired frequency, no amount of fussing with the transmitter will cure it. Excitation can be quickly checked by measuring the grid current of the stage under consideration; if it is not at or near the value given in the tube tables, assuming that the plate and bias voltages are approximately as given, it is time to look for circuit defects, if the tube line-up is reasonable, or to alter the design in accordance with the principles outlined in the preceding section.

Occasionally a driver stage will give all the signs of operating efficiently and appear to be capable of delivering the required output, but the excitation is deficient. In such cases the trouble often can be traced to the interstage coupling circuit used. Some methods of coupling are preferable to others with certain types of tubes and at certain frequencies, as explained earlier in this chapter. Also, improper arrangement of return leads, particularly those acting as r.f. ground leads, often will cause a reduction in excitation. All grounds should be made to a single point for each stage, with these ground points connected together between stages. Loops in common ground connections or unduly long ground leads should be avoided. This point is considered further in Chapter Nine.

Improper adjustment is another cause of inefficiency. Particular attention should be paid to link-coupled circuits, for instance, to make sure that maximum power is transferred. The number of turns in the link is likely to be rather critical, and time spent in making adjustments to the end of greater power transfer is well worth while. In capacity-coupled circuits, particularly those in which the coupling condenser is attached to the plate end of the driver tank, overloading because of the use of too-large coupling capacity should be avoided. When a stage is overloaded, its plate current will be higher than normal and the resonance dip will not be pronounced.

Parasitic Oscillations

● If the circuit conditions in an oscillator or amplifier are such that oscillations at some frequency other than that desired can and do exist, such oscillations are appropriately termed "parasitic." The energy required to maintain a parasitic oscillation is wasted so far as useful output is concerned, hence an oscillator or amplifier afflicted with parasitics will have low efficiency and frequently will operate erratically. In addition, parasitic oscillations in the self-controlled oscillator can ruin the frequency stability and spoil completely the character of the note.

Parasitic oscillations may be higher or lower in frequency than the nominal frequency of the oscillator or amplifier. Low-frequency parasitics are relatively uncommon, but occasionally exist as the result of unfortunate choice of bypass condenser and r.f. choke values. One way in which such a parasitic oscillation can be generated is shown in Fig. 833. A driver and neutralized amplifier are indicated, but this type of oscillation can exist in any circuit having r.f. chokes in both the plate and grid circuits. There is always some capacity shunt-

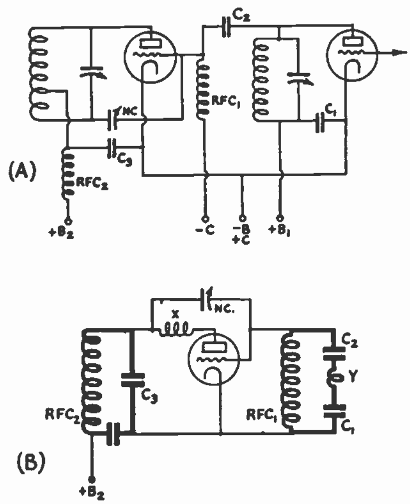


FIG. 833 — HOW LOW-FREQUENCY PARASITIC OSCILLATIONS CAN BE GENERATED

ing the chokes; if the inductances of the chokes and the shunting capacities happen to be such that both chokes are tuned to approximately the same frequency, a tuned-grid tuned-plate type of oscillation may be set up. The normal tank circuits will have but little effect on the oscillation. If oscillations of this type occur they can be avoided, usually, by changing the size of the plate bypass condenser or by removing a choke in series-feed circuit. In general, it is better to omit r.f. chokes with series feed and depend upon the bypass condensers to keep the r.f. currents in the right path. If the bypass condensers are large enough the chokes will not be necessary.

A type of parasitic oscillation peculiar to the neutralized amplifier is indicated in Fig. 834. It results from the use of a tapped plate tank coil for neutralizing and a similar tap on the driver tank coil for control of excitation. The parasitic circuit, again a t.p.t.g. type of oscillation, is through the shaded parts of the tank coils. This is a particularly vicious type of parasite; it is a persistent oscillator and usually requires a change in the design of the transmitter for its cure. A neutralizing circuit using a split-stator condenser (Fig. 818-C) will cure it; so also will discarding the tap on the driver tank, feeding the amplifier grid through a smaller coupling condenser connected directly to the plate end of the driver tank coil. The latter scheme does not result in particularly efficient coupling between driver and amplifier, however. A change to inductive or transmission-line interstage coupling also will be beneficial.

Fig. 835 shows one way in which ultra-high

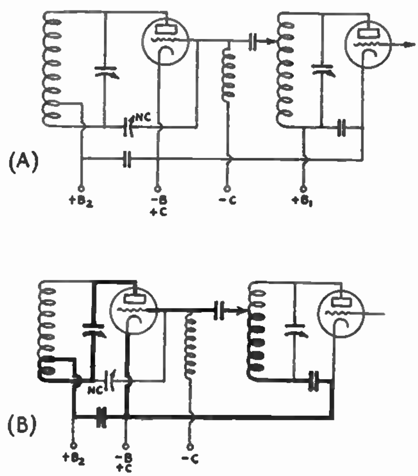


FIG. 834 — A HIGH-FREQUENCY PARASITIC CIRCUIT RESULTING FROM THE USE OF A TAPPED EXCITATION COIL

frequency parasitic oscillations can be set up in a neutralized amplifier; the same type of oscillation could exist in a Hartley oscillator with too-long leads. The leads to the tank circuit, if more than a few inches long, possess enough inductance to tune the shaded circuit in the three- to five-meter region; an ultraudion-type oscillation is set up. Changing the physical layout to shorten the leads should eliminate the parasitic.

A great many combinations of lead lengths can cause the generation of ultra-high frequency parasitic oscillations, particularly with tubes having large physical dimensions and large interelectrode capacities. When this trouble occurs, it is often possible to kill the parasite by inserting a wave trap, tuned to the ultra-high frequency region, in one of the leads. A representative example is given in Fig. 836. The trap condenser is adjusted to resonance at the parasitic frequency, causing it to stop. Such a trap will have negligible effect on the normal operation of the circuit.

Neutralizing Difficulties

● Trouble is sometimes experienced in getting a triode amplifier completely neutralized. In cases of this kind 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.

Although the neutralizing circuit itself is a well-defined bridge and consequently should be capable of perfect balance, in practice 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 unconsidered 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

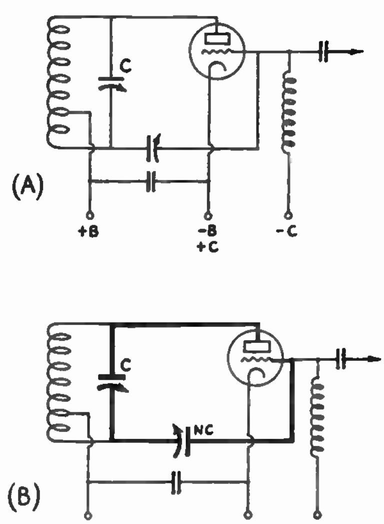


FIG. 835 — ULTRA-HIGH-FREQUENCY OSCILLATIONS CAN BE GENERATED IF THE LEADS FROM THE AMPLIFIER TUBE TO THE TANK CONDENSER ARE TOO LONG

the same base. With large tubes, especially those having relatively high interelectrode capacities, these commonly neglected stray capacities can prevent perfect neutralization, or can operate in such a way that the amplifier will be neutralized with the plate tank set exactly at resonance but will go out of neutralization if the tuning is changed slightly. Symmetrical arrangement of a push-pull amplifier is about the only way to obtain a practically perfect balance throughout the amplifier.

Coil Specification Table

● Turns specifications for various popular types of transmitting coils are given in the Table. The approximate tank capacity required for resonance is indicated. If a condenser having a maximum capacity rating near that specified is chosen, the band will be found near the full-capacity end of the condenser scale.

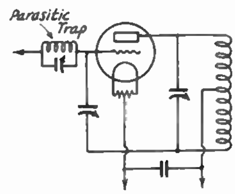


FIG. 836 — ULTRA-HIGH FREQUENCY TRAP TO ELIMINATE PARASITIC OSCILLATIONS

The trap is quite effective when ultra-high frequency parasitic oscillations cannot be avoided by suitable circuit layout. Suggested values for the trap are a variable condenser of about 25 μμfd. maximum capacity and a coil having about three turns, two inches in diameter, with about a quarter inch between turns.

SOME SUGGESTED COIL SPECIFICATIONS

Band →	1750			3500				7000				14,000			28,000		
Max. condenser capacity—μμfds.	500	250	100	500	250	100	50	500	250	100	50	250	100	50	250	100	50
*¼" c.t., i.d. 1½"	—	—	—	—	—	—	—	9	17	—	—	5	11	—	2	4	6
¼" c.t., i.d. 2"	—	—	—	18	—	—	—	6	10	22	—	4	7	12	—	3	5
¼" c.t., i.d. 2½"	—	—	—	12	—	—	—	5	7	15	—	3	6	9	—	2	4
¼" c.t., i.d. 3"	—	—	—	10	17	—	—	4	6	12	—	—	5	7	—	—	3
¼" c.t., i.d. 4"	20	—	—	7	11	24	—	—	—	8	15	—	—	5	—	—	—
¼" c.t., i.d. 6"	12	20	—	—	—	—	24	—	—	—	10	—	—	—	—	—	—
*3/16" c.t., i.d. 1½"	—	—	—	—	—	—	—	8	13	—	—	5	10	16	2	4	6
3/16" c.t., i.d. 2"	—	—	—	16	—	—	—	5	9	20	—	4	7	10	—	3	4
3/16" c.t., i.d. 2½"	—	—	—	11	20	—	—	4	6	14	24	3	5	7	—	2	3
3/16" c.t., i.d. 3"	27	—	—	9	15	—	—	—	—	10	20	—	4	6	—	—	—
3/16" c.t., i.d. 4"	18	32	—	—	10	22	40	—	—	—	13	—	—	—	—	—	—
No. 12 wire, spaced[1] 1½"	—	—	—	16	28	—	—	6	9	19	—	4	7	11	—	3	4
No. 12 wire, spaced[1] 2"	34	—	—	10	19	40	—	4	7	13	24	3	5	8	—	2	3
No. 12 wire, spaced[1] 2½"	24	45	—	8	14	29	50	—	5	10	16	2	4	6	—	2	3
No. 12 wire, spaced[1] 3"	18	34	—	—	11	22	40	—	—	8	12	—	—	—	—	—	—
No. 12 wire, spaced[1] 3½"	16	26	54	—	9	15	30	—	—	—	—	—	—	—	—	—	—
No. 14 wire, d.c.c. 1½"	30	53	—	10	17	35	—	—	7	11	22	3	6	8	—	2	4
No. 14 wire, d.c.c. 2"	20	35	75	8	12	24	40	—	5	9	16	2	4	6	—	—	—
No. 14 wire, d.c.c. 2½"	16	25	53	7	10	19	32	—	4	8	12	—	3	5	—	—	—
No. 14 wire, d.c.c. 3"	14	22	40	—	9	16	24	—	—	7	10	—	—	—	—	—	—

* Spacing between turns (not centers) is ⅛" for these coils. Abbreviations — Copper tubing, c.t.; inside diameter, i.d.
[1] Spacing between turns, in this case, equals wire diameter.
Where blanks appear in the above table, coils of this construction are not recommended for that frequency and condenser capacity.

CHAPTER NINE

Building Transmitters

TYPES OF CONSTRUCTION — WIRING POINTERS — OSCILLATORS — EXCITER UNITS — AMPLIFIERS — COMPLETE TRANSMITTERS

The construction of a transmitter, whether small or large, offers an excellent opportunity for the exercise of ingenuity along both mechanical and electrical lines. Mechanically, the design of a transmitter is not so restricted as that of a receiver, which is customarily constructed so that its controls are continually within reach on the operating table. The transmitter, however, can be built for table or floor mounting, for direct or remote control; it may be run horizontally or vertically, in one piece or unit style.

Transmitter construction usually follows one of several general types. For experimental work the "breadboard" type of construction, in which the apparatus is mounted on a flat wooden board and arranged for best performance, has long been popular. In recent years metal chasses have been made available to set constructors, and these have been adapted to use with transmitters. Again, many amateurs like to mount their apparatus on shelves which are stacked one above the other in a wooden or metal frame, usually with controls brought out to a panel covering the front. The vertical type of construction reaches its highest development in the relay rack, a unit-type rack-and-panel method of building in which separate units are self-contained and completely interchangeable, since relay-rack dimensions are standardized.

Breadboard and Metal Chassis

● The breadboard type of construction offers many advantages. It is inexpensive; circuit components can be arranged for electrical efficiency rather than for ease of control, since there is no panel to which all controls must be brought; and all parts are readily accessible for adjustment or replacement. Insulation presents no great difficulties, since the baseboard itself is a good insulator, for supply voltages at least. On the other hand, the breadboard transmitter collects dust very readily and hence must be frequently cleaned. It does not have the finished appearance of the more advanced types of construction, although careful layout and workmanlike wiring undoubtedly can be combined to make an attractive job.

The metal chassis is closely related to the breadboard, at least when used for open construction without a panel. Unlike the breadboard, however, the metal chassis offers a means for making grounds and serves as a basis for shielding. Then too, most of the wiring and small parts are conveniently mounted underneath the chassis so that the appearance of the set is improved. Present day components, such as tube sockets, bypass condensers, resistors, etc., utilized in low-power transmitters are more suitable for mounting on metal than wood. A metal chassis unit of the proper size and provided with a panel can very easily be adapted to relay-rack style of construction.

Metal chassis pans are available in many sizes, from two inches deep and about seven by seven inches square up to three inches deep and 23 by 10 inches.

The Vertical Frame

● Eventually most amateurs come to the vertical frame or rack type of construction, in which all parts of the transmitter are grouped together in one unit. This type is preferable for a permanent outfit, but usually is not so readily accessible for experimenting and trying out different tubes and circuits as the breadboard type. Since most of the apparatus is concealed by the panel, good external appearance can be attained even though the constructor does not have the knack of making layout and wiring in commercial style.

Frames usually are four-posted affairs made from 1 by 2, 2 by 2 or even larger wood, depending upon the weight to be carried. The shelves holding the apparatus may be breadboards or similar flat boards; they can be fastened to the corners of the frame by small metal angles or mounted on cross-strips screwed to the posts. Provision should be made for removing the shelves for alterations or replacements without too greatly disturbing the remainder of the transmitter. The panel, usually in one piece, can be made from plywood or from one of the wood-pulp products such as Presdwood.

In mounting apparatus in the frame the power supply equipment, being heaviest, usually occupies the bottom section, with the r.f. equipment above. The antenna-tuning apparatus usually is at the top.

The Relay Rack

● The relay rack type of construction offers many advantages not to be found in the other styles. Its appearance is good, parts are quite accessible, and alterations which change the physical size of one section of the transmitter can be made without requiring corresponding alterations in other sections, as would be the case with a frame-mounted transmitter. The reason for this is that each section of the transmitter — such as a power supply unit, exciter, amplifier, and so on — is provided with its own mounting shelf and panel and thus is in itself a complete unit, quickly removable after disconnecting supply wires. All the apparatus of the unit is supported by the panel.

The true relay rack has two uprights made of channel iron, mounted on an iron base. Panels are also of metal, usually steel or aluminum, and generally are 3/16 or 1/4 inch thick. The universality of the relay rack is attained because dimensions have been completely standardized. Panels are 19 inches wide, and of varying heights measured in "rack units," a rack unit being 1¾ inches. To allow for stacking and slight inaccuracies in cutting, a relay-rack panel is always made to be a certain number of rack units high less 1/32nd inch for clearance. Thus a panel four rack units high will measure 7 inches less a 32nd. The channel uprights of the rack are drilled to take 10–24 mounting screws at standardized intervals as shown in Fig. 901. The edge of a panel always comes midway between two holes spaced one-half inch apart.

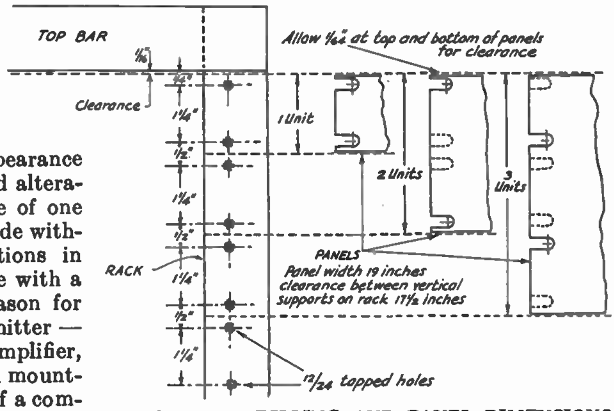


FIG. 901 — DRILLING AND PANEL DIMENSIONS OF THE STANDARD RELAY RACK

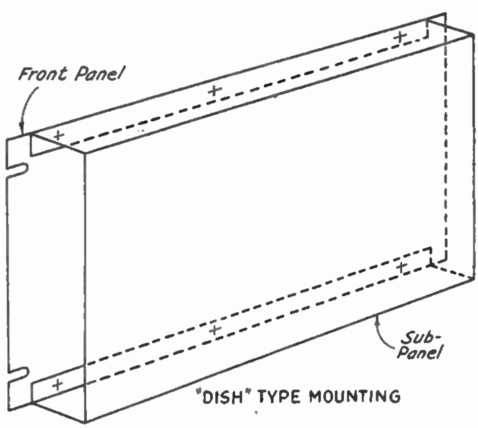


FIG. 902 — THE "DISH" TYPE OF SUB-PANEL MOUNTING FOR THE RELAY RACK

Although the apparatus usually is mounted on a shelf suspended from the rack panel, an alternative type of construction, using a vertical sub-base, also may be used. This type of construction, known as "dish" mounting, has several advantages. Parts and tubes are more readily accessible than on a shelf; also, the apparatus usually will take up less room when mounted in this way.

Home-Made Racks

● Commercial relay racks may be obtained either for floor or table mounting. The floor type is quite expensive and comparatively few amateurs can afford it, while the table size may not be large enough to contain a complete transmitter. Nevertheless the advantages of the relay rack type of construction are well worth having, especially the standardization of sizes and interchangeability of units.

An acceptable substitute for the iron rack can be made by following the standard dimensions and using wooden uprights. Two by three dressed lumber, when properly braced at the bottom, will serve quite satisfactorily. The heavy power supply apparatus should be mounted at the bottom, of course. A suggestion for this type of rack is given in Fig. 903. Panels and shelves can be made of metal, wood or other suitable materials, adequately braced to carry the weight. It may be necessary to brace the shelves to the wooden uprights. Other arrangements than those suggested will readily occur to the constructor.

Materials for Construction

● Besides the metal chassis pans already mentioned, many other useful "gadgets" and materials are available to the constructor. Metal frames suitable for holding transmitters of moderate size are marketed by a number of manufacturers. Some types come complete as one unit, with a single panel, while others have separate panels. One manufacturer furnishes panels suitably drilled to take a considerable number of circuit arrangements, thus saving the builder the labor and necessity for acquiring tools and equipment for cutting holes in metal.

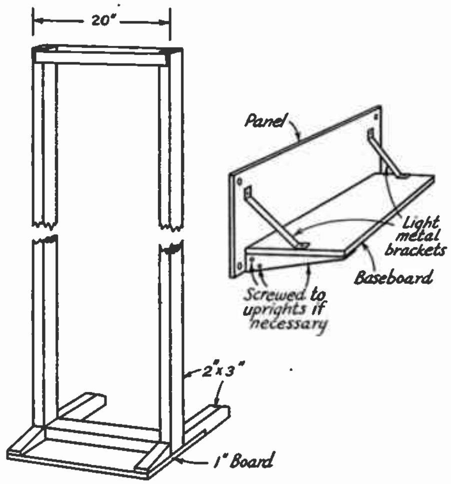


FIG. 903 — SUGGESTED CONSTRUCTION OF AN INEXPENSIVE WOODEN RELAY RACK AND SHELF

The height of the uprights will depend upon the number of panels to be used. The space available for panels should be some multiple of a rack unit (1¾ inches). See Fig. 901 for standard dimensions.

Relay rack panels of various sizes, made of aluminum or steel finished in crackle, also can be obtained from amateur suppliers. Wood-fibre panels, likewise finished in the popular black crackle, also are available. These are easily worked, besides being relatively inexpensive.

Winding Transmitting Inductances

● Although most circuit components can be purchased at quite reasonable prices, many amateurs wind their own transmitting inductances. This is partly because the inductance of the coil must be adjusted to fit the particular condenser used, and partly because of mechanical considerations.

Coils for low-power stages, handling ten watts or less, can be wound on ordinary receiving coil forms, using relatively small wire. However, when the power to be handled is fairly large, heavier conductors must be used to avoid heating. Number 14 or 12 wire, properly spaced, will carry the output of most medium-power amplifiers without undue heating, especially when the optimum or higher *L-C* ratio is used. In high-*C* circuits or in high-power tank circuits copper tubing is generally used; sizes of tubing range from ⅛ to ¼ inch.

The chief requirements for a good transmitting coil are that its resistance be low (large conductor and proper proportioning of dimensions) 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.-type plugs fitting into jacks mounted in a strip of bakelite or in special stand-off insulators.

The easiest way to wind copper tubing is to clamp one end of a piece of the requisite length in a vise, and fasten the other end to a piece of iron pipe approximately the desired diameter of the finished coil, and then wind by turning the pipe in the hands while pulling hard on the tubing to keep it straight. The turns should be wound tightly together, spacing being adjusted after the coil is finished by spreading the turns with the shaft of a screwdriver.

A second type of coil construction utilizes thin bakelite strips, drilled at proper intervals to give the desired turn spacing, to support the turns. Three or four such strips will be sufficient. Coils of this type are illustrated later

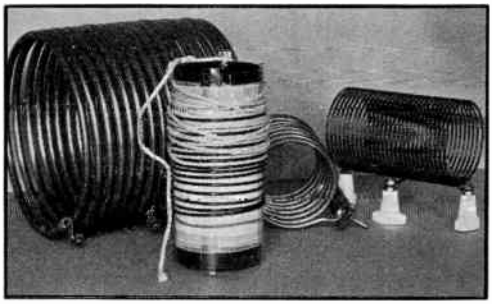


FIG. 904 — COILS WOUND ON CELLULOID STRIPS, SHOWING THE WORKING MATERIALS NEEDED FOR CONSTRUCTION

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.

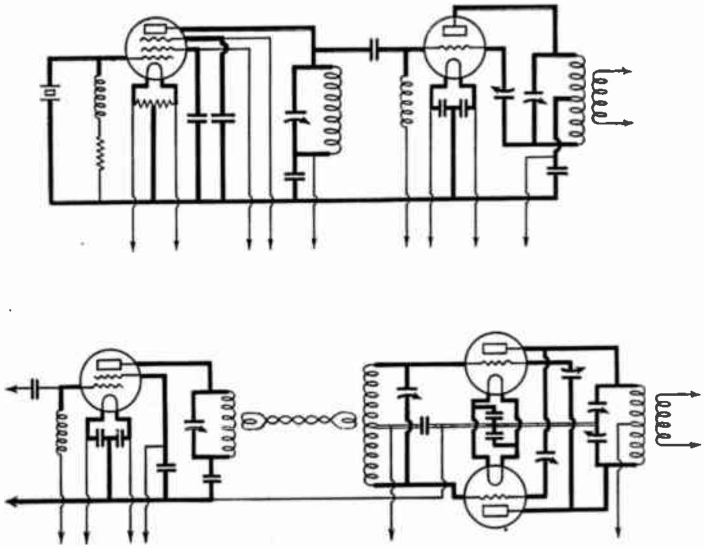


FIG. 905 — LEADS CARRYING RADIO-FREQUENCY CURRENT, INDICATED BY THE HEAVY LINES, SHOULD BE AS SHORT AS CIRCUMSTANCES WILL PERMIT

in the chapter. To make them, 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 or tubing without binding. After threading through the strips the turns may be fastened firmly in place with Duco cement.

A third type of coil is shown in Fig. 904. In this case the supporting strips are celluloid, cemented to the coil turns. A winding form such as a bakelite tube of proper diameter 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 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, although it is generally used with wire coils.

Arrangement of Circuit Components

● In fixing upon a layout for the parts of the circuit, care should be taken to make those leads carrying r.f. as short as possible. The leads carrying supply voltages need not be so short, although they should be kept well removed from r.f. parts of the circuit.

Fig. 905 indicates the leads which should be short in two typical diagrams. It is not enough to have short leads in the tank circuits; by-passes should be made as directly as possible to the ground point. Neither should "hot" r.f. leads be close together; this introduces stray capacity coupling and may cause feedback or prevent neutralization of an amplifier. Considerable thought should be given to the arrangement of apparatus to obtain short r.f. leads and yet keep each component isolated as

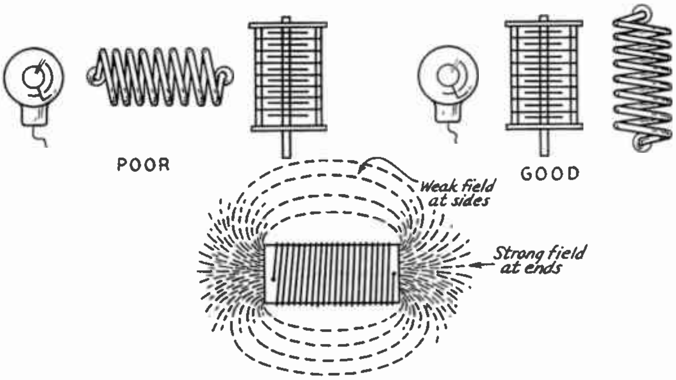


FIG. 906 — THE RIGHT AND WRONG WAY TO MOUNT COILS IN THE SET

much as possible. The time thus spent will be well repaid in improved performance.

Unnecessary losses can be caused by improper placement of inductances. Whenever a metallic object is introduced into the field of a coil, currents are induced in the object which cause heating and resultant power loss. Fig. 906 shows the right and wrong way to mount inductance coils in relation to other circuit components. The field of the coil is strongest at the ends and weakest at right angles to the axis, hence the ends of the coil should be isolated from other parts of the circuit whenever possible. To confine the field of the coil to a small space, its length should be two or three times its diameter.

Coils for r.f. circuits, particularly at the higher frequencies, should be space wound. The distributed capacity of the coil is reduced by spacing the turns. Since at high frequencies an appreciable current can flow between turns because of distributed capacity, the current and hence the losses can be reduced by spacing. Spacing equal to the diameter of the conductor used is sufficient.

Grounds

● The way in which ground returns are made can have a considerable effect on the operation of the circuit. It is good practice to make *all* grounds in a single circuit to one point, as indicated by Fig. 907. If grounds are made at different points, the reactance of the leads between two of them may be sufficient to cause an appreciable r.f. voltage drop, which may cause regeneration or degeneration. If the former, the amplifier may break into oscillation or be difficult to neutralize; if the latter, it may be impossible to drive the tube properly even though the output of the driver is sufficient for adequate excitation.

On metal chasses the same principle should be followed. Even though the base is metal and therefore apparently a good conductor, all ground returns should be made to one point. Otherwise different parts of the chassis may be at different r.f. potentials, causing the same difficulties to arise.

Because of the necessity for physical spacing between stages, it may not be possible to bring all the grounds in the transmitter to one single point without having unduly long leads. In such cases, each stage should have its own ground point, and these should be connected together with a single wire. This is important in frame or rack type construction, where several stages may be mounted one above the other. There should be only one ground wire; loops and circuitous returns up and down the opposite sides of the frame should be avoided. If a ground is made to a metal frame, it should

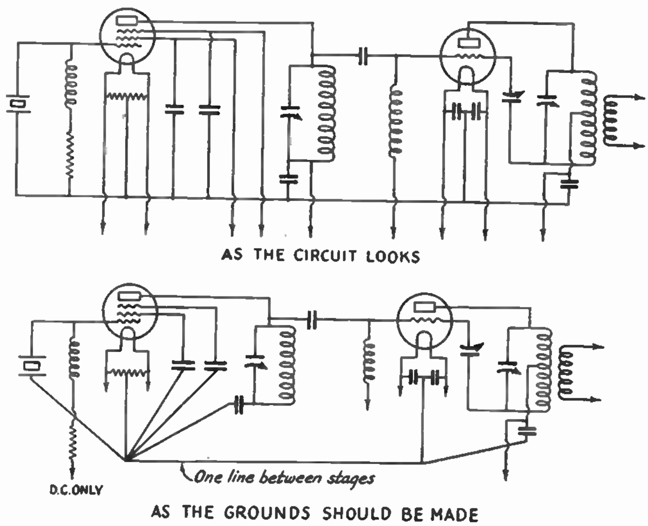


FIG. 907 — GROUND LEADS FOR EACH STAGE SHOULD BE BROUGHT TO ONE POINT, WITH GROUND CONNECTIONS BETWEEN STAGES MADE AS SHOWN

be made at one point only, if circumstances will permit. Poor grounding can account for many transmitter eccentricities, particularly inadequate excitation in a transmitter layout which on paper has ample driving power.

Practical Examples of Transmitter Design

● The following examples of oscillator, amplifier and complete transmitter construction have been selected to illustrate different types of mechanical arrangement and representative methods of circuit design. The amateur who does not wish to duplicate a particular transmitter or unit undoubtedly will find many ideas which will be of value to him in planning a layout to fit his individual needs.

A Practical Low-Power Crystal Transmitter

● Since it is possible to obtain an output of five watts or more from a crystal oscillator, its use without auxiliary amplifiers is perfectly practical for low-power work. Using the tritet oscillator circuit for harmonic operation and the regular pentode circuit for the fundamental, a single tube and crystal can be made to work equally well on two bands so that a fair degree of flexibility is obtained. A circuit dia-

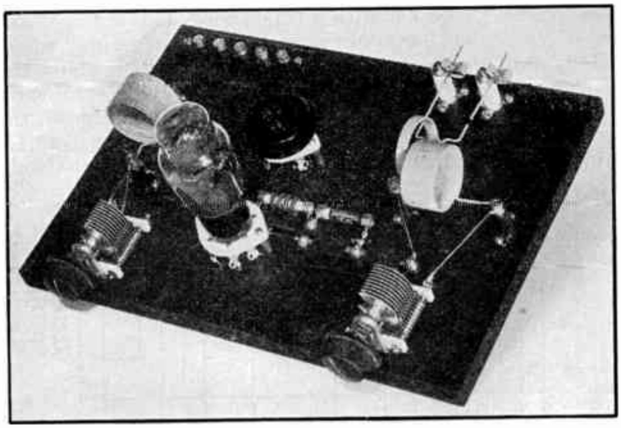


FIG. 908 — A SIMPLE CRYSTAL OSCILLATOR SUITABLE FOR LOW-POWER WORK

It will operate on two bands with a single crystal.

gram of such an oscillator using a Type 59 tube is given in Fig. 909. Photographs of the set appear in Figs. 908 and 910. Since interchangeable coils are used, the transmitter can be used on any frequency for which a crystal is available. Breadboard-type construction is used.

The change from tri-tet to pentode circuit is made by short-circuiting the cathode tuning condenser, C_1 which is done by bending the tip of one rotary plate so that it touches the stator when the condenser is turned with the plates fully interleaved. The screen grid and suppressor grid of the 59 are connected together at the tube socket to act as a single element.

The apparatus is mounted on a baseboard measuring 10 by 14 inches. The two tuning condensers, C_1 and C_2 are mounted along the front edge, each 2½ inches in from the edge, with C_1 at the left. The grid and plate coils, L_1 and L_2 are mounted on small porcelain standoff insulators located behind their respective condensers.

The screen and plate by-pass condensers, C_3 and C_4 respectively, are mounted end to end just to the rear of and between C_2 and the socket for the 59 tube, by machine screws which pass through the condenser lugs to the under side of the baseboard. The tube socket is mounted slightly to the left of the center of the board to accommodate the length of the by-pass condensers so mounted. The junction between C_3 and C_4 is used as a common ground point for the circuit. Just behind the parallel to C_3 is the grid leak, R_1, and next to it the radio-frequency choke, *RFC*, which is connected between R_1 and the grid of the tube. The tube socket is mounted with the filament terminals (the two large holes) facing the front edge of the board. The socket for the crystal holder is mounted behind the tube socket.

Power supply connections are brought out to a bakelite strip mounted flat on the baseboard at the rear left-hand corner. Ordinary 6-32 machine screws are used as terminals. Five half-inch holes in the baseboard underneath the screw terminals give plenty of room for the screw heads and for running in the connecting wires.

The output posts at the right are National Type GS-1 insulators. Fahnestock clips are mounted underneath the metal heads to hold the antenna coil.

The self-supporting coils used with the transmitter are wound with double cotton-covered wire on a celluloid base. In making the coils, a piece of sheet celluloid is wrapped around a cardboard tube

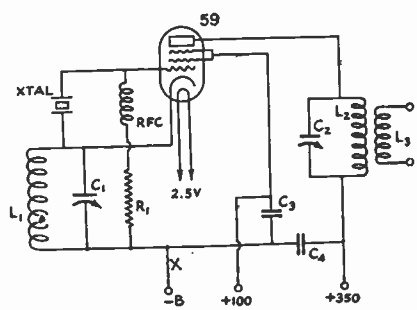


FIG. 909 — CIRCUIT OF THE SINGLE-TUBE CRYSTAL TRANSMITTER

C_1, C_2 — 100-μμfd. variable tank tuning condensers (National Type ST-100).
C_3, C_4 — 0.005-μfd. fixed mica screen and plate bypass condensers (Dubilier Type 3).
L_1, L_2 — Cathode and plate coils. See coil table.
L_3 — Antenna coil; see text.
R_1 — Grid leak, 50,000 ohms, 2-watt (I. R. C.).
RFC — High-frequency choke (National Type 100).

The key is connected in the negative lead at the point marked with an "x."

COIL DATA

No.	Wire Size	Turns	Diameter
1	22 d.c.c.	75	1⅝ inches
2	" "	45	" "
3	16 d.c.c.	40	" "
4	" "	18	" "
5	" "	16	" "
6	" "	7	" "
7	" "	8	" "

All coils close-wound.

Crystal Frequency	Coil at L_1	Coil at L_2	Output Frequency
1750–2000 kc.	s	No. 1	1750–2000 kc.
" "	No. 2	No. 3	3500–4000 kc.
3500–3650 kc.	s	No. 3	3500–3650 kc.
" "	No. 4	No. 5	7000–7300 kc.
7000–7200 kc.	s	No. 5	7000–7200 kc.
" "	No. 6	No. 7	14,000–14,400 kc.

"s" indicates short circuit across C_1.

of the proper diameter and held in place with string or rubber bands; the winding is then put on and given several coats of lacquer or prepared coil dope. After drying, the excess celluloid can be trimmed off and the coil ends bent to fit the mountings. Winding data are given under Fig. 909, together with information on using the coils with crystals of various frequencies. Limits of crystal frequencies for harmonic operation are indicated in the table; for operation at the fundamental a crystal having any frequency inside the band can be used.

The tuning procedure for both the pentode and Tri-tet connection is explained in Chapter Eight. The method of antenna tuning will depend upon the antenna system; complete instructions are given in Chapters Eight and Twelve. The oscillator plate current should rise to 30 or 40 milliamperes when the antenna circuit is tuned to resonance. After adjusting the antenna circuit, C_2 should be retuned to give maximum output and to make certain that the oscillator "starts" quickly each time the plate circuit is closed. The transmitter should be keyed and the signals monitored to make certain that the keying is clean. It may be necessary to set C_2 slightly off the maximum output point to get the necessary keying stability.

When operating as a Tri-tet for second-harmonic output the plate current should again be in the vicinity of 40 to 50 milliamperes with the antenna connected and tuned.

The 350-volt power supply shown in Chapter Ten can be used with this transmitter provided a voltage divider is installed to give 100 volts for the screen grid. A satisfactory divider can be made by connecting a 7000- and 10,000-ohm resistor in series across the output of the supply, with the 7000-ohm unit at the negative side. The tap between the two will give approximately the correct voltage. It is important that the screen voltage be kept as nearly as possible at 100 volts. Lower voltage will reduce the output while higher voltage is likely to cause the tube to heat and perhaps stop oscillating after a few minutes' operation.

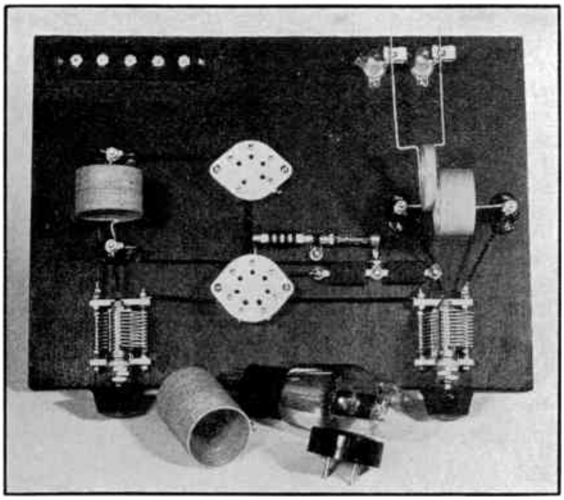


FIG. 910 — A TOP VIEW OF THE CRYSTAL OSCILLATOR WITH THE TUBE AND CRYSTAL HOLDER REMOVED

The coils in place are those used to operate the transmitter as a Tri-tet oscillator for 7000-kc. output from a 3500-kc. crystal. The 3500-kc. output coil and the Bliley crystal holder are in the foreground.

An RK20 Tri-Tet Oscillator

● An example of the use of the RK20 as a medium power Tri-tet crystal oscillator is shown in Figs. 911–915, inclusive. Although a complete transmitter in itself, this set also can be used to excite a more powerful amplifier requiring grid driving power of the order of 25 to 50 watts. The construction is of the vertical open-frame type.

The RK20 transmitter can be used on three bands with crystals ground for two, 3.5 and 7 mc. Provision also is made for the use of 14-mc. crystals if available. No plug-in coils are used, band-changing being accomplished by the use of tapped coils and shorting devices. The set is capable of delivering an output of about 60 watts on the 80- and 40-meter bands and about 25 watts on 20 meters, using only 80- and 40-meter crystals. It can be used for c.w. on all three bands, break-in operation being possible, and for 75-meter 'phone with a suitable modulator.

The upright and cross-panel layout combines the conveniences of both breadboard and rack-type construction in that controls are panel-mounted yet all parts are readily accessible. The uprights are pieces of ¾ by 1½-inch wood, each being 13 inches high. Triangular shaped pieces of thinner wood screwed to the bottom of each upright preclude the possibility of upsetting the transmitter by accident. The panels each measure 9 by 3 inches, and are of 3/16-inch bakelite.

The circuit diagram, Fig. 913, is the Tri-tet arranged for tapping of both plate and cathode tank coils for quick band changing. The cathode coils, L_1 and L_2, are wound on a short piece of 2-inch bakelite tubing. The wire used is No. 14 d.c.c., with L_2 wound on the form and L_1, which is tapped, wound right on top of L_2. The very close coupling thus obtained between L_2 and L_1 makes it unnecessary to tap both coils, since the short-circuited portion of L_1

also short-circuits the magnetic flux about the corresponding portion of L_2. The four ends of the two windings are brought through the coil form to machine screw terminals along the bottom edge. The drop in filament voltage through the windings is negligible.

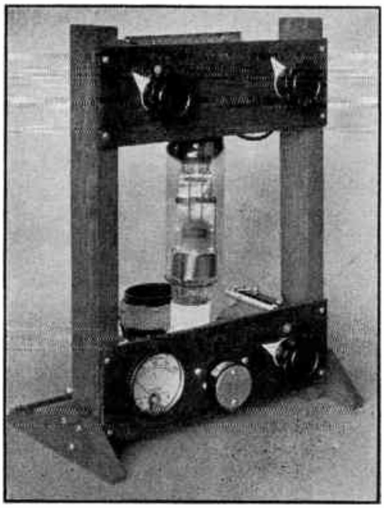


FIG. 911 — AN RK-20 TRI-TET OSCILLATOR

This transmitter will give a crystal-controlled output of 60 watts on 3.5 and 7 mc. and about 25 watts on 14 mc. Its 'phone rating in the 4-mc. band is 15 watts carrier for 100% modulation.

The lower panel contains the plate milliammeter, the crystal mounting, and the cathode tank circuit tuning condenser, C_1. The crystal mounting is made by drilling two holes, of a size sufficient to pass the holder pins and the proper distance apart (¾ inch) in the panel, and mounting behind them a pair of pin-grips taken from a discarded wafer socket. The plate tank tuning condenser and plate-coil band-changing switch are mounted on the upper bakelite panel.

Bypass condensers and other parts are mounted on a skeleton frame made of pieces of quarter-inch square brass rod. The rear and bottom views, Figs. 912 and 914, indicate the construction. The main "girder" runs horizontally across the bottom of the transmitter. On it are mounted the plate, screen and suppressor by-pass condensers. The brass-rod frame forms a common ground and negative bus for the transmitter. The socket for the tube is set on top of two upright pieces of rod, long enough for the socket to clear the condensers underneath, fastened to the main crosspiece. The filament by-pass condensers are mounted horizontally from these uprights. Additional bracing for the socket is provided by lengths of rod which connect the uprights on which the socket is mounted with the front panel. All power leads (properly insulated) are run through holes drilled in the crosspiece and go to the rear of the set where they connect to the terminal strip. The cathode coil assembly is held in place by short pieces of copper strip which serve both as connections and mechanical braces between the lower coil terminals and the filament by-pass condensers.

The plate tank coil, L_3 is mounted between the plate tuning condenser and the left-hand wooden upright (rear view) by means of brass pieces. The coil is wound of No. 14 bare wire threaded into strips of thin bakelite previously drilled to give the desired turn spacing (⅛-inch center to center). The method of making coils of this type is described earlier in this chapter. The wire is cut six turns in from one end to provide an output coupling coil insulated from the plate coil. The coupling coil is at the "dead" end of the plate coil to avoid capacity effects and reduce harmonic transfer, the turns being shorted from the plate or "hot" end.

The shorting switch has three contacts, only two of which are used, the unconnected tap being the 80-meter position, when the whole of the tank coil is used.

Assuming a 3.5-mc. crystal is to be used, set the switch in the open position, leave the cathode-coil clip floating, and turn C_1 down from maximum until the plate current drops, indicating that oscillations have started. Con-

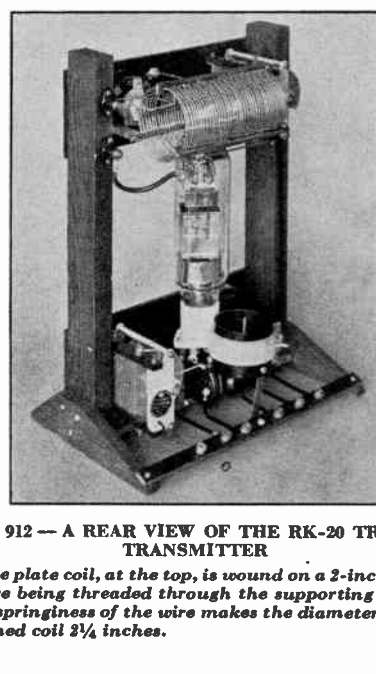


FIG. 912 — A REAR VIEW OF THE RK-20 TRI-TET TRANSMITTER

The plate coil, at the top, is wound on a 2-inch form before being threaded through the supporting strips. The springiness of the wire makes the diameter of the finished coil 2¼ inches.

tinue to decrease the capacity of C_1 until the plate current rises to a maximum and then adjust C_2 for the plate current dip which indicates resonance. With C_1 at about half scale the off-resonance plate current will be 100 milliamperes or more; at resonance it should drop to about 20 ma. The antenna may then be coupled and its tuning circuits adjusted for maximum output. After the antenna is tuned, C_2 and C_1 should be readjusted to determine the optimum settings. An antenna coupler of the type shown in Figs. 939 and 940 may be used with this transmitter.

For operation on the second harmonic the procedure is the same except that the plate-coil switch is set on the 7-mc. tap. The dip in plate current when C_2 is adjusted to resonance will not be so great as when the output is on the fundamental frequency of the crystal nor will the output be as high. Also, a slightly higher-capacity setting of C_1 will give greater output on the harmonic.

To use the set with a 7-mc. crystal, both the plate switch and the cathode-coil clip should be set on the proper taps. The tuning procedure is identical with that just described. The second-harmonic plate current dip on 20 is comparatively small and the output drops to about 25 watts. A 14-mc. crystal can be used if the cathode clip is set on the proper tap. The output should be higher than when doubling from a 7-mc. crystal.

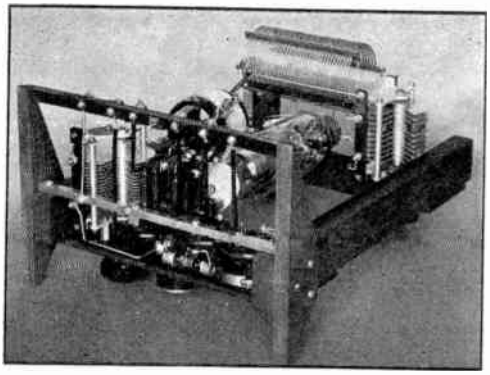


FIG. 914 — A BOTTOM VIEW OF THE RK-20 TRI-TET

By-pass condensers are mounted on the brass-rod supporting structure.

The resistor near the panel is the grid leak. The grid choke is fastened by its pigtail connections between the grid prong on the tube socket and one end of the leak.

Before the tuning operations are attempted, the section on Tri-tet oscillators in Chapter Eight should be read carefully.

This transmitter requires a power supply delivering 7.5 volts at 2 amperes for the filament, 1000 volts at 80 ma. for the plate, 300 volts at 40 ma. for the screen, and 50 volts at negligible current for the suppressor. A suitable voltage divider to supply screen and suppressor currents from the high-voltage source is suggested in Fig. 915.

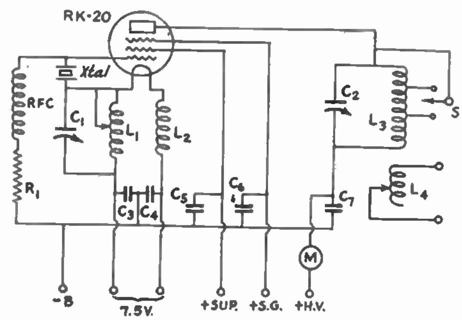


FIG. 913 — THE RK-20 TRANSMITTER CIRCUIT DIAGRAM

C_1 — 350-μμfd. variable, receiving type.
C_2 — 100-μμfd. variable, transmitting type.
C_3, C_4 — .005 μfd. (value not critical).
C_5, C_6 — .002-μfd. mica condensers, receiver type.
C_7 — .002-μfd. mica condenser, 2500- or 5000-volt rating.
R_1 — 15,000 ohms, 2-watt rating.
RFC — Short-wave choke, universal wound.
L_1 — 10 turns No. 14 d.c.c. wire, close wound on 2-inch form. 7-mc. tap at 5 turns from lower (filament supply) end; 14-mc. tap at 2 turns from lower end.
L_2 — Same as L_1, but without taps. L_1 is wound directly over L_2 on the form.
L_3 — 28 turns of No. 18 bare wire, turn spacing 1/8 inch center-to-center; coil diameter 2 1/4 inches; 7-mc. tap 12 turns from plate end. 14-mc. tap 23 turns from plate end.
L_4 — 6 turns same as L_3. L_4 is a continuation of L_3, the wire being cut at the appropriate turn.
M — 0-200 milliammeter.

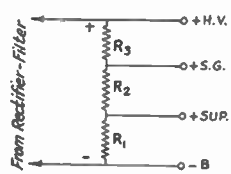


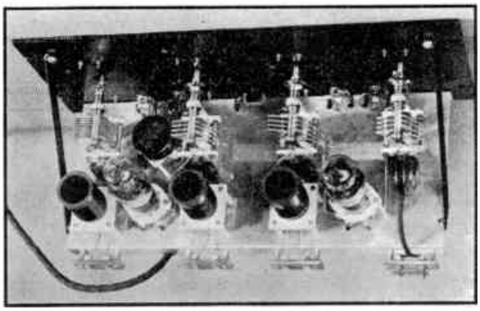
FIG. 915 — SUGGESTED VOLTAGE DIVIDER FOR SUPPLYING SCREEN AND SUPPRESSOR VOLTAGES FROM 1000-VOLT PLATE SUPPLY

R_1 — 2500 ohms, 5-watt rating.
R_2 — 12,500 ohms, 25-watt or higher rating.
R_3 — 12,500 ohms, 40-watt rating.

The resistors may be standard units of the values specified, or individual adjustment may be made to the voltages by using variable resistors of the type having sliding taps.

A Six-Band Exciter Unit

● We have seen in Chapter Eight that the purpose of the exciter unit is to provide a small but uniform output on several bands for the excitation of following amplifier stages. An exciter unit which delivers power output of the



following amplifier stage should be provided with plugs to fit the output jack-strips on the exciter. Plate current to each tube should be in the vicinity of 30 ma. at the plate voltage specified.

Tuning of oscillator and doublers is as described in Chapter Eight.

FIG. 916 — A PANEL-MOUNTED EXCITER UNIT USING TWO TYPE 53 TUBES

This unit, with appropriate crystals, will give sufficient output in five bands to excite a following low- or medium-power amplifier.

order of three to five watts is shown in Fig. 916. It uses two Type 53 tubes, each of which has two separate triodes in one bulb. The two tubes are therefore equivalent to four. Relay-rack type construction is used. The circuit diagram is given in Fig. 917.

Referring to Fig. 916, the tuned circuits run in regular order from left to right, starting with the crystal circuit at the left. The tuning condensers are insulated from the subpanel and are connected to the tuning dials by insulated couplings and extension shafts. The 56-mc. coil is mounted on the tuning condenser at the extreme right. Each of the plug-in coils is provided with an output link winding which connects to jacks on the small strips at the rear of the chassis. In this circuit the number of stages in use is determined by the frequency at which output is desired and by the frequency of the crystal, as shown in the table at the top of the next page.

If 56-mc. output is not wanted (the efficiency in doubling to this band is low and the output is therefore quite small) a fourth coil socket can be installed and the regular coils plugged in at L_7 and L_8. This will make it possible to double once more from any crystal and thus increase the flexibility of the exciter for five-band operation.

The excitation taps on the plate coils are used to give maximum power transfer and to avoid overloading of the previous stage. The link line to the

A Band-Switching Exciter Unit

● Convenience in band-changing is very desirable in the exciter unit, especially when the

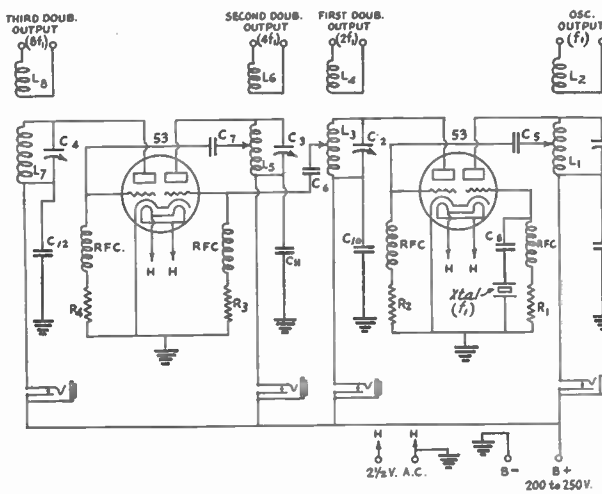


FIG. 917 — CIRCUIT DIAGRAM OF THE 53 EXCITER UNIT

C_1 — Oscillator tuning condenser, 100 μμfd. (National Type SE-100).
C_2, C_3, C_4 — Tuning condensers for first, second and third doublers, respectively; 20 μμfd. each (National Type SEU-20).
C_5, C_6 C_7 — Interstage coupling condensers, .001 μfd. each.
C_8 — Insulating condenser, .001 μfd.
C_9, C_{10}, C_{11}, C_{12} — Plate by-pass condensers, .01 μfd. each.
R_1 — Oscillator grid leak, 5000 ohms, 2-watt, non-inductive.
R_2 — First doubler grid leak, 20,000 ohms, 2-watt, non-inductive.
R_3 — Second doubler grid leak, 10,000 ohms, 2-watt, non-inductive.
R_4 — Third doubler grid leak, 10,000 ohms, 2-watt, non-inductive.
RFC — R.f. chokes (National Type 100).
Jacks are of the single-closed-circuit type.

Coil specifications are given in the table below. All are wound on 1½-inch diameter receiving-coil forms with the exception of the 56-mc. coil. Link windings for output coupling (L_2, L_4, L_6, L_8) are each two turns of the same size wire as the main winding, and are wound between the turns of the latter at the ground end. Pin and socket connections should be the same for each coil and stage so that the coils will be interchangeable to give proper combinations with different crystals. The 56-mc. coil is a self-supporting winding of No. 10 wire, diameter of coil 1¼ inches.

Frequency	*1.75 mc.*	*3.5 mc.*	*7 mc.*	*14 mc.*	*28 mc.*	*56 mc.*
Total Turns	*60*	*35*	*20*	*10*	*4*	*3*
*Tap Turns **	*20*	*12*	*6*	*3*	*1⅓*	*—*
*Length ***	*1½"*	*1½"*	*1½"*	*1¼"*	*⅞"*	*1"*
Wire Size	*No. 28*	*No. 22*	*No. 16*	*No. 16*	*No. 14*	*No. 10*

* Excitation tap turns are counted from grid end of coil.
** The turns are spaced to occupy the winding length given.

Output Frequency	*Crystal Frequency*	L_1	*Coil At* L_3	L_5	L_7	*Output From*
1.75	1.75	1.75	—	—	—	L_2
3.5	1.75	1.75	3.5	—	—	L_4
"	3.5	3.5	—	—	—	L_2
7	1.75	1.75	3.5	7	—	L_6
"	3.5	3.5	7	—	—	L_4
"	7	7	—	—	—	L_2
14	3.5	3.5	7	14	—	L_6
"	7	7	14	—	—	L_4
28	7	7	14	28	—	L_6
56	7	7	14	28	56	L_8

transmitter is shifted frequently from one band to another. A band-switching exciter for four bands — 3.5 to 28 mc. — is shown in Figs. 918 and 919. Also of relay-rack construction, this exciter is similar in design to the 53 exciter just described with the addition of a screen-grid pentode amplifier, thus raising the output level to the order of 10 to 15 watts on all bands. Fixed tuning is used in all stages as a further aid to convenience.

FIG. 918 — A BAND-SWITCHING EXCITER UNIT FOR FOUR BANDS

The output of the unit is approximately 10 watts on all bands covered. A feature of the circuit is pre-tuning of various stages, so that tank condensers need not be readjusted when shifting bands. This unit was built by W9DRD.

The circuit of the exciter is shown in Fig. 920. The first triode section of the first 53 serves as the crystal oscillator; provision is made for using up to six crystals, any of which may be selected by the six-point switch. The second triode section of the same 53 is tuned to 7 mc. The first section of the second 53 is tuned to 14 mc. and the second section of the same tube to 28 mc. These four tanks once peaked will require no retuning with crystals whose fundamental frequencies fall between 3500 kc. and 3575 kc. It will be necessary to retune the oscillator rank condenser for a crystal in the 3.9 mc. 'phone band.

The four sections of the two 53's are permitted to run constantly. Capacity feed is used, with the tap coming directly off the plates of the 53's, through a four-point switch the arm of which is hooked to the RK23 grid.

A feature of the exciter is the use of separate tank circuits for each band for the RK23. The tank condensers are mounted at the tops of the shield cans, the tank coils being suspended below. The coil turns indicated are quite critical; and in the case of the 14- and 28-mc. combinations, the tanks will not tune to resonance until the load of the final stage is added. For simplicity, the plate of the RK23 is shunt-fed, so that one side of the coil and condenser may be grounded. One lead from the high side of each coil is brought out through a grommet in the side of the coil shield and is fed through a four-point switch to the RK23 plate.

Referring to the rear view, Fig. 919, at the right are six crystal holders along the edge of the chassis. The mounting is a strip of Victron, using wafer socket clips for contacting the holder prongs. Along the rear of the chassis, from right to left, are the 3.5-mc. oscillator coil, the first 53, the 7-mc. coil, the 14-mc. coil, the second 53, and the 28-mc. coil. The tuning condensers are mounted on the bakelite strip which forms the back edge of the chassis. In the center is the RK23 buffer with its four tank circuits.

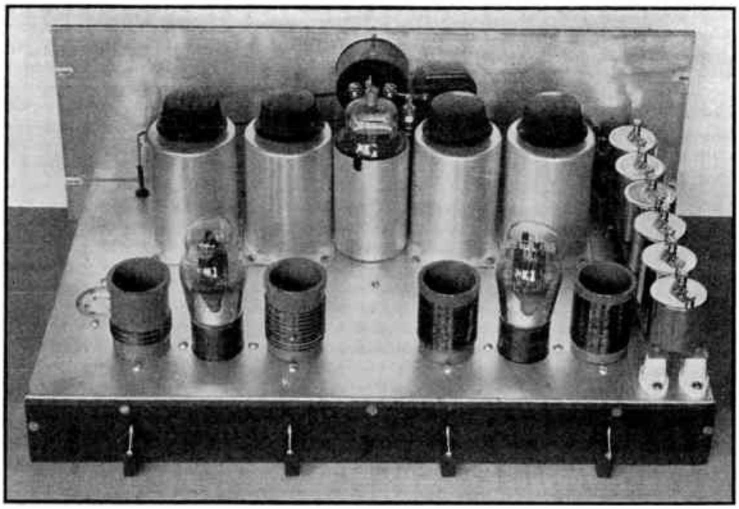


FIG. 919 — A REAR VIEW OF THE BAND-SWITCHING EXCITER

Showing oscillator and doubler coils as well as the shielded tank circuits for the RK23. The knobs in the foreground tune the oscillator and doubler circuits.

Since both 53's are always in circuit, band-changing is simply a matter of selecting the proper tap on the RK23 grid switch and the corresponding tap on the plate switch. The tank circuits ordinarily should be resonated at about the centers of the various bands unless only one crystal is used, when they may be tuned exactly to resonance.

Plate currents for the various 53 sections should be in the vicinity of 25 to 35 ma. The RK23 will draw approximately 50 ma. when loaded. The RK23 output circuits may be coupled to the following amplifier stage by appropriate methods described in Chapter Eight. Link coupling is especially suitable.

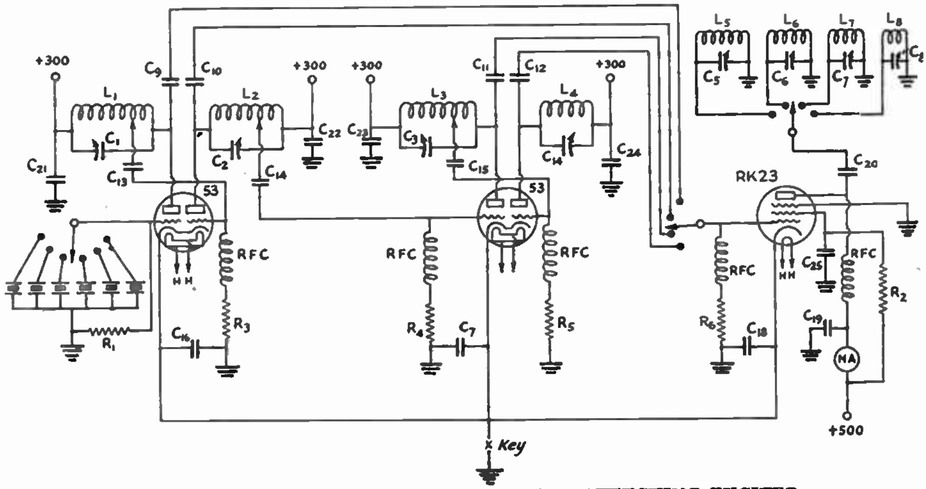


FIG. 920 — CIRCUIT DIAGRAM OF THE BAND-SWITCHING EXCITER

C_1 — 100-μμfd. midget air condenser.
C_2, C_3, C_4 — 50-μμfd. midget.
C_5 — 100-μμfd. midget.
C_6 — 50-μμfd. midget.
C_7, C_8 — 35-μμfd. midget.
C_9 — C_{20} inc. — .001-μμfd. mica condensers.
C_{21} — C_{25}, inc. — .01-μfd. mica condensers.
R_1 — 5000 ohms, 2-watt.
R_2 — 10,000 ohms, 2-watt.
R_3 — 20,000 ohms, 2-watt.
R_4, R_5, R_6 — 10.000 ohms, 2-watt.
L_1 — 3.5-mc. oscillator coil; 35 turns No. 22, diameter 1½ inches, winding length 1½ inches.
L_2 — 7-mc. doubler coil; 20 turns No. 16, diameter 1½ inches, winding length 1½ inches.
L_3 — 14mc. doubler coil; 10 turns No. 16, diameter 1½ inches, winding length 1¼ inches.
L_4 — 28 mc. doubler coil; 3½ turns No. 14, diameter 1½ inches, winding length ¾ inch.
L_5 — 3.5-mc. buffer coil; 30 turns No. 16, diameter 1½ inches, winding length 1½ inches.
L_6 — 7-mc. buffer coil; 16 turns No. 14, diameter 1½ inches, winding length 1¼ inches.
L_7 — 14-mc. buffer coil; 9 turns No. 10, diameter 1¼ inches, winding length 1¼ inches.
L_8 — 28-mc. buffer coil; 3¼ turns No. 10, diameter 1¼ inches, winding length ¾ inch.
RFC — Sectional-wound chokes, high-frequency type.
The tuning condensers, C_1-C_8, inclusive, are Cardwell Trim-Aires.

A Low-Power Neutralized Triode Amplifier

● An example of breadboard construction for the neutralized amplifier is shown in Fig. 921. This unit can be used with any type of triode having all element connections brought out to a 4-prong receiving-type base, such as the 10, 841, 802, 830, etc. It is arranged for capacity coupling to the preceding stage, and uses the split-stator circuit for neutralization.

The circuit diagram is given in Fig. 922. The baseboard measures 11 by 14 inches. The split-stator tank tuning condenser is centrally located on the baseboard; to its left are the plate blocking condenser, the plate r.f. choke, the tube socket, and the neutralizing condenser. Toward the rear are the grid r.f. choke and the two input coupling condensers. The coupling condenser in the input lead to the filament center tap, C_2, is an insulating condenser in case the filament of the tube is not at the same d.c. potential as the filament of the driver tube. It may not be needed.

Filament and plate power and bias leads are brought in through a terminal strip at the rear left edge of the board. Connections from these terminals run under the baseboards to appropriate parts of the circuit. By-pass condensers for the filament are mounted vertically on a piece of brass strip located close to the filament terminals on the tube socket. The r.f. input and output terminals are Isolantite stand-off insulators at the rear center and rear right, respectively. All circuit components carrying r.f. potentials are mounted on small porcelain stand-offs. The placement of parts is such that the wiring is as short and direct as possible.

The final amplifier tank coils are a factory-made product. They are wound on grooved forms provided with a slot into which special clips can be inserted, thus making it possible to tap any turn without the necessity for soldered tabs. The coils are fitted out with plugs which are inserted in jack-top stand-off insulators. The turns specifications are given under Fig. 922. The inductances are such that resonance will be reached in each band with a tuning capacity of about 70 μμfd.

The grid choke RFC_1, should be designed to be most efficient at 14 mc., the frequency at which the excitation is lowest in the normal course of events. A home-wound choke is used to avoid the possibility of parasitic oscillations of the low-frequency t.p.t.g. type (see Chapter Eight) likely to be set up when chokes of approximately the same inductance are used in both grid and plate circuits.

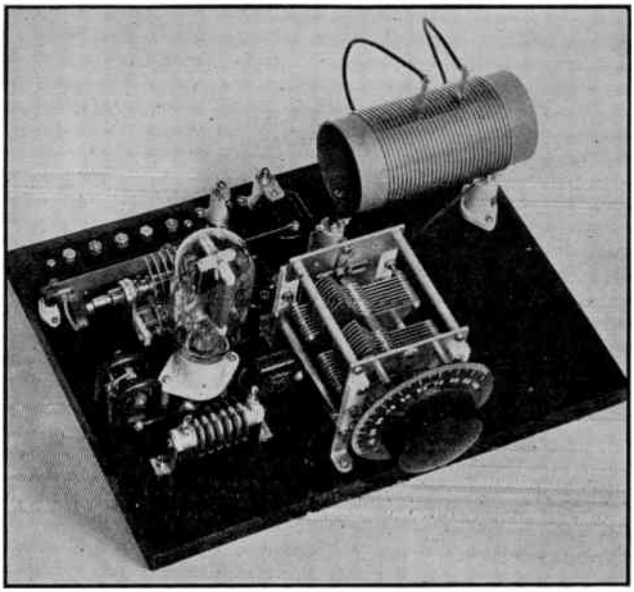


FIG. 921 — A NEUTRALIZED AMPLIFIER FOR USE WITH A 10, 801 OR 830 TUBE

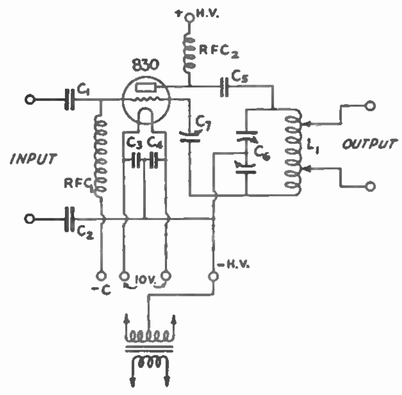


FIG. 922 — THE SINGLE-TUBE AMPLIFIER CIRCUIT DIAGRAM

C_1 — 70-μμfd. mica grid coupling condenser.
C_2 — 500-μμfd. mica blocking condenser.
C_3, C_4 — .005-μfd. mica filament bypass condensers.
C_5 — 500-μμfd. mica plate blocking condenser, 2500-volt rating.
C_6 — Split-stator variable tank condenser, 350-μμfd. each section (National).
RFC_1 — Grid choke; 3-inch winding of No. 34 s.s.c. on half-inch bakelite form.
RFC_2 — Plate r.f. choke (Hammarlund).
L_1 — Plate tank coil 1.75 mc.: 45 turns No. 14 wire on 3-inch diameter form, winding length 4½ inches.
3.5 mc.: 30 turns No. 14 wire on 2½-inch diameter form, winding length 3¾ inches.
7 mc.: 15 turns No. 14 wire on 2½-inch diameter form, winding length 3¾ inches.
14 mc.: 10 turns No. 14 wire on 2-inch diameter form, winding length 4 inches.

The amplifier is neutralized and tuned as described in Chapter Eight. Output connections are by clips from the plate tank coil. This unit can be used to excite a following high-power amplifier or to work into an antenna. The clips make possible the use of either the filter network described in Chapter Eight or the antenna tuning unit shown in connection with the push-pull transmitter described later in this chapter.

Plate currents and voltages should be the rated values for the type of tube used. With a Type 10 or 801 tube the output should be in the vicinity of 25 or 30 watts; with an 830, 50 to 60 watts, assuming proper excitation.

A Push-Pull Band-Switching Amplifier for 50T's or 800's

● A typical example of breadboard layout for the push-pull amplifier is shown in Figs. 923 and 924. This amplifier unit, arranged so that three bands can be covered without changing coils, is adaptable to either a pair of 50T's or 800's. With 1000 or 1250 volts on the plates, the power output obtainable will be between 130 and 150 watts with normal excitation. An output of better than 200 watts can be secured from the 50T's if the plate voltage is increased to 2000 or more and suitable circuit components are substituted to take care of the higher voltage.

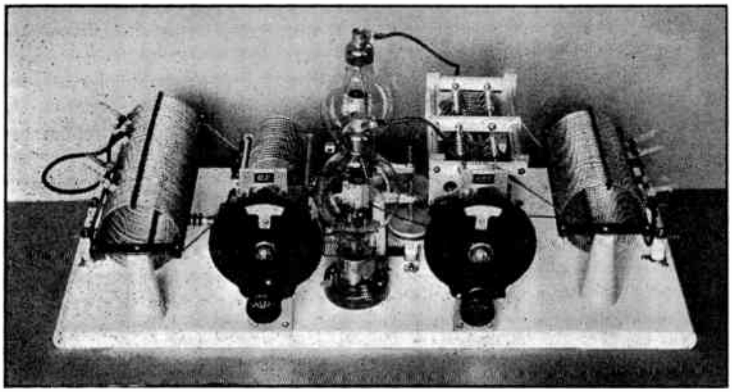


FIG. 923 — A PUSH-PULL AMPLIFIER FOR 50T'S OR 800'S

Band changing is accomplished by short-circuiting turns in both grid and plate tank coils.

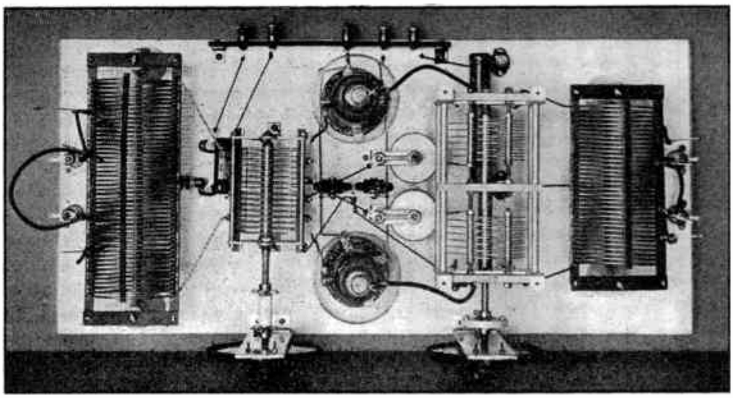


FIG. 924 — TOP VIEW OF PUSH-PULL AMPLIFIER SHOWING ARRANGEMENT FOR SYMMETRY AND SHORT LEADS

This arrangement may be used with type 50-T, RK18, 800 or similar tubes.

The complete circuit of the amplifier is shown in Fig. 925. Provision is made for link coupling to the grids and similar output coupling to an antenna tuning unit. Any of three bands, 3.5, 7 and 14 mc., can be selected by proper placement of the shorting clips on the grid and plate coils; shorting is from the center outward, the taps being kept symmetrical about the center of the coil.

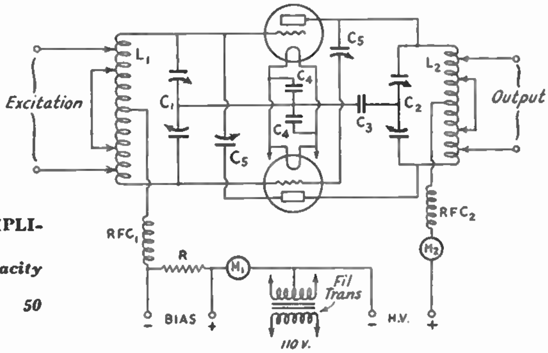


FIG. 925 — CIRCUIT OF THE PUSH-PULL AMPLIFIER

C_1 — Cardwell Midway — MT70GD — total capacity 35 μμfds., air gap .070.
C_2 — National — TMC-100D — total capacity 50 μμfds., air gap .077.
C_3 — Sangamo .01 μfds., 2500 volt.
C_4 — Sangamo .01 μfds. receiving type.
C_5 — National — NC-800 — low capacity neutralizing condenser.
R — Ohmite — 5000 ohms, 25 watts.
L_1 — 48 turns No. 12 bare wire 3 inches diameter, turns spaced diameter of wire; tapped at 4½ turns from each end for 14 mc., and 10½ turns from each end for 7 mc.
L_2 — 35 turns No. 12 bare wire 3 inches diameter, turns spaced diameter of wire; tapped at 3½ turns from each end for 14 mc., and 13½ turns from each end for 7 mc.
RFC_1 — National type R-100.
RFC_2 — Ohmite r.f. choke (large size).

Referring to the photographs, the grid tank circuit is to the left and the plate tank to the right, with the neutralizing condensers and filament bypasses between the two tubes. The grid and plate tuning condensers are mounted above the baseboard on brass strips, the length of the strips being adjusted so that the shafts are on the same level. The plate choke, a solenoid winding on a ceramic core, is on the baseboard underneath the plate tank condenser. The grid leak resistor, R, is held above the board by two midget porcelain standoffs, located between the grid coil and its tuning condenser. Power supply connections are brought out to a terminal strip at the rear of the board. The tuning dials, National Type B, are mounted on vertical pieces of aluminum, held to the baseboard by small aluminum angles. Both dials are insulated from the condenser shafts by isolantite couplings.

For operation at more than 1250 volts on the plates, it is recommended that a tank condenser, C_2, having greater plate spacing than that shown be used, although the total capacity should be the same. The blocking condenser, C_3, also should have an appropriately high voltage rating. The grid circuit need not be changed for high-voltage operation. Since both 800's and 50T's take rather heavy filament current, it is essential that the sockets used have large pin contacts with low resistance.

Adjustment and neutralization should be carried out as described in Chapter Eight for the type of circuit used. The positions of the input and output taps for maximum excitation and maximum output are likely to be found quite critical. If the center-tap of the amplifier is keyed, the bias may be supplied wholly by the grid leak, but it is preferable to have some fixed bias as well. This can be done satisfactorily by connecting a "B" eliminator having an output of 180 to 250 volts across the leak terminals. If 50T's are operated at high plate voltage, extreme caution should be used in making adjustments, since it is possible to run the plate dissipation to dangerous values with a slight misadjustment.

The driver should have an output of 10 or 15 watts for operation at 1000 or 1250 volts. Grid current under operating conditions should be between 30 and 50 ma. This amplifier can be excited without difficulty by the general-purpose transmitter described later in this chapter, using a pair of 10's at about 500 volts. It could also be excited by an amplifier of the type shown in Fig. 921, using an 801 properly driven. For high-voltage operation, more driving power will be required.

An 803 Pentode Amplifier with Band-Switching

● A screen-grid pentode amplifier using a Type 803 tube having an output of approximately 200 watts and requiring driving power of the order of only a few watts, is shown in Figs. 926 and 928. It is built on a metal chassis measuring 17 by 10 by 3 inches, and is arranged for mounting on a relay-rack panel. The metal construction is preferable to wooden breadboard for a screen-grid amplifier, since shielding is advisable to prevent feedback in the circuit external to the tube itself.

The layout is indicated in the rear view photograph, Fig. 926. The tube is at the left, mounted through a hole in the chassis on a socket suspended from brackets about an inch below the chassis. The lower part of the tube is enclosed in a shield can (National Type B30) with a hole cut in the top so the tube can project through. The spacing between tube socket and chassis should be adjusted so that the top of the shield surrounds the cylindrical shield plate in the tube just below the elements.

The plate tank condenser, C_1, is mounted on ceramic standoffs to insulate it from the chassis, since series feed is used. An insulated coupling

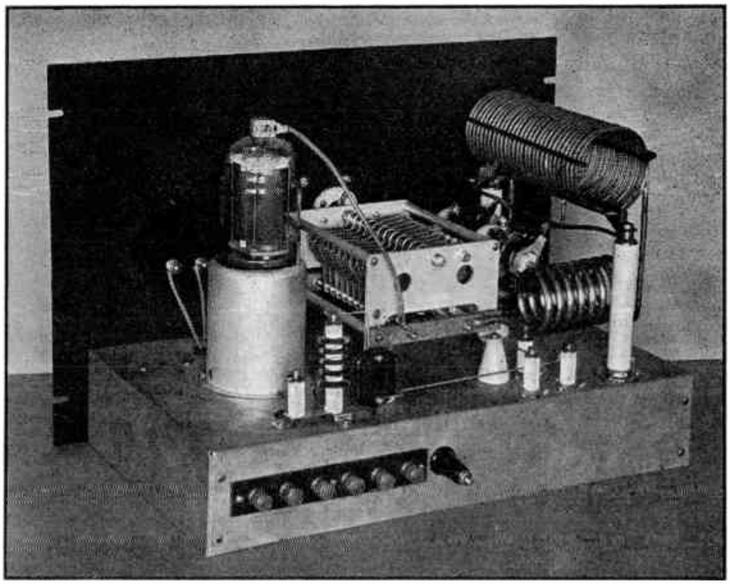


FIG. 926 — AN 803 BAND-SWITCHING AMPLIFIER FOR 3.5, 7 AND 14 MC.

This unit will give an output of approximately 200 watts with grid excitation of but a few watts. It can be used as an amplifier following the band-switching exciter unit of Fig. 918.

also is used between the condenser shaft and the tuning dial to avoid danger to the operator. The plate choke, RFC_2, is behind the tube, (to the front in the photograph); beside it is the plate bypass condenser, C_3.

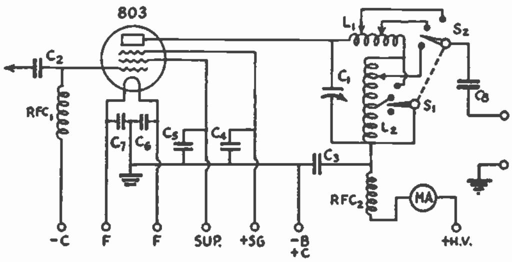


FIG. 927 — CIRCUIT DIAGRAM OF THE 803 AMPLIFIER

C_1 — 150-μμfd. variable condenser, high-voltage type (National Type TMA-150A).
C_2 — Grid coupling condenser, 100-μμfd. mica.
C_3 — .002-μfd. 5000-volt mica condenser.
C_4, C_5 — .002-μfd. mica condensers.
C_6, C_7 — .002 to .005 μfd., mica condensers.
C_8 — .002-μfd. 5000-volt mica condenser.
RFC_1 — Receiving type-universal-wound choke (National Type R100).
RFC_2 — Transmitting-type universal-wound choke (National Type R154).
S_1, S_2 — Ohmite band switch, type T-503.
L_1 — 8 turns ¼-inch copper tubing, diameter 2 inches, length 4 inches.
L_2 — 28 turns ⅜-inch copper tubing, diameter 2⅝ inches, length 7 inches. Tapped at 20th turn from ground end for 7 mc.
MA — 0–300 d.c. milliammeter.

The two sections of the amplifier tank coil, L_1 and L_2, are at the right in the photograph. The two coils are in series for 3.5-mc. operation; part of L_2 is shorted out for 7 mc., and L_1 is used alone for 14 mc. The coils are arranged so that coupling between them is minimized. The band switch shorts out turns from the ground end. Output coupling is provided for by a second switch, ganged with the shorting switch with an Isolantite coupling between, and clips with flexible leads for adjustment. The taps may be adjusted to fit the load into which the amplifier is working. Fig. 928 shows the details of the inductances, switches and wiring. The switches are mounted on standoff insulators because they work in the high-voltage circuit. An Isolantite shaft coupling insulates the switch assembly from the controlling knob on the front of the panel.

Filament, screen and suppressor bypass condensers are mounted underneath the chassis, as are also the grid coupling condenser, C_2, and grid choke, RFC_1. These condensers should be mounted close to the tube socket. It is also advisable that all be grounded at the same point on the chassis. Power supply terminals, with the exception of the high-voltage terminal, are brought out to a bakelite strip with binding posts at the rear. The high-voltage terminal is a porcelain feed-through insulator.

The 803 amplifier can be driven by any exciter unit having an output of the order of 3 to 5 watts. The band-switching exciter of Fig. 918 is a fitting unit for driving this amplifier. Tuning is simply a matter of setting the switches on the band desired and adjusting C_1 to resonance, indicated by the usual dip in plate current. With proper excitation the plate current should drop to about 30 ma. with no load at resonance. Under load conditions the rated plate current, 160 milliamperes, can be drawn. Grid current should be about 15 ma. with the amplifier loaded, assuming 500 volts on the screen and 40 on the suppressor. Grid bias should be 30 to 40 volts negative.

The settings of the output taps must be adjusted according to the load. The amplifier can be worked into a non-resonant transmission line (see Chapter Sixteen) or into a link-coupled antenna tuner.

A High-Power Amplifier

● High power demands larger tubes, larger apparatus, and a consequent modification of the construction. An amplifier unit using a 204-A tube is illustrated in Fig. 929. It is capable of outputs of the order of 350 to 500 watts, depending upon the frequency. Because of the high input and output capacities of the 204-A, care must be used in circuit design at high frequencies. The circuit of this amplifier,

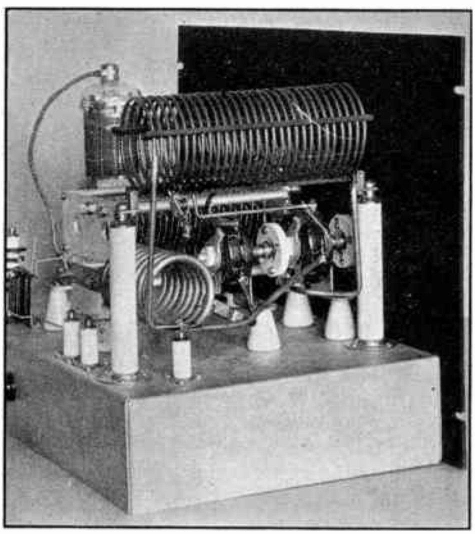


FIG. 928 — A CLOSE-UP OF THE COIL AND SWITCH ASSEMBLY

The shorting leads are made from copper tubing.

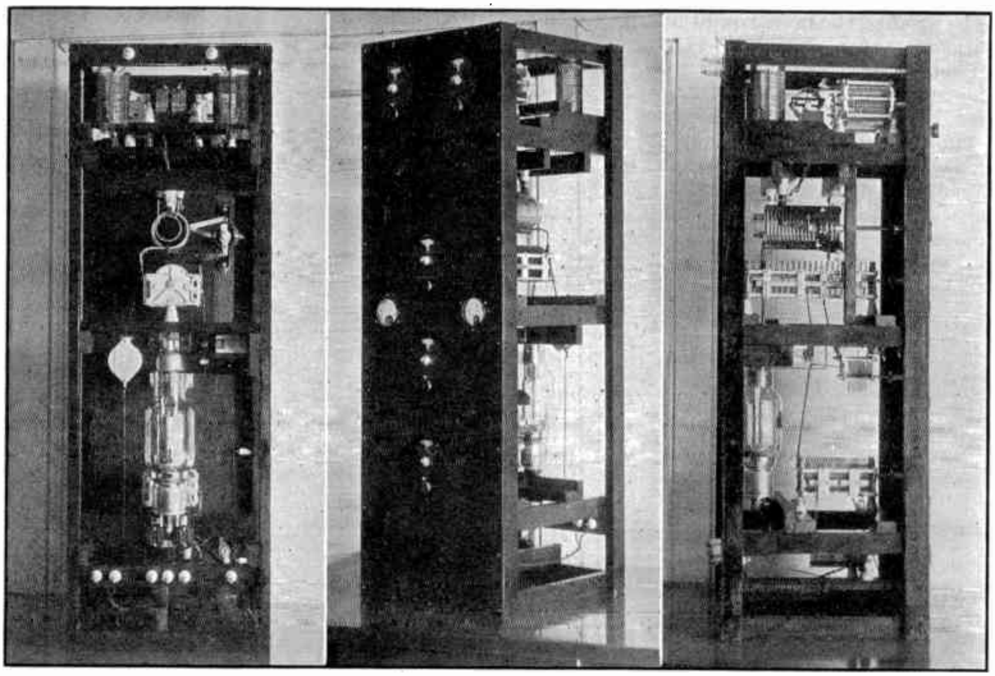


FIG. 929 — THREE VIEWS OF THE HIGH-POWER AMPLIFIER

LEFT — Visible in this photograph are the plate blocking condenser, to the right of the plate terminal of the tube, the fixed neutralizing condenser to the left and the terminal connections. CENTER — Panel switching of plate and grid circuits plus fixed neutralization make rapid frequency shifts easy with this rig. RIGHT — The frame consists of three main decks holding the equipment. The tuned grid circuit equipment is supported by the lower deck, with plate circuit on the central deck. The feeder tuning condensers and coils are mounted at the top.

shown in Fig. 930, has been quite successful. Link coupling is used for feeding excitation to the amplifier. An antenna tuning unit, incorporated in the amplifier, also is link-coupled to the plate tank.

Features of the circuit are the use of tapped coils for band-switching — the amplifier covers 3.5, 7 and 14 mc. — and a special neutralizing arrangement using a fixed neutralizing condenser.

The frame is constructed of 1- by 2-inch stock while the panel is a single piece of quarter-inch plywood. The four vertical corner posts are 45½ inches long, the cross-members running from front to rear 15¾ inches long and those running from left to right 13¾ inches long. The panel is 15⅜ inches by 45½ inches.

The lower deck contains the grid circuit coil and condenser with the grid end of the 204-A. The central deck serves as a mounting for the plate circuit condensers, the fixed neutralizing condenser, r.f. choke, plate blocking condenser, and the plate end of the tube. The third and top deck supports the plate circuit tank coil and the antenna tuning equipment. Horizontal cross-members below the lower deck hold the grid coil switch and grid circuit link coil. The plate coil switch is mounted on a vertical strip running between the central and upper decks. This construction results in an extremely rigid frame. All units are insulated from the frame and controls by means of stand-off insulators or insulating flexible shaft couplings. Filament by-pass condensers are mounted directly upon the lower tube mounting by means of small pieces of brass strip one-half inch wide.

The grid circuit and antenna circuit coils are constructed by threading the No. 12 wire through drilled bakelite strips, as described earlier in this chapter. Holes are spaced 5/32-inch between centers.

The plate tank coil is made in a similar manner except that the conductor is 3/16-inch copper tubing. The holes for the tubing are made with a quarter-inch drill and the hole centers spaced 5/16-inch. The link coupling coil for the grid circuit and the one for the plate circuit are constructed similarly to the other wire-wound coils, using short pieces of fibre strips for separators. The grid circuit link coil is mounted upon a pair of stand-off insulators close to the ends of the coil.

In winding the plate circuit link coil, several turns more than the number required should be added. After the strips have been threaded to the center of the coil, the extra turns at each end should be straightened out and bent around as shown in the photographs. By using two large binding posts with holes for the wire a simple variable coupling arrangement is provided. To vary the coupling, the two post tops are loosened and the end wires of the coil slid through the holes in the posts.

The fixed air dielectric condenser C_3 is constructed from pieces of aluminum sheet with four National Type GS-1 stand-off insulators as the mounting posts. Each plate is 2 inches by 2⅞ inches. Holes are drilled in two edges of each plate 3/16-inch from the edge with a No. 28 drill to pass a long 6-32 screw. Brass spacers 5/16-inch long and ¼-inch outside diameter separate each set of plates, giving plate separation of approximately 5/32 inch. Similar spacers ⅛-inch long are used between the top of the insulator and the first one of set of plates. A total of five plates is used for this condenser. The four insulators carrying the plates are mounted on a bakelite base 3 inches square. A similar condenser might be constructed for the neutralizing condenser C_6. One with 5 or 6 plates 3 inches by 3½ inches spaced ¼-inch should be satisfactory.

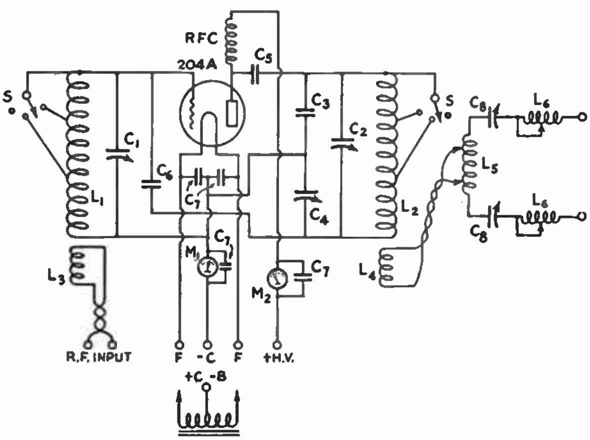


FIG. 930 — CIRCUIT DIAGRAM OF THE 204-A AMPLIFIER

C_1 — 150-μμfd. maximum. Hammarlund TC-150-B, 0.08-inch spacing.
C_2 — 200-μμfd. maximum. Hammarlund TCD-100-A with sections connected in parallel — 0.192-inch spacing.
C_3 — Fixed air condenser, capacity approximately 25 μμfd. (See text.)
C_4 — 100-μμfd. maximum. National type TMC-100 — 0.077-inch spacing.
C_5 — Plate blocking condenser. .0015-μfd. 5000-volt Dubilier Type 86.
C_6 — Fixed neutralizing condenser. 20-μμfd. 3000-volt Dubilier type PL-370-54.
C_7 — .001-μfd. fixed by-pass condenser — Sangamo mica, receiving type.
C_8 — 230-μμfd. maximum. National TM-230 — 0.077-inch spacing.
L_1 — 24 turns No. 12 wire, 2¼ inches diameter, turns spaced 5/32 inch center to center, tapped at 3¼ and 10¼ turns from filament end. (See text.)
L_2 — 20 turns 3/16 inch diameter copper tubing, 2⅝ inch inside diameter, turns spaced 5/16 inch center to center, tapped at 3¼ and 11¼ turns from neutralizing end. (See text.)
L_3 — 3 turns No. 12 wire 3 inches diameter, turns spaced 5/32 inch center to center. (See text.)
L_4 — 4¼ turns No. 12 wire, 1⅞ inches diameter, turns spaced 5/32 inch center to center. (See text.)
L_5 — 12 turns No. 12 wire, 2¼ inches diameter, turns spaced 5/32 inch center to center. (See text.)
L_6 — 24 turns No. 12 wire, 2¼ inches diameter, turns spaced 5/32 inch center to center. (See text.)
M_1 — Grid circuit milliammeter — 0–200 scale.
M_2 — Plate circuit milliammeter — 0–500 scale.
S — Inductance tap switch — Ohmite transmitting.

The leads between the grid and plate coils and their short-circuiting switches should be made as short as possible. This is also true of the remainder of the r.f. wiring, but with high-power tubes of this type and the necessarily larger dimensions of the circuit equipment, longer than normal leads cannot be avoided. Long leads with high tube capacities are likely to lead to parasitic oscillations in the 5-meter region. Should such a parasitic be observed, it can be eliminated by connecting a trap circuit, tuned to the frequency of the parasite, in series with the grid of the tube as described in Chapter Eight in the section on parasitic oscillations.

The amplifier can be excited to full output by any of the transmitters described in this chapter having an output of about 50 watts on the desired frequency. Tuning and other adjustments are carried out as described in Chapter Eight, with the exception of the neutralizing. Because of the circuit employed, neutralizing is accomplished by adjusting C_4 in the same way as though it, instead of C_6, were the neutralizing condenser. The purpose of this arrangement is to ensure having a neutralizing capacity approximately equal to the tube capacity, thus making it necessary to have a capacity at C_4 which will be equal to C_3 plus the output capacity of the 204-A. This arrangement avoids capacity unbalance in the circuit as a whole because it compensates for the capacity of the tube, neglected when a regular split-stator condenser is used. Adjustment of C_4 affects the tuning of the plate tank circuit, so C_2 must be readjusted each time the setting of C_4 is changed during the neutralizing process.

Fixed bias of the order of 90 volts has been found to be preferable to grid-leak bias.

A Two-Stage Transmitter

● A complete transmitter of moderate output, simple in construction, can be built by using tubes which give full output with low grid driving power such as the screen-grid pentodes. The transmitter shown in Fig. 931 is an example. The metal-chassis type of construction is illustrated.

The transmitter consists of but two tubes — a 59 pentode-Tri-tet oscillator, and an RK-20 amplifier. With 3.5- and 7-mc. crystals, it can work in any of three bands, and can be used for either c.w. or 'phone, giving up to 100 watts output on the former and approximately 20 watts carrier (suppressor-grid modulation) on the latter. The small number of tubes and stages reduces operating complications to a minimum; thus band-changing becomes relatively simple. Provision for using the oscillator electron-coupled for output on 7 and 14 mc. also is built into the set, so that frequency changes within a band can be made quickly and easily.

A cadmium-plated steel chassis is the foundation; its dimensions are 23 by 10 by 3 inches, allowing ample room and a reasonable space between oscillator and amplifier so that interstage shielding is unnecessary.

All sockets are Isolantite wafer type. Three 4-prong sockets are required, for the e.c. cathode coil, Tri-tet cathode coil and plate coil, respectively. One 7-prong socket, for the 59, and one 5-prong, for the crystal mounting, also are needed. The amplifier uses another 5-prong socket, making six in all. The oscillator coils are wound on Hammarlund Isolantite coil forms, the amplifier coils on General Radio forms.

The variable condensers are mounted on a combination of tinymite stand-offs and feed-throughs of the same height. In the case of the oscillator tuning condensers, the forward ends are supported by stand-offs, the rear by the small feed-throughs. The rotor connections are made to these feed-throughs. Because none of the condensers are worked at ground potential, feed-through insulators are mounted adjacent to the rear condenser feed-through supports to carry the stator connections through the chassis. The amplifier tank condenser is supported on three legs by stand-offs and the fourth leg by a feed-through. The amplifier coil forms are provided with small G.R. plugs and the large stand-off insulators supporting the tank coil are fitted with G.R. jacks to facilitate coil changing.

The RK-20 is mounted vertically through the chassis. A hole large enough to give ⅛ inch clearance for the tube is cut in the chassis; the 5-prong socket is mounted on the bottom of a small aluminum box, open at the top and fastened to the chassis underneath the hole for the tube. The height of the box is just sufficient to bring the tube's internal shield (the cylindrical plate near the bottom of the envelope) flush with the top of the chassis. This provides a simple buffer shield between the input and output elements of the RK-20.

On 3.5 mc. and 7 mc. the oscillator is operated as a straight pentode, the cathode coil being shorted. This is done by bending over a corner of one rotary plate of C_1 so it touches the stator when set at full capacity. Two crystals (3.5 and 7 mc.) are needed for operation on three bands, 3.5, 7 and 14 mc. On 14 mc. the oscillator is operated Tri-tet, doubling in the plate circuit of the 59. Two coils are used in the amplifier; one exclusively on 14 mc. the other for 3.5 and 7 mc. A small copper clip, with its jaws slightly extended, shorts out 4 turns of the 3.5 mc. tank coil very handily and permits very low C operation of the tank at 7 mc. Without the clip, approximately 85 μμfd. tunes the combination to 3.5 mc. It is but a matter of seconds to shift bands with this line-up.

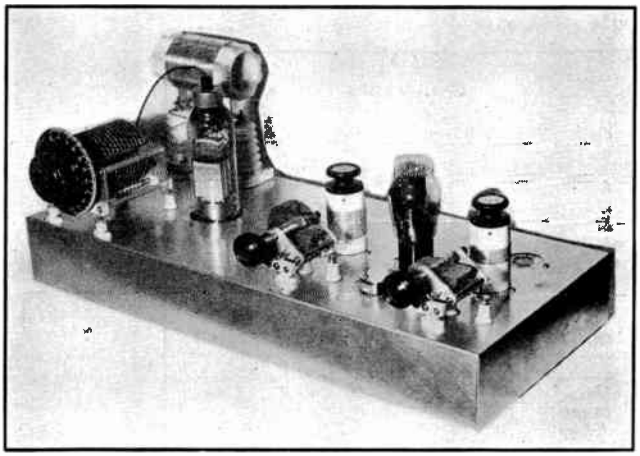


FIG. 931 — A THREE-BAND TWO-STAGE PENTODE TRANSMITTER

A 59, pentode or Tri-tet, drives an RK-20 amplifier, using 3.5- and 7-mc. crystals. No buffer stages are needed. This outfit was built by W1AF.

Any of the speech-amplifier modulator combinations described in Chapter Twelve capable of delivering audio power of the order of a watt or so will fully modulate the RK-20's output for 'phone operation. Adjustment for complete modulation is described in Chapter Eleven.

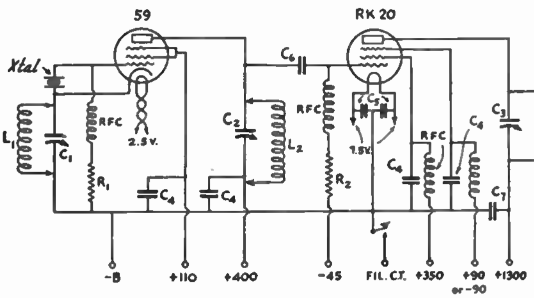


FIG. 932 — CIRCUIT DIAGRAM OF THE TWO-STAGE PENTODE TRANSMITTER

C_1 — 250-μμfd. cathode tuning condenser (National TMS-250).
C_2 — 100-μμfd. oscillator plate condenser (National TMS-100).
C_3 — 150-μμfd. amplifier plate condenser (National TMC-150).
C_4 — .002-μfd. mica condenser, receiving type (Sangamo).
C_5 — .004-μfd. mica condenser, receiving type (Sangamo).
C_6 — 100-μμfd. mica condenser, receiving type (Sangamo).
C_7 — .002-μfd. mica condenser, 5000-volt (Sangamo).
R_1 — 50,000 ohms, 2-watt rating (I. R. C.).
R_2 — 15,000 ohms, 2-watt rating (I. R. C.).
RFC — S.w. chokes (National Type 100).
See separate table for coil data.
Antenna tuning equipment will depend upon the type of antenna system used. With series tuning of Zepp feeders, tuning condensers of 250-μμfd. each will be satisfactory.

Typical operating conditions are 400 volts plate and 110 volts screen on the 59; 1000 to 1250 volts plate and 350 volts screen on the RK-20; grid bias to the RK-20, 45 negative by battery to limit plate current without excitation plus a grid leak of 15,000 ohms; optimum grid current 5 to 6 mils. Plate current to the 59 oscillator is of the order of 20 to 25 ma.; to the RK-20 amplifier 100 ma. on c.w. Tuning adjustments are made as described in Chapter Eight.

COIL TABLE

Coil	*Turns*	*Length of Winding*	*Tap*	*Wire Size*
A	*35*	*1¼*	*4*	*No. 22 d.c.c.*
B	*15*	*1¼*	*2*	*No. 18 bare*
C	*7*	*⅝*		*"*
D	*6*	*⅝*		*"*
E	*21*	***		*No. 12 bare*
F	*17*	****		*"*
G	*6*			*"*

OPERATION WITH CRYSTAL CONTROL

Output	*L_1*	*L_2*	*L_3*	*Crystal*
3.5 mc.	*C_1 shorted*	*Coil A*	*Coil E*	*3.5 mc.*
7 mc.	*C_1 shorted*	*Coil B*	*Coil F*	*7 mc.*
14 mc.	*Coil C*	*Coil D*	*Coil G*	*7 mc.*

ELECTRON COUPLED

Output	*L_1*	*L_2*	*L_3*
7 mc.	*Coil A*	*Coil B*	*Coil F*
14 mc.	*Coil B*	*Coil D*	*Coil G*

Electron-coupled control not used on 3.5 mc.
Coils A, B, C and D wound on Hammarlund Isolantite forms.
** Coils for amplifier plate wound on G.R. Forms, 2½-inch diameter, 7 grooves per inch.*
*** Coil E actually is used, a tap being taken off at 17 turns.*

A General-Purpose 50-Watt Transmitter

● A transmitter for operation in five bands, in which several types of tubes may be used according to the wishes of the operator, is shown in Figs. 934–940, inclusive. Breadboard and panel mounting are combined in its construction.

This transmitter is a three-stage outfit having a pentode crystal oscillator, a second stage which operates either as a self-neutralized straight amplifier or as a back-to-back doubler, and a permanently-neutralized push-pull

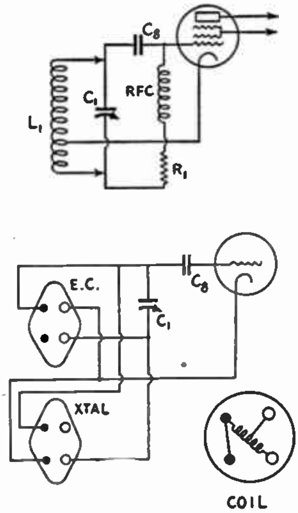


FIG. 933 — ALTERNATIVE OSCILLATOR GRID CIRCUIT CONNECTIONS FOR SELF-CONTROLLED OPERATION

Shifting the cathode coil to an appropriate socket and plugging in either a crystal or grid condenser gives a choice of either crystal or electron-coupled operation. The grid condenser, C_8, is a 250-μμfd. receiving-type mica condenser.

final amplifier stage using 801's, 10's or 830's. A separate antenna-tuning unit transmission-line coupled to the transmitter, also is provided.

The circuit diagram of the transmitter is given in Fig. 936. The oscillator uses the regular pentode circuit with a Type 2A5 tube. Its plate tuned circuit, L_1C_1, is coupled inductively to the tuned and balanced grid circuit of the second stage, L_2C_{11}. In this stage a pair of 2A5 tubes is arranged with the grids in push-pull and the plates in parallel. A switch Sw_1, is cut in one heater leg of one of the tubes; when it is open this tube does not operate but simply serves as a neutralizing capacity for the other for operation on the same frequency as the oscillator. For doubling, Sw_1 is closed, whereupon the two tubes work together to produce second-harmonic output. The output circuit is tuned by C_2L_3, the inductance L_3 being coupled to L_4, the final amplifier grid coil.

The grid coil of the final stage is, in all cases except one, tuned only by the tube and circuit capacities and its own distributed capacity. The single exception is the 1750-kc. coil, where the physical dimensions of such a coil would be so large as to make the untuned coil impracticable with ordinary coil forms. Therefore for this band only an auxiliary condenser, C_{12}, is used to tune the grid circuit.

The plate circuit of the final stage uses a split-stator condenser with grounded rotor. The plate coil is tapped at the center and fed d.c. through an r.f. choke. The amplifier is cross-neutralized, and because of the grounded-condenser plate circuit will be neutralized for all frequencies once the neutralizing adjustments have been correctly made on the first frequency tried. A pair of clips tapping on the amplifier tank coil provide for transferring the r.f. output to the antenna tuner.

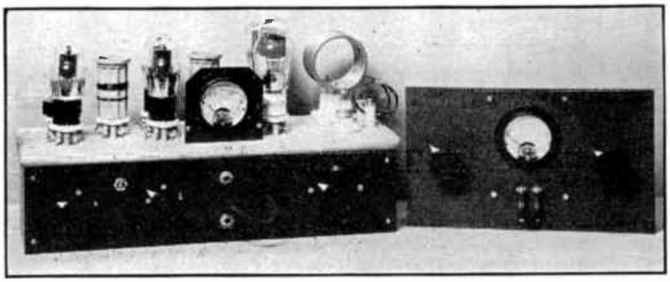


FIG. 934 — A GENERAL VIEW OF THE 50-WATT TRANSMITTER AND THE ANTENNA TUNING UNIT

Grid-leak bias is used on all three stages. A combination of battery and leak bias might be used on the last stage, the battery being for protective purposes. The 2A5's in the second stage need no protection of this type, since their plate current drops to a very low value if excitation fails. These tubes are not used as pentodes but as Class-B triodes, the control grid and screen in each tube being tied together.

Plate power for the oscillator is secured from the second-stage supply through a dropping resistor, R_5. A second dropping resistor, R_4, reduces the voltage to the right value for the oscillator screen. Jacks are provided in all three circuits for measuring plate currents.

The fixed apparatus on top of the baseboard consists almost exclusively of sockets of various descriptions into which tubes, coils and crystals can be inserted. The exceptions are the plate milliammeter, which is mounted on a small bakelite panel, and the output terminal standoffs. The progression is from left to right; the oscillator tube is at the extreme left front, with the crystal socket directly behind it. Next is the plug-in coil for the oscillator plate, then the two tubes in the second stage, followed by the plate coil for that stage, then the amplifier tubes, the standoff-sockets for the amplifier tank coils, and finally the output posts.

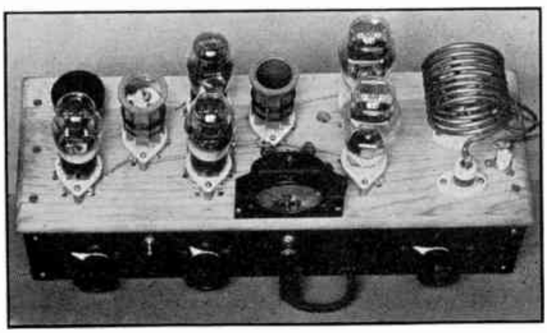


FIG. 935 — THIS PLAN VIEW OF THE TRANSMITTER SHOWS THE LAYOUT ABOVE THE BASEBOARD

Coils for all stages are plug-in to facilitate frequency changing and the use of crystals ground for different bands. The final stage neutralizing condensers are screwdriver-adjusted, through the holes in the baseboard just to the left of the 801's. The coils shown are for straight-through operation from a 14-mc. crystal.

The panel controls, from left to right, are the oscillator tuning condenser, on-off switch, Sw_1 second-stage tuning condenser, plate current jacks, and finally the amplifier tuning condenser.

In the bottom view of the transmitter

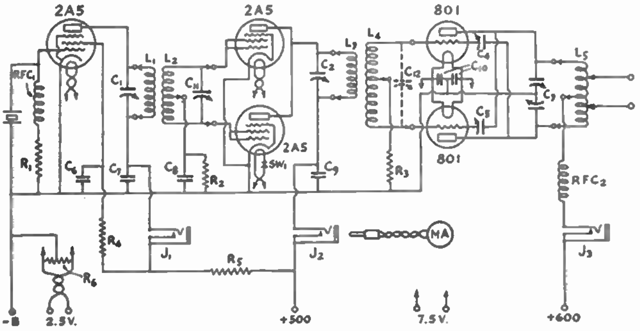


FIG. 936 — CIRCUIT DIAGRAM OF THE TRANSMITTER

C_1 — 100-μμfd. variable (Cardwell Type 404-B).
C_2 — 100-μμfd. variable (Cardwell Type 412-B).
C_3 — 100-μμfd. (net) split-stator transmitting condenser (Cardwell Type 157-B).
C_4, C_5 — 25-μμfd. variables, transmitting type (National SEU-25).
C_6, C_7, C_8, C_9, C_{10} — .002-μfd. paper by-pass condensers, 1500-volt transmitting type (Sprague Type SW-22).
**C_{11} — Air-padding condensers; for 1.75-mc. coil, 100 μμfd. (Hammarlund APC-100); for 3.5, 7, and 14 mc., 50 μμfd. each (Hammarlund APC-50).*
**C_{12} — 100-μμfd. air padding condenser (Hammarlund APC-100), used only on 1.75-mc. coil.*
R_1 — 5000 ohms, 2-watt (I.R.C.).
R_2 — 1250 ohms, 5-watt (I.R.C.).
R_3 — 10,000 ohms, 5-watt (Ward-Leonard 507-206).
R_4 — 50,000 ohms, 2-watt (I.R.C.).
R_5 — 5000 ohms, 15-watt (Ward-Leonard 507-341).
R_6 — 20 ohms, center-tapped.
RFC_1, RFC_2 — High-frequency chokes (National Type 100).
J_1, J_2, J_3 — Single circuit-closing jacks.
Sw_1 — S.p.s.t. toggle switch.
MA — 0–300 d.c. milliammeter.
Winding data on coils is given in the Table.

* Mounted in coil forms.

the order is reversed. The oscillator tuning condenser, C_1, is at the right, mounted on the panel. Just above it in the photograph are the r.f. choke RFC_1 and the resistor, R_1, in the oscillator grid circuit. A little to the left of these components are the screen by-pass condenser, C_6, and dropping resistor, R_4; beside them to the left is the oscillator plate by-pass condenser, C_7. All by-pass condensers in the set are of the tubular paper type made for transmitting use.

The second variable condenser in line is the second-stage tuning condenser, C_2, also mounted on the panel. Between this and the oscillator condenser is the toggle switch, Sw_1. The condenser and resistor just above C_2 are the grid resistor R_2 and by-pass condenser C_8. The filament center-tap resistor, R_6, is mounted on the baseboard behind C_2.

The resistor mounted on the two nearer jacks is the oscillator plate dropping resistor, R_5. Above the jacks on the baseboard are the plate by-pass condenser C_9 and the amplifier grid resistor, R_3.

The two neutralizing condensers, C_4 and C_5, are mounted on a 1- by 4-inch bakelite strip elevated about a half-inch from the baseboard. The condenser shafts, which are slotted by a hacksaw, project through half-inch holes in the baseboard so they can be adjusted with a screw-driver from the top. The filament by-pass condensers, C_{10}, for the final stage are fastened to the baseboard underneath the neutralizing condensers, as is also the amplifier plate choke, RFC_2.

The split-stator tuning condenser for the final stage is at the extreme left. All power leads are brought to the terminal strip at the upper right. Bus bar is used for the r.f. wiring, while the filament circuits are wired with heavy flexible rubber-covered wire.

The overall dimensions of the transmitter (with tubes in place) are 18½ by 11 by 8 inches. The control panel measures 18 by 4 inches and the baseboard 18½ by 6½ inches.

Complete winding data for the coils are given in the Table.

The oscillator plate and buffer grid windings, L_1 and L_2, are on the same form. A buffer grid tuning condenser, C_{11}, is mounted inside each coil form. These condensers are adjusted by means of a screwdriver when the set is in operation. One setting will suffice for work in any one band. The grid circuit L_2C_{11} is tuned to a frequency considerably higher than that of the crystal; it cannot be tuned to resonance

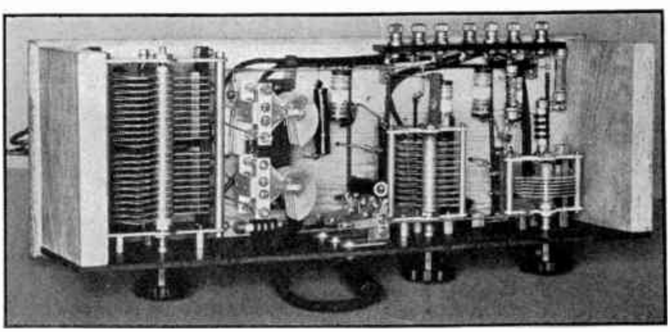


FIG. 937 — BELOW THE BASEBOARD AND BEHIND THE CONTROL PANEL

with the circuit L_1C_1 because of the tight coupling between L_1 and L_2.

The buffer plate coils and amplifier grid coils are wound on the same type of form. In this case the grid coils are untuned, being wound to be self resonant, except for the 1.75-mc. coil. This grid coil is tuned by a 100-$\mu\mu$fd. air-dielectric midget. All other coils are wound to be resonant at a frequency slightly below the particular band for which they are designed. In winding the grid coils, care should be taken to have the same number of turns each side of the center tap, otherwise the circuits may not neutralize properly.

Specifications for the amplifier plate coils also are given in the Table. The coils for the 1.75- and 3.5-mc. bands are wound with enamelled wire on celluloid strips as described earlier in this chapter. The ends of the coils are looped around G.R. plugs for the two outer connections. The center tap is made by cutting off most of the threaded shaft of a similar plug and soldering it directly to the center turn.

The 7-mc. plate coil is made of ⅛-inch copper tubing. Lugs made from 3/16-inch tubing slip over the ends of the winding and are flattened and drilled so the plugs can be bolted in place. The center plug is fastened to a small strip of copper which is formed around the center turn and soldered in place. These expedients are necessary because the tubing is too thin to permit drilling to pass the plug shanks.

The 14- and 28-mc. coils are wound with 3/16-inch tubing with the ends bent and flattened to fit the sockets. The center taps are made simply by drilling through the center turn and bolting the plug in place.

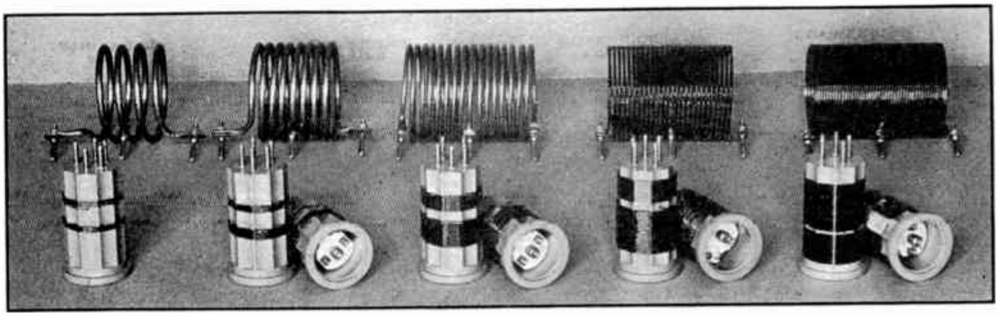


FIG. 938 — A COMPLETE SET OF COILS FOR OPERATION IN FIVE BANDS WITH CRYSTALS GROUND FOR FOUR BANDS

For working in two bands with a single crystal, only five coils will be needed, one for the oscillator, two for the buffer-doubler and two for the final amplifier. Other combinations readily can be worked out.

The coils are grouped according to frequency. The air padders can be glimpsed in the ends of the oscillator coils, lying on their sides.

Antenna Tuning Unit

● The antenna tuner is mounted on a 7 by 12 bakelite panel. The two tuning condensers, C_{13} and C_{14}, are at opposite ends of the panel with the tuning coil, L_6, mounted between them on National Type GS-1 insulators. A pair of similar insulators at the lower edge of the panel serves as input terminals and as supports for the coupling coil, L_7, which is concentric with L_6. The method of construction of L_6 is identical with that of the 3.5-mc. amplifier tank coil. Taps are made by soldering wire "ears" to the turns. There are four taps, the first pair being four turns in from the ends of the coil, and the second pair four turns in from the first. The output terminals to the feeders or antenna system are at the top of panel. A double-pole single-throw switch for changing the tuning condensers from series to parallel is mounted on the front panel just below the r.f. ammeter.

Small copper spring-clips are used to make connections to the taps on the coil L_6 and also to the amplifier tank coil, L_5.

Tuning and neutralizing adjustments are in general as described in Chapter Eight. The one special adjustment is that of tuning the grid circuit of the second stage. Starting with C_{11}

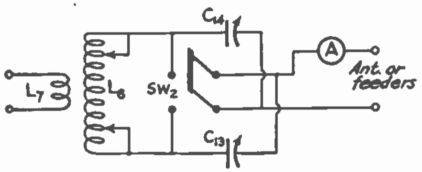


FIG. 939 — WIRING OF THE ANTENNA TUNER

C_{13}, C_{14} — 300-$\mu\mu$fd. variables (National Type TMS-300).

Sw_2 — D.p.s.t. knife switch.

A — Antenna ammeter, 0–2.5 amp.

L_6 — 24 turns No. 12 enamelled wire, turns spaced to occupy a winding length of 3½ inches, coil diameter 2 inches, tapped as described in text.

L_7 — 2 turns No. 12 enamelled wire, diameter 2½ inches. With Sw_2 open, tuning condensers are in series with L_6, with Sw_2 closed, in parallel.

at minimum, and with L_3 out of its socket, the plate voltage should be applied to the oscillator and C_1 adjusted for oscillation. The capacity of C_{11} then should be increased in small steps, with corresponding readjustments of C_1, until the oscillator is drawing about 25 ma. with C_1 set in the optimum operating region as described in Chapter Eight. L_3 may then be plugged in and the doubler adjusted to resonance, bearing in mind the use of Sw_1 in connection with straight amplification and doubling. The other adjustments are carried out in the regular way.

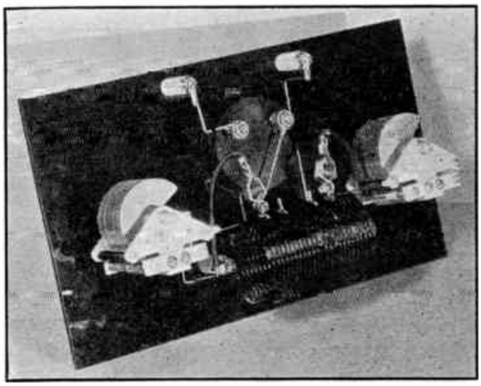


FIG. 940 — A REAR VIEW OF THE ANTENNA TUNER

This unit may be mounted on a wall or beside the window through which the feeders enter.

With applied voltages as indicated, the oscillator plate current should be 20 to 25 ma., second stage, 50 to 100 ma. depending on the band in use and whether the stage is used as an amplifier or doubler, and up to 150 ma. on the final stage when loaded. Adjustment of the antenna coupling unit also is described in Chapter Eight.

This transmitter may be used as an exciter for a higher power amplifier such as the push-pull 50T amplifier or the 204-A amplifier described in this chapter.

Other Transmitter Combinations

● Obviously it is impossible even to begin to describe the many possible tube and circuit combinations which will result in a successful transmitter. In presenting the apparatus descriptions already given, the aim has been to illustrate different types of construction and circuit design. Specific tube types in which the reader is interested may not have been shown, however; therefore some additional representative transmitter diagrams are given in Fig. 941.

These circuits are offered chiefly as suggestions; parts of one circuit can be combined with parts of another, different oscillator circuits can be substituted for those shown for feeding one type of amplifier if the same or a similar-power driver tube is retained, or different interstage coupling and neutralizing arrangements can be substituted in the amplifiers, and so on. For example, in the circuit at (C) a pair of Type 10 or 801 tubes could be substituted in the final amplifier; in fact any three-element tubes could be used. Similarly, an 841 or a 46 with Class-B triode connections could replace the 10 buffer-doubler. Plate and grid voltages suitable for the tube used should replace those indicated, of course. If more than one doubler stage is needed, a circuit identical with one of those shown could be placed between the existing doubler and amplifier diagrams. Simple changes in the filament wiring would make it possible to use tubes having indirect instead of direct-heated cathodes.

For proper tuning procedure to follow with any of these circuits, refer to Chapter Eight. Various antenna-coupling systems shown in Chapter Eight can be substituted for the inductive coupling shown.

Band		*1.75 mc.*	*3.5 mc.*	*7 mc.*	*14 mc.*	*28 mc.*
Oscillator L_1	*No. of turns*	55	31	18	7	
	Wire size	No. 26	No. 18	No. 18	No. 18	
	Length of winding (in.)	0.850	1.300	0.750	0.300	
	Space between L_1–L_2 (in.)	0.250	0.300	0.300	0.400	
L_2	*No. of turns*	40	26	12	6	
	Wire size	No. 26	No. 26	No. 26	No. 26	
	Length of winding (in.)	0.600	0.400	0.175	0.100	
Buffer L_3	*No. of turns*	50	26	16	6	3
	Wire size	No. 26	No. 18	No. 18	No. 18	No. 18
	Length of winding	0.850	1.150	0.650	0.250	0.100
	Space between L_3–L_4	0.100	0.200	0.250	0.400	0.500
L_4	*No. of turns*	80	60	28	12	6
	Wire size	No. 26	No. 30	No. 26	No. 26	No. 26
	Length of winding	1.250	0.600	0.425	0.180	0.200
Amplifier L_5	*No. of turns*	44	26	16	8	4
	Wire size	No. 14	No. 12	1/8" t.	3/16" t.	3/16" t.
	Length of winding	3.75	3.5	4.0	2.5	2.5

Oscillator and buffer coils are wound on Hammarlund Type XP-53 coil forms, diameter 1½ inches. Amplifier coils are self-supporting.

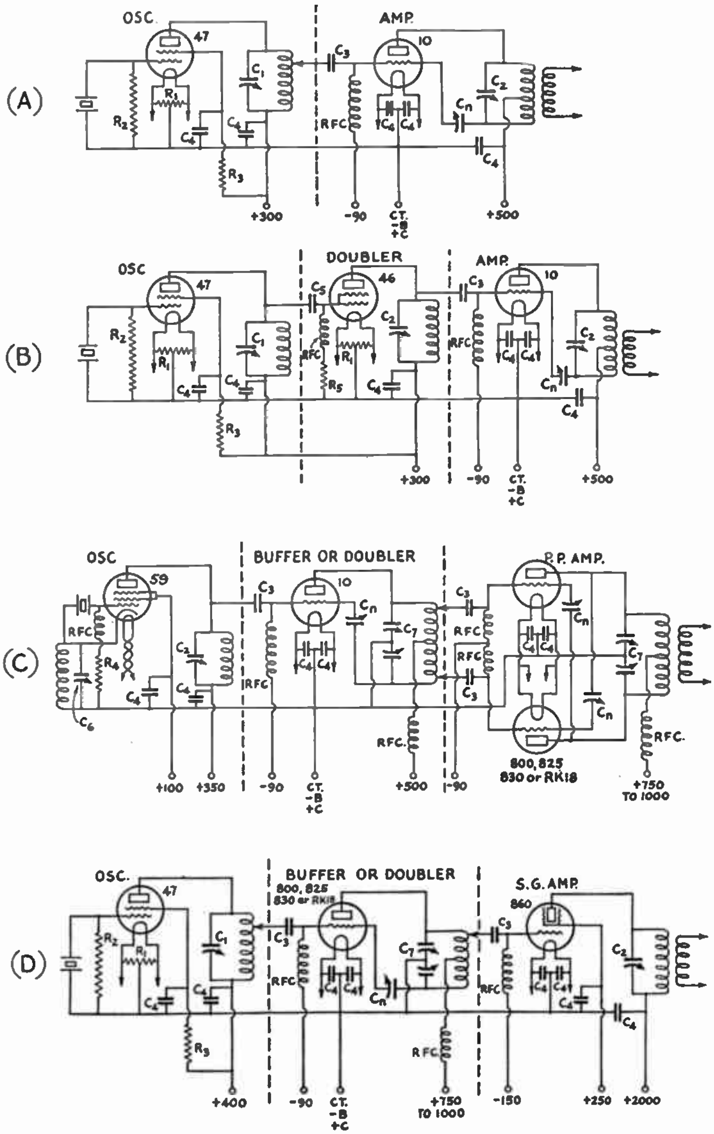


FIG. 941 — SOME CRYSTAL-CONTROL TRANSMITTING LAYOUTS

Substitutions or modifications can be made in any of these circuits.

The simple crystal oscillator and amplifier shown at A is good for operation in only one or at the most two bands with a single crystal; the amplifier can be used as a doubler for operation on the second harmonic of the crystal frequency. The arrangement at B will work on two bands. Circuit C illustrates the use of the Tri-tet oscillator, neutralized buffer or doubler, and changing from a single-ended stage to push-pull. In D the power step-up in each stage is greater than in the first three circuits; this transmitter could be used with good results on three bands.

Circuit values should be approximately as follows:

C_1 — 250-μμfd. variable condenser.
C_2 — 100-μμfd. variable condenser.
C_3 — 100-μμfd. fixed mica condenser.
C_4 — .002-μfd. or larger fixed mica condenser.
C_5 — 50-μμfd. fixed mica condenser.
C_6 — 350-μμfd. variable condenser.
C_7 — 100-μμfd. (both sections in series) split-stator condenser.
C_n — Neutralizing condenser; see Tube Table and section on "Neutralizing."
R_1 — 20 ohms, center-tapped.
R_2 — 10,000 ohms.
R_3 — 50,000 ohms.
R_4 — 100,000 ohms.
R_5 — 5000 ohms.

Tank coil sizes will be found in the table of coil specifications in Chapter Eight; select a coil which will tune to the desired frequency in conjunction with the variable condenser recommended.

CHAPTER TEN

Keying Methods

AND ELIMINATION OF INTERFERENCE WITH BROADCAST RECEPTION

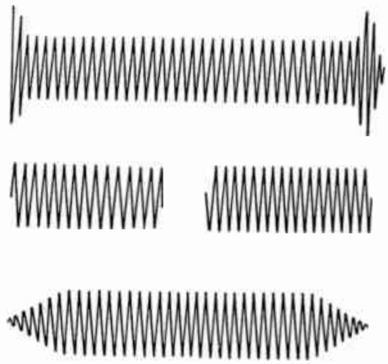
The output of a continuous-wave transmitter cannot be utilized for the communication of intelligence until a means is provided for breaking it up into the dots and dashes corresponding to the characters of the International Morse Code. This rapid turning on and off of power is the most elementary form of modulation. While keying may at first thought seem so essentially simple that detailed treatment is hardly required, there are many considerations which make it a very important subject indeed. These concern not only the simple act of forming dots and dashes, but the possible undesired effects that may result from so breaking up the transmitter's output.

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." Several obvious methods of doing this will occur to the reader; the key could be connected in series with the primary of the plate power transformer, in series with one of the d.c. plate supply leads to the tube itself, and so on. While any number of methods will fulfill the primary purpose of turning the power on and off, all have their inherent advantages and disadvantages. Certain methods also will appeal to one individual more than to others. We shall discuss a number of different keying systems in this chapter so that the amateur can weigh their merits according to his own particular set of conditions and make his choice accordingly. The selection of a keying system is distinctly an individual proposition; almost any keying method can be applied to almost any transmitter.

Fundamental Keying Methods

● Methods by which the output of a vacuum tube can be controlled may be divided into two groups. These are, respectively, direct control of the plate input by turning the plate power on and off; and control of the excitation supplied to the tube's grid circuit. A combination of the two also may be used. With multi-element tubes such as tetrodes and pentodes, the same result may be achieved by proper application of keying methods to the additional elements in the tube.

Three varieties of plate-keying methods are shown in Fig. 1001. In the first, the key is connected in series with the primary of the plate power transformer. The second diagram shows the key connected in the center-tap lead from the secondary of the plate transformer, making and breaking the circuit between the transformer and rectifier-filter input. The lower drawing shows the key placed in the



HOW DIFFERENT TYPES OF KEYED SIGNALS LOOK

The upper drawing shows a signal with pronounced keying transients at the beginning and end of a character. Such a signal would cause considerable interference locally and at a distance as well. The middle drawing is the ideal type — no variation in amplitude at the start or ending of a character, no keying transients. The lower drawing shows the effect of using lag circuits for eliminating key clicks; the signal builds up gradually and stops gradually.

These drawings are copies of oscillographic records taken on actual signals.

negative lead from the plate supply to the tube; it could be placed in the positive lead if desired, but since the latter connection places the key at the plate potential it is seldom used except when a keying relay is available.

The operation of these keying methods is

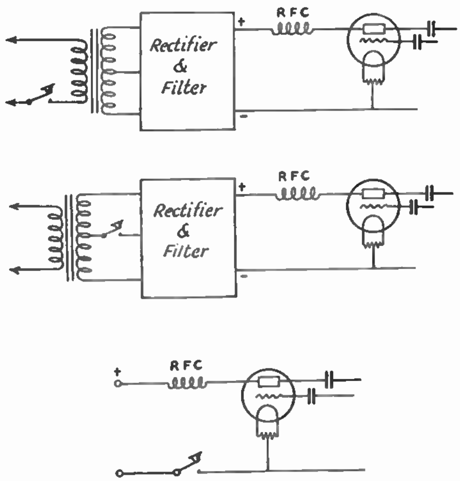


FIG. 1001 — PLATE-KEYING METHODS

easily understood, since the key alternately connects and disconnects the source of plate power.

Grid Keying

● Grid keying methods operate on the principle of controlling plate current flow through application of proper bias values with the key open and closed. Three representative arrangements are shown in Fig. 1002. 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.

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 middle drawing of Fig. 1002. 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 battery is connected in series with the leak through the resistor *R*. The chief function of *R* is to limit the flow of current from the battery when the key is closed, since without *R* the key would be a direct short circuit for the battery. The value of *R* is not critical but should be quite high — at least 5000 ohms for every 45 volts of battery — to limit the current to a safe value. A "C" power pack can be substituted for the battery if desired. 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

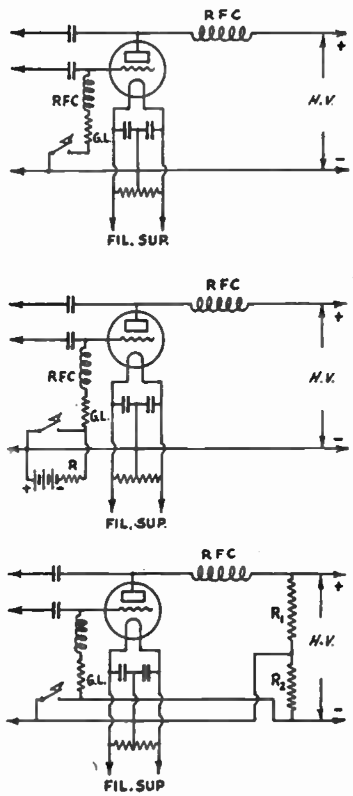


FIG. 1002 — THREE METHODS OF BLOCKED-GRID KEYING

In all these diagrams a center-tapped filament transformer can be substituted for the center-tapped resistor shown.

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.

The lower drawing of Fig. 1002 shows a method of blocked-grid keying in which the keying or blocking bias is obtained from the plate supply, thus eliminating the need for a separate bias source. Resistors R_1 and R_2 are in series across the output of the power supply, R_1 being the regular power supply bleeder. The filament center-tap is connected to the junction of R_1 and R_2 and the grid return to the negative terminal of the power supply, the key being connected across R_2. With the key open, the voltage drop across R_2 is applied to the grid of the tube as blocking bias; when the key is closed, however, the negative power supply terminal is connected directly to filament center-tap, thus leaving only the regular operating bias — in this case supplied by the flow of grid current through the grid leak — in the circuit. As before, a battery or other bias source may be substituted for the leak. The blocking bias may be made as great as desired by choosing a suitable value of R_2 with respect

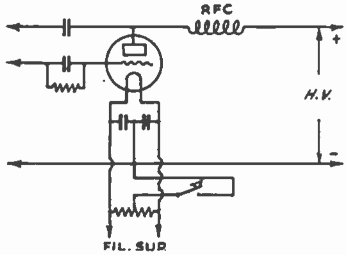


FIG. 1003 — CENTER-TAP KEYING

to R_1. For most oscillators or amplifiers, sufficient keying bias will be obtained when the resistance of R_2 is one-third to one-half that of R_1.

Center-Tap Keying

● A combination of both grid and plate circuit keying is shown in Fig. 1003. This method, known as center-tap keying, has attained wide popularity, although recently the grid-blocking methods have been gaining in favor. 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.

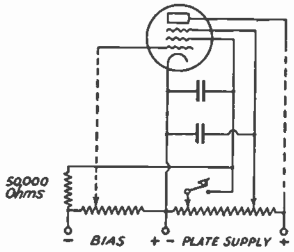


FIG. 1004 — SUPPRESSOR KEYING OF A PENTODE TRANSMITTING TUBE

The keying system is arranged to put positive bias on the suppressor grid with the key open, and negative bias with the key closed.

Center-tap keying combines some of the good and bad features of both grid and plate keying.

Keying Multi-Element Tubes

● All of the foregoing keying methods can be used with tetrode and pentode type transmitting tubes, since they operate on d.c. circuits common to all types of tubes. With multi-element tubes, however, additional keying circuits are possible.

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.

If the keyed tube is a pentode, the suppressor-grid offers a means of satisfactory keying. Maximum output with pentode tubes ordinarily is secured when the suppressor grid is biased positive a small amount — 50 to 100 volts. 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 when the key is open. This can be done much in the same way as in the grid-keying methods already described. Fig. 1004 illustrates one method, using a separate power pack which supplies operating bias for the control grid and keying bias for the suppressor grid. With the key open, the suppressor receives negative bias through the 50,000-ohm resistor, the value

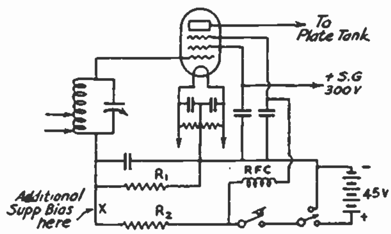


FIG. 1005 — A SUPPRESSOR KEYING SYSTEM IN WHICH KEYING BIAS IS OBTAINED FROM THE GRID LEAK

of bias being adjusted to cut off plate current. When the key is closed, the suppressor bias is made positive through connection to a suitable tap on the plate-supply bleeder. The 50,000-ohm resistor prevents short-circuiting the bias supply, performing the same function as resistor *R* in Fig. 1002. A bias supply delivering 200 volts or more will be sufficient for keying any of the pentode transmitting tubes now available.

Another method of suppressor keying is shown in Fig. 1005. In this case no additional bias source is needed, the keying bias for the suppressor being obtained from the voltage drop caused by the flow of rectified grid current through the grid leak. The leak therefore replaces the separate bias supply. For this method to be successful, it is essential that the drop across the leak be large enough to cut off plate current when applied to the suppressor. This usually calls for a fairly high-resistance leak (about 15,000 ohms) and a grid current of 5 to 10 milliamperes, depending upon the type of tube used.

Sources of Bias for Grid Keying

● In many respects grid-blocking systems (including screen- and suppressor-grid as well as control-grid systems) are to be preferred to other types of keying. The chief objection to their use is the cost of the keying bias supply. In the lower diagram of Fig. 1002 this objection is overcome through obtaining keying bias from the plate supply; the suppressor keying method of Fig. 1005 likewise is an economical one. It is also 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. The way in which this can be done is illustrated in Fig. 1006. 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. 1006, 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 five watts.

General Considerations in Keying

● A good keying system should fulfill three requirements — it should prevent completely the radiation of energy from the antenna when the key is open and should give full power output when the key is closed; 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.

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

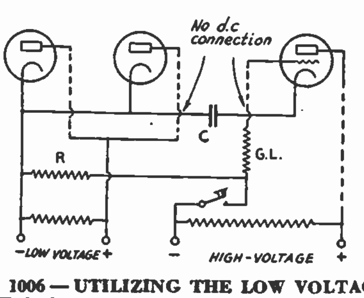


FIG. 1006 — UTILIZING THE LOW VOLTAGE POWER SUPPLY FOR BLOCKING BIAS IN BLOCKED-GRID KEYING

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. 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. 1002, the tube will not be completely blocked 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 buffer stage preceding the final amplifier. Naturally in such a case there will be less likelihood that energy will get through to the antenna, since it would have to go through two stages instead of one. Keying the oscillator also will prevent radiation of a back-wave.

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 be reduced to a value such that the d.c. input does not exceed the rated plate dissipation of the tube. Cathode bias, explained in the chapter on transmitter design, may be used for this purpose.

The stability of the transmitter can be adversely affected by keying if the keyed stage follows the oscillator. Practically all oscillators, including crystal-controlled types, 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. So long as the frequency is stable with the key closed, this will not do particular harm, although if a back-wave is radiated the back-wave will give a beat note differing slightly from that of the keyed signal. However, if a lag circuit — to be described later — is used with the keying system the change in frequency will be gradual instead of instantaneous, giving rise to a chirpy or "yooping" signal, which is highly undesirable. 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.

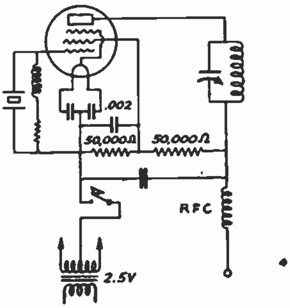


FIG. 1007 — PENTODE CRYSTAL OSCILLATOR KEYING TO ELIMINATE CHIRPS

Essential to the system is the use of a voltage divider instead of series resistor for obtaining screen voltage. A center-tapped resistor may be connected across the filament leads if the filament transformer has no center-tap.

When the oscillator itself is keyed there is no variation in load, although the keying may be chirpy for other reasons. In general, an oscillator will tend to chirp under keying if the loading is too great or, if a crystal oscillator, with the plate condenser set too near the point where oscillation stops. In pentode crystal oscillators, chirps also may result if the screen voltage varies when the key is open and closed, as may be the case if the screen voltage is obtained through a dropping resistor from the plate supply. Separate screen supply, or supply from a voltage divider across the plate supply, often will prevent chirps in such a case. A "chirpless" circuit using center-tap keying of the crystal oscillator is shown in Fig. 1007.

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.

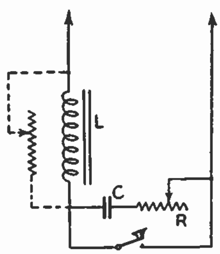


FIG. 1008 — A TYPICAL LAG CIRCUIT FOR ELIMINATING KEY CLICKS OR THUMPS

The primary of a bell-ringing transformer often will serve at L in low-power transmitters. See text for discussion of values.

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.

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.

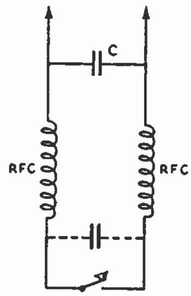


FIG. 1009 — AN R.F. FILTER FOR THE ABSORPTION OF KEYING TRANSIENTS

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.

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.

A complete key-click filter of this type — often called a "lag" circuit because of the delay or lag in application of power to the transmitter — is shown in Fig. 1008. In general, all values, *L*, *C* and *R*, must be determined experimentally for the particular transmitter and local conditions. Identical values may not give the same performance with different transmitters or at different locations where wiring conditions, location of receivers, etc., are seldom duplicated. They usually will be found to lie in the ranges already mentioned, however. A variable resistor, shown connected by dotted lines in Fig. 1008, can be used to vary the effect of the inductance. A variable resistor also is useful as the spark absorber, permitting quick adjustment to the most desirable operating value.

The values of *L* and *C* should be the smallest that will give satisfactory key-click elimination. If the inductance and capacity are too great, the slowing-up will be so pronounced that the dots and dashes will not be cleanly defined. This will make the signals hard to read.

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.

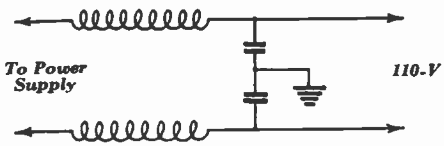


FIG. 1010 — R.F. FILTER FOR THE POWER LINE

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 condenser as shown in Fig. 1009. 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.

Other Considerations in Key Click Prevention

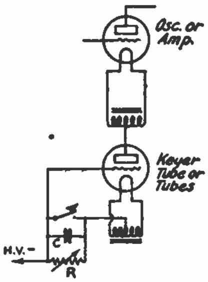
● It is reasonable to expect that less trouble will be encountered in eliminating key clicks if the power supply for the keyed stages has good voltage regulation (see Chapter Fifteen). If the voltage regulation is poor, the plate voltage with the key open may be 50% to 100% higher than with the key closed; 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.

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.

FIG. 1011 — A VACUUM-TUBE KEYING METHOD TO PREVENT CLICKS

One or more keyer tubes may be used; the larger the number the greater the plate current that can be safely passed. Condenser C may be between .25 and 1.0 μfd. Resistor R should be adjusted to cause the plate current to drop to zero when the key is open. A variable resistor of about 50,000 ohms should give enough range.



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. 1010. 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.

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 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.

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 the oscillator is desirable from this standpoint, since the oscillator is the lowest-powered stage and the transients are therefore of comparatively small amplitude in the first place. Also, the maximum r.f. filtering in following-stage tank circuits is secured when the oscillator is keyed.

Keyer Tubes

● A vacuum-tube lag-circuit keying arrangement which has attained considerable popularity is shown in Fig. 1011.

In this system a vacuum tube is placed with its plate-filament circuit in the center-tap of the tube to be keyed, while the key itself is in the grid circuit of the auxiliary or "keyer" tube. 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 to the oscillator or amplifier being keyed. The time-constant of the inductance 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, so the plate voltage on the oscillator or amplifier 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 need not be center-tapped; in fact, the filaments may be connected in series if desired.

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 current in the keyed circuit is small, although there may be occasional exceptions to this rule. First choice, then naturally would fall to those methods which key a 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.

Probably the worst keying circuit from the standpoint of click elimination is simple plate-circuit keying of the type shown in the lower diagram of Fig. 1001. Sparking at the key usually is excessive with this circuit, which makes the problem of key-click prevention more difficult. The two upper circuits of Fig. 1001 are ideal for introducing a time lag in the keying, the power-supply filter being utilized for this purpose. However, the lag ordinarily is so great that the transmitter can not be keyed at more than a few words per minute when a filter adequate to give pure d.c. is used. With a single-section filter it may be possible to get clean keying at reasonable speeds; this type of filter may in fact be quite satisfactory to give a d.c. note if the lower-power stages are fed with well-filtered d.c. Only a trial can show whether either of these systems will work out to the operator's satisfaction. Both are prone to give rise to transients which feed back into the power line and therefore require r.f. filters at the key. In the middle drawing, the current broken by the key is much less than in the upper, so that the problem of getting suitable chokes is less bothersome.

Center-tap keying, Fig. 1003, 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. In general, however, it is easier to eliminate clicks with grid keying than with either plate or center-tap keying. The keyed current usually is fairly small. The chief objection to grid-keying methods is the necessity for providing additional keying bias. This can be overcome, however, as has already been explained.

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.

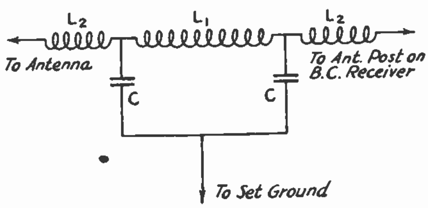


FIG. 1013 — A LOW-PASS FILTER FOR REDUCTION OF INTERFERENCE WITH BROADCAST RECEPTION

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. Cutoff frequency is approximately 1600 kc.

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. 1012. The condenser may be an old one with about 250 or 350 μμfd. 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

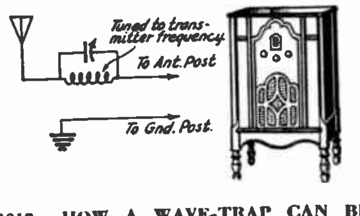


FIG. 1012 — HOW A WAVE-TRAP CAN BE INSTALLED TO PREVENT CERTAIN TYPES OF INTERFERENCE

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

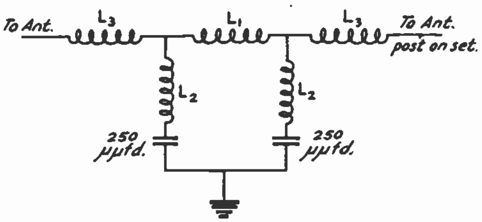


FIG. 1014 — CIRCUIT DIAGRAM OF SHARP CUT-OFF LOW-PASS FILTER

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 1 ⅜"-diameter form.

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. 1013. 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. 1014. 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 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,

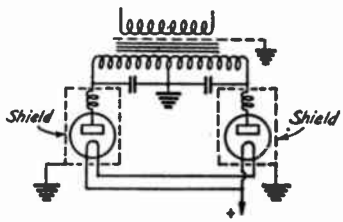


FIG. 1015 — DEVICES FOR ELIMINATING NOISE FROM MERCURY-VAPOR RECTIFIER TUBES

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.

and the interference is just as strong whether the antenna is connected to the receiver or not.

Rectifier Noise

● Mercury-vapor rectifiers often are the source of a peculiar and easily indentifiable 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. 1010 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. 1015. 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.

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. 1010 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. If none of the usual methods is wholly effective a reduction in power often will allow the station to be worked during the evening hours without bothering the neighbors.

Radiophone 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 Eleven covers this subject thoroughly.

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.

CHAPTER ELEVEN

Fundamentals of Radiotelephony

PRINCIPLES OF MODULATION AND 'PHONE TRANSMITTER CIRCUIT DESIGN

In the discussion of modulation and detection in Chapter Four, it was pointed out that both radio telegraph and radio telephone transmission require modulation in order that the transmitted wave may convey intelligence to the receiver. In subsequent chapters we have seen how this modulation is applied in relatively simple form for c.w. telegraph. In this chapter we shall take up the principles and methods involved in speech modulation for radio telephone communication. It must be realized that radiotelephony is much more complicated than c.w. telegraphy, not only in the amount of apparatus involved but also in its technical aspects. The 'phone transmitter not only must have radio-frequency equipment typical of the good c.w. set and additional audio-frequency equipment to accomplish voice modulation, but also there must be careful coördination of the r.f. and audio sections to insure that the outfit's performance meets modern requirements. Satisfaction of these requirements can be realized by following the established and proved design and adjustment procedure which will be given. The information is based on actual experience in practical amateur transmitter construction and operation.

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. When such a wave is detected in the receiver, as explained in Chapter Four, there should result a true reproduction of the original modulating signal which, in amateur 'phone, would be the speech of the operator at the transmitting station. The degree of amplitude 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. These basic definitions are very important and should be thoroughly memorized and understood.

Graphic illustration of modulation of a radio wave is given in Fig. 1101, in which *C* shows an actual cathode-ray oscilloscope reproduction of the unmodulated carrier, *D* shows this carrier modulated approximately 50 percent, and *E* shows the carrier completely modulated by a single-tone signal of the good waveform pictured in *A*. The picture *B* of this figure shows undesirable distortion of the modulating signal.

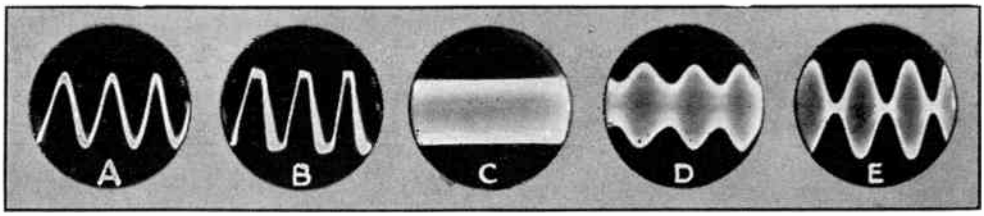


FIG. 1101 — PICTURE A SHOWS THE WAVE FORM OF THE 500-CYCLE MODULATING SIGNAL WITH THE AUDIO STAGES OPERATING PROPERLY

B shows the same audio signal with distortion from over-excitation of the Class-B driver stage. C pictures the unmodulated carrier and D the carrier modulated approximately 50% with good wave form. E represents the carrier properly modulated 100 per cent.

Fig. 1102 gives conventionalized sketches of amplitude modulation, with the amplitude 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 a distortion of the wave envelope — the envelope being the outline of the radio-frequency cycle peaks.

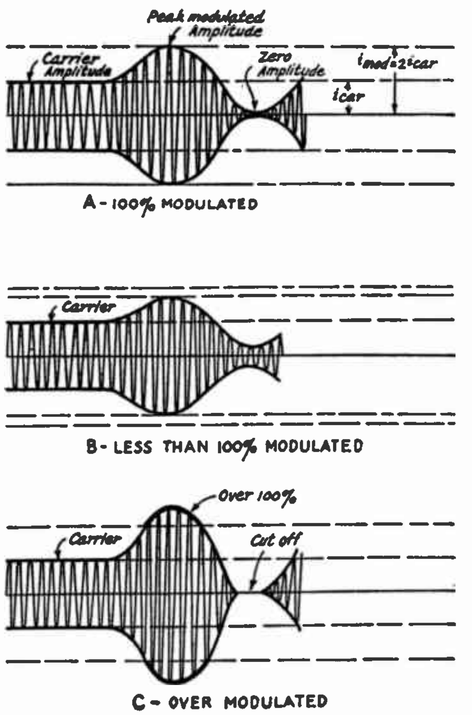


FIG. 1102 — GRAPHICAL REPRESENTATION OF THE AMPLITUDE MODULATED WAVE

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.

Such distortion not only affects the quality of the received signal but also broadens the communication band of the transmission and causes needless interference. This broadening results from the fact that unnecessary side-band frequencies are generated. As was pointed out in Chapter Four, the process of modulation produces additional radio frequencies in pairs either side of the carrier frequency, constituting the *side bands*. There will be one such pair for each frequency component in the modulating signal. If the wave form is distorted, as it will be with overmodulation, there will be further side bands generated and these spurious radiations will broaden the wave accordingly. It is for this reason that government regulations prohibit overmodulation.

In connection with the dual nature of side bands in the type of transmission under discussion, it should be pointed out that the intelligence conveyed by the modulated wave is all contained in the side-band components. Our present technical methods necessitate the transmission of the carrier and both side bands, although it is theoretically possible to communicate with the carrier suppressed and only the two side bands transmitted, or with the carrier and a single side band transmitted, or even with the carrier suppressed and only a single side band transmitted. The carrier is only useful for beating with the side-band components to reproduce the original signal in the receiving detector. Hence, it is possible to dispense with transmission of the carrier and use a locally-generated carrier in the receiver to serve the purpose. However, single-side-band technique is not yet sufficiently developed to make it economically feasible for amateur work, although it is being used on high frequencies to a limited extent in experimental commercial communication.

Amplitude and Power Relations

● The maximum permissible modulation factor, imposed by the requirements that the modulation envelope shall not be distorted, is 100 percent. This limit is reached when the total amplitude of the two side bands equals the amplitude of the carrier, each side band therefore having a total amplitude equal to one-half the carrier amplitude. Since the amplitude is doubled at 100 percent 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 single pure tone the *average power* will be 50 percent greater than the unmodulated power, in accordance with the effective evaluation for complex waves which was given in Chapter Three. That is, the carrier and the two side bands represent three different frequency components of which the carrier would have an effective value of 1 and the side bands each an effective value of 0.5. The square root of the sum of the squares of these three effective current (or voltage) values would be 1.226. Power being proportional to the square of the current, the average power value at 100 percent sinusoidal modulation would be 1.226^2 or 1.5. Speech, however, is of complex form. Experience has shown that for the most practical purposes it can be taken as equivalent to two tones of equal amplitude. The maximum total amplitude restriction necessitates, therefore, that the total amplitude of the four equivalent side-frequency components shall be no greater than the carrier amplitude; the two frequency components in the modulating signal are altogether likely to be in phase aiding at least occasionally. With such a modulating signal, the instantaneous peak power at 100 percent modulation also would be four times the unmodulated power. However, the average power, by the root-sum-square calculation, would be 1.25 times the unmodulated power, or 25 percent greater than the unmodulated power. The effective current would be 1.12 times the unmodulated effective current value. Hence, although a radio-frequency ammeter in the antenna circuit would show an increase in current reading of slightly more than 22 percent with 100 percent sustained modulation by a sinusoidal signal, the sustained speech-equivalent signal would give an effective current reading only 12 percent greater than the unmodulated reading. Moreover, the varying nature of speech modulation would give a considerably smaller percentage increase in practical operation, because of the sluggishness of such measuring instruments and their inability to indicate truly the maximum effective current value. From experience, a reading increase of only about 5 percent should be obtained with usual speech.

Modulation Capability And Stability

● It is entirely possible for the modulation envelope to be distorted at less than 100% modulation, as in a transmitter which was incapable of increasing the maximum amplitude to twice the unmodulated amplitude. *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 ten-watt carrier modulated 100 percent is practically as effective as a 40-watt carrier modulated 50 percent.

With transmitters of high-percentage modulation capability, particular care must be exercised to prevent variation in the carrier frequency as an accompaniment to amplitude modulation. Such variation constitutes *frequency modulation*. It has been shown that frequency instability is a serious defect in c.w. telegraph transmission, and it must be realized that frequency modulation is far more objectionable in 'phone transmission. It not only causes unnecessary interference with other stations working on adjacent frequencies in the same amateur band, but also can cause interference with services operating on greatly different frequencies. An amateur 'phone working on the 3900-kc. band is even likely to cause interference on the broadcast band, as a result of frequency modulation accompanying amplitude modulation. The combination may cause radiation of spurious frequencies over a band as wide as several hundred kilocycles. 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. An extremely stable oscillator is necessary, with provision for isolating it from the modulated stage as by an intervening buffer amplifier.

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 percent 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. 1104.

In A of Fig. 1103 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% 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*.

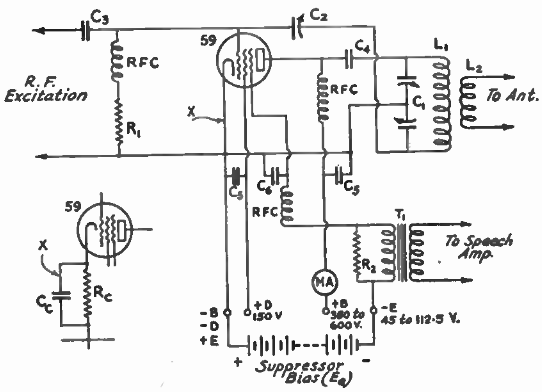


FIG. 1104 — CIRCUIT OF THE SUPPRESSOR-GRID MODULATED R.F. AMPLIFIER

In Fig. 1103-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% 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 65%.

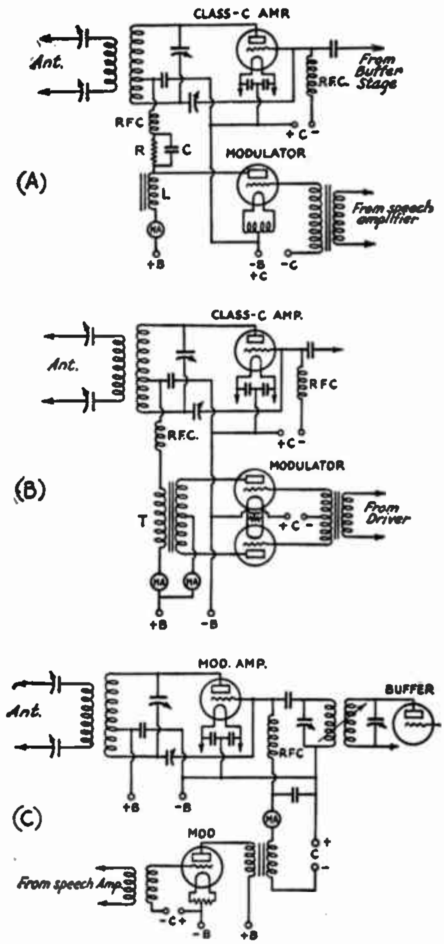


FIG. 1103 — CIRCUITS FOR THREE METHODS OF MODULATION

A and B are for plate modulation, C for grid-bias modulation.

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 or somewhat less in usual practice. At 100% modulation it rises to approximately 60%.

The circuit arrangement for suppressor-grid modulation of a pentode type tube is shown in Fig. 1104. 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

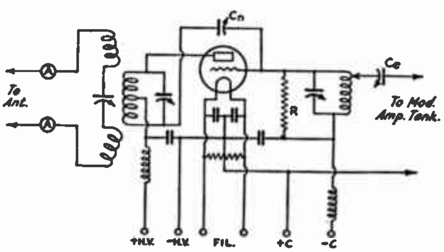


FIG. 1105 — CIRCUIT OF A SINGLE-ENDED CLASS B LINEAR R.F. AMPLIFIER

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.

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% at full modulation. With tubes having suitable suppressor-grid characteristics, linear modulation up to practically 100 percent can be obtained with negligible distortion.

Class-B Linear Amplifiers

● When the final r.f. stage of the transmitter is modulated, it is considered as a *high-level* system, since modulation takes place at the highest power level in the transmitter. If the modulation takes place in an intermediate stage with a higher-power r.f. amplifier stage or several such stages following, it is called *low-level* modulation. Amplifiers so used to increase the power output from a low-level stage are operated as *linear amplifiers.* Such amplifiers are operated under Class-B conditions, as described in Chapter Five, with minor modifications in the circuit to maintain the output power proportional to the square of the excitation voltage over the range of amplitude with modulated excitation. The circuit of a Class-B linear amplifier stage is shown in Fig. 1105. The principal modification usually required is the r.f. load resistor *R* which serves to improve the r.f. voltage regulation of the modulated exciter's plate circuit. Some such stabilization is necessary because the input impedance of the linear stage varies considerably with variation in the amplitude of the modulated r.f. excitation. A Class-B linear stage should be operated as a "straight" amplifier; that is, its output should be on the same frequency as the input. If operated as a frequency doubler, the depth of modulation will be increased in the output, and spurious frequencies are likely to be generated. Plate efficiency is of the same order as with grid modulation.

Controlled-Carrier Transmission

● In the above systems as outlined, 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 is not only of varying amplitude but is also 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, and its nuisance effect is disproportionate to its utility. The deficiencies can be overcome to a considerable extent if the carrier amplitude is automatically varied to maintain it just suffi-

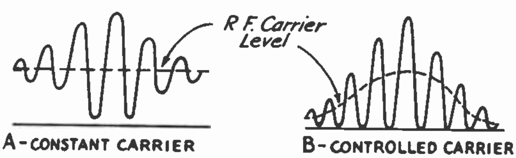


FIG. 1106—CONTRASTING MODULATED WAVES OF THE CONSTANT-CARRIER TYPE (A) AND CONTROLLED-CARRIER TYPE (B)

cient 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. 1106. 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 of modulation. Practical details of controlled-carrier transmitting circuits are given in the next chapter.

The Plate-Modulated R. F. Amplifier

For distortionless or linear plate modulation with 100-percent 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, present a load or *modulating impedance* to the modulator equal to the modulator's rated plate load impedance. To satisfy these conditions it is necessary that the modulated r.f. amplifier operate so that its plate circuit presents a constant resistance of proper value as viewed from the modulator's output, the value of this load resistance in ohms being the r.f. amplifier d.c. plate voltage (volts) divided by its d.c. plate current (amperes).

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. The plate current and output current vary as the plate voltage between the limits of zero plate voltage and twice the mean plate voltage. This is accomplished by operating the modulated amplifier with a negative grid bias more than sufficient to reduce the plate current to zero with no excitation (usually twice "cut-off" bias) and by supplying the grid with r.f. excitation sufficiently ample to cause plate current saturation. Grid bias may be obtained from a fixed-voltage source (batteries), or by means of a grid leak, or by a combination of fixed and leak bias in series, or by a dropping resistor in the negative (cathode) circuit. A combination of automatic grid-leak bias and cathode-drop bias is desirable for full-range linear modulation.

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% 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.

The tubes most suitable for use in modulated Class-C amplifiers are those designated for r.f. power amplifier use, such as are listed in the transmitting tube table of Chapter Seven. Triodes in a neutralized circuit, are capable of making best use of the modulator audio power output. Screen-grid tubes are also used but require simultaneous modulation of both plate and screen voltages. Tubes chosen for Class-C amplifier operation should have plate voltage and current ratings that will not be exceeded in modulated service. Excessive plate voltage or plate current will not only shorten the life of the tube but also may cause non-linear modulation, distortion and interfering spurious radiation. This applies particularly to receiving-type tubes (such as the 46) 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 d.c. plate voltage and plate current product. The audio-frequency power is superimposed on this average input, and with 100 percent modulation by a sinusoidal signal will be 50% greater than the average power indicated by d.c. meters and approximately 25% greater with a speech signal, in accordance with the explanation of pulsating current calculation given in Chapter Three. Hence, the maximum plate dissipation may be 50 percent greater than the d.c. meter readings might lead one to believe. Allowance for this additional dissipation should be made in choosing the plate voltage. Plate-voltage ratings for Class-C modulated amplifiers are usually about 25 percent less than the maximum allowable for c.w. service with the same tubes.

Coupling Calculations for Plate Modulation

● With a modulator of given power output and load resistance (or impedance) requirement, calculation of the proper plate input to the Class-C amplifier and of coupling circuit values can be made quite easily. Determination of Class-A load impedance and power output from the tube plate characteristics is described in Chapter Five. In the case of a Class-A modulator with choke coupling to the Class-C amplifier plate circuit, as shown in Fig. 1103-A, the procedure is as follows:

As has been stated, for 100 percent sinusoidal modulation the Class-C amplifier d.c.

input power should be twice the modulator's rated maximum undistorted power output (u.p.o.). 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 I in next chapter). 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 resistance value for the dropping resistor, *R* of Fig. 1103-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; an RK-31, 830, RK18 or 800 would be a likely choice.

In the case of transformer coupling between the modulator and Class-C amplifier, as shown in Fig. 1103-B, the procedure is somewhat different. This method of calculation is generally applicable to any type of modulator, Class-A or Class-B, with transformer coupling. The purpose is to calculate the turns ratio of the transformer to match the modulating impedance of the Class-C amplifier to the required load impedance of the modulator. For illustration, take the case of a modulator using a pair of Type 800 tubes in Class-B, operating at a plate voltage of 1000 volts (Table II of next chapter). The rated power output with negligible distortion is 100 watts and the plate-to-plate load impedance is specified as 12,500 ohms. The Class-C amplifier using two similar tubes is to operate at the same plate voltage, 1000 volts, with a mean (d.c.) power input of twice the modulator's rated maximum output, or 200 watts. The Class-C amplifier plate current is, therefore,

$$I_b = \frac{P_o}{E_b} = \frac{2 \times 100}{1000} = 0.2 \text{ amp.} = 200 \text{ ma.}$$

The modulating impedance of the Class-C amplifier is

$$Z_m = \frac{E_b}{I_b} = \frac{1000}{0.2} = 5000 \text{ ohms.}$$

The transformer therefore must match a 5000-ohm load to the modulator's 12,500-ohm load requirement. This calls for a step-down transformer having an impedance ratio of 12,500 to 5000. The turns ratio, *total primary to total secondary* will be the square root of the impedance ratio:

$$\text{Turns Ratio} = \sqrt{\frac{12,500}{5000}} = \sqrt{2.5} = 1.58 \text{ to } 1$$

(or 1 to 0.63).

In the case of Class-B output transformers it is customary to specify the turns ratio of ½ *primary to total secondary,* which would be 1 to 1.26 in the example given. In the actual design of the transformer the secondary turns would be increased slightly over the theoretical calculated value, to allow for losses. Manufactured types having suitable characteristics for standard modulator combinations are widely available at reasonable prices. The transformer may be designed to carry the Class-C amplifier d.c. plate current through its secondary without saturating the core. Otherwise it will be necessary to feed the amplifier plate d.c. through an audio-frequency choke and couple the transformer, across the choke, through a large condenser.

Economy Class-B Modulation for Speech Only

● Although it is customary to calculate modulator power requirements on the basis of a sine-wave modulating signal, a somewhat smaller modulator power capability is possible in the case of the Class-B modulator which is to be used only for speech transmission. We have shown that the *average* power in a speech signal is approximately half as great as the average power in a sinusoidal signal of equal amplitude. Hence, although the maximum amplitude and peak power values are the same with either type of signal, giving the same amplitude limitation in the design procedure for both, the power dissipation limitation is modified in the case of speech. With Class-A modulators this does not apply because the power ratings have to be based on the no-signal condition, during which the plate must dissipate the entire d.c. input.

In general, doubling the unmodulated Class-C amplifier input for a given Class-B modulator tube combination necessitates an increase in the modulator plate voltage, an increase in audio driving power and perhaps also a change in the output transformer ratio. The modulator tubes must be capable of operating at this increased plate voltage and supplying the peak emission demanded. The application is thereby restricted to certain types of tubes as Class-B modulators, the design being determined from the characteristic curves and ratings. Details of such a modulator unit are given in the next chapter.

Speech Input Circuits — Types of Microphones

A microphone is the device used to convert the sound waves of speech into corresponding alternating currents or voltages which, after amplification, excite the modulator. Typical circuit arrangements of five types of microphones generally used in amateur transmitters are shown in Fig. 1107. 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 a piezo-electric (crystal) type microphone.

Carbon-grain microphones, both single- and double-button, convert sound waves into pulsating electrical current by the variation in the resistance with pressure between carbon granules in contact with a metal or graphite diaphragm which is caused to vibrate by the sound waves striking it. In the single-button microphone, M_1 of *A*, one connection is made to the diaphragm and the other is made to the cup containing the carbon granules, called a button. The microphone terminals are connected in series with a variable resistor (to adjust microphone current), which is connected across a battery, and the primary winding of a transformer. The current through the primary is a pulsating direct current which induces alternating voltage in the secondary winding. This voltage in turn is applied to the grid circuit of the speech-amplifier tube. In the double-button microphone, M_2 of *B*, there is a cup of carbon granules on each side of the diaphragm. These "buttons" are connected to the two ends of the primary winding of the microphone transformer and the diaphragm is connected in series with a battery to the center of the winding as shown in *B*. The granules in one button are compressed and their resistance is reduced while the granules on the other side loosen and their resistance is increased when the diaphragm is vibrated, with the result that there is an increase in current flow between one button and the diaphragm while there is a decrease in current flow between the other button

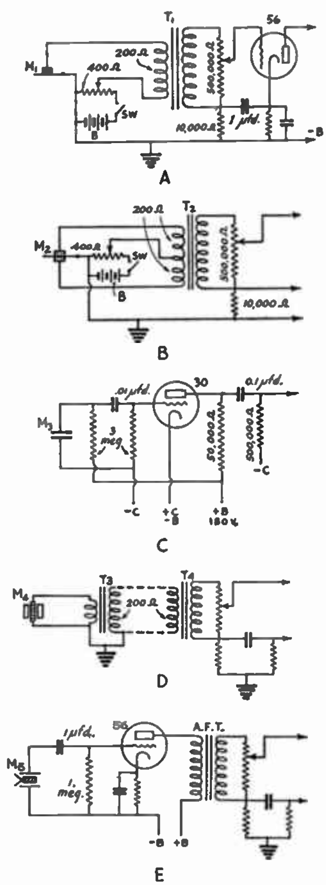


FIG. 1107 — SPEECH INPUT CIRCUIT ARRANGEMENTS FOR FIVE GENERALLY USED TYPES OF MICROPHONES

M_1, single-button carbon; M_2, double-button carbon; M_3, condenser; M_4, ribbon or velocity type; M_5 crystal type.

and the diaphragm. The average current flow through the common circuit and the battery will remain constant if the buttons have been properly adjusted. The diaphragm of the "high-quality" double-button microphone is "stretched" to make its natural resonant frequency well above the normal audio-frequency range. This makes the microphone's sensitivity comparatively low but improves its frequency characteristic. More sensitive double-button microphones have an "unstretched" metal or graphite diaphragm.

The condenser microphone illustrated in C utilizes an entirely different principle — that the variation in electrostatic capacity between two plates causes a change in the potential difference between them. In the microphone one of the plates is fixed and incapable of vibration but the other is of thin metal, tightly stretched, separated from the fixed plate by about a thousandth-inch. A high d.c. potential, which may be obtained from the amplifier "B" supply, is applied between the plates and the variation in the potential which results when the thin plate vibrates in response to a sound wave is applied across a high resistance (several megohms) in the grid circuit of an amplifying tube.

The velocity or ribbon-type microphone, M_4, operates on the electromagnetic principle. A light corrugated ribbon of conductive material, such as dural, is suspended with slight tension between the poles of an electromagnet so that its motion will be transverse to the magnetic field. When vibrated by sound waves, the ribbon conductor cuts the magnetic lines of force and a corresponding alternating current flows through the ribbon and the primary of a transformer in its external circuit. The impedance of the ribbon is very small, a few ohms, permitting the use of a transformer with a small primary and large turns (voltage) step-up ratio for coupling to the grid of the first amplifier. The frequency response of this type microphone is very uniform over the audio range, since its inherent characteristics are such that the voltage generated is proportional to the amplitude of the sound wave and nearly independent of frequency, the velocity of the ribbon being proportional to the sound-wave intensity. For this reason this type of dynamic microphone is also known as the "velocity" microphone. A somewhat different type of dynamic microphone has a low-impedance coil mechanically coupled to a diaphragm, the electrical current being induced in the coil by motion caused by sound waves. The moving-coil type microphone is relatively more complex and expensive than the ribbon type and is not so widely used for amateur work.

The input circuit for a piezo-electric or crystal type microphone is shown in Fig. 1107-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. This electro-mechanical action is the reverse of that utilized with the quartz crystals used in transmitters and described in Chapters Eight and Nine. 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.

Wide-frequency response speech input equipment is not required for voice transmission, uniform frequency response up to 2800 or 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.

A microphone of any type is a piece of apparatus deserving careful handling. The carbon types should never be moved or even touched while current is flowing through them because the slightest jar will give the diaphragm a jolt far greater than that caused by a loud sound. The carbon microphone should never be operated with excessive current through the buttons because the heat generated by high current may fuse the carbon granules together, causing "freezing." The current to each button of a double-button microphone should be of the same value and sometimes adjustment of the pressure on the buttons may be necessary to make it so. This adjustment must be made very carefully, preferably by an experienced microphone repair man.

If a carbon microphone should become "frozen" the granules may be loosened by lightly tapping the frame with one finger *after the microphone battery circuit has been opened.* The microphone should be suspended by springs in a frame or hung from the ceiling in preference to having it unprotected from shock and vibration on the operating table. A good shock-proof mounting will eliminate a lot of the "background" noise which afflicts many amateur outfits. Crystal microphones are much less affected by vibration and "cord noise."

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, or with the microphone against the cheek, slightly to one side of the speaker's lips.

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 about 100 ma.

The sensitivity of good-quality double-button microphones is considerably less, ranging from 0.025 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 10 or 15, 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 (40 db) 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. The sensitivity of piezo-electric crystal microphones also varies from type to type. Useful data from coöperating manufacturers of representative types popularly used by amateurs are given in the accompanying table. The figures are for 7-foot connecting cords. The voltage available at the grid of the first tube is decreased by lengthening the connecting cable, although the frequency characteristic is unaffected. The lower values of load resistance (1 megohm and less) affect the frequency response by attenuating the lower frequencies, but this is not disadvantageous for speech transmission since the loss is principally effective below 100 cycles, which tends to lessen the high-amplitude peaks without detracting from the intelligibility.

CRYSTAL MICROPHONE OUTPUT LEVELS FOR CLOSE TALKING

Type Microphone	*Load Impedance*	*Volts Across Load*
Astatic Type D-104	1 megohm	0.02 v.
Shure Type 70-H	1 megohm	0.036 v.
Shure Type 70-S	0.5 megohm	0.054 v.
Shure Type 73-A	1 megohm	0.03 v.
Turner Type G	5 megohms	0.15 v.
Turner Type S4-MX	5 megohms	0.06 v.

Speech Amplifiers

● The speech amplifier of the 'phone transmitter includes the audio stages between the microphone and the grid circuit of a Class-A modulator or the grid circuit of the Class-A power driver stage for a Class-B modulator. The speech amplifier stages are operated as Class-A voltage amplifiers; that is, they are designed to give high undistorted voltage amplification and their output circuits are of high impedance, as contrasted with audio power amplifiers. The tubes used are the smaller receiving types having medium to high amplification factors, resistance or transformer coupling being generally used with the medium-μ types and resistance coupling with the high-μ types.

Knowing the approximate value of voltage output obtainable from the microphone and the voltage excitation requirement of the Class-A modulator or driver stage, the total voltage amplification necessary can be estimated. The voltage swing required by the 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 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. 1108. The voltage step-up in a coupling transformer is assumed the same as its turns ratio, while the approximate gain of a tube is taken as 60 or 65 percent of its rated amplification factor (μ) in the case of a triode, and about 10 percent in the case of a screen-grid (pentode) tube. 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. Voltage amplifier data for popular combinations are given in the table.

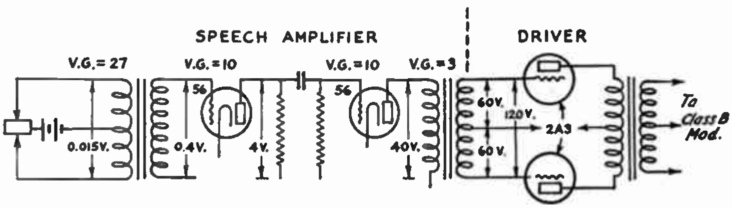


FIG. 1108 — SKELETON DIAGRAM OF SPEECH-AMPLIFIER AND DRIVER STAGES, SHOWING APPROXIMATE VOLTAGE GAIN AND PEAK VOLTAGE PER STAGE

HIGH-GAIN VOLTAGE AMPLIFIER DATA

Type Tube	*Element Connection*	*Plate Supply Volts*	*Plate Load Resistance*	*Grid Bias Volts or Cathode Res.*	*Screen Volts*	*Approx. Voltage Amp.*	*Approx. Peak Voltage Output*
57, 6C6, or 6J7	Pentode	275	250,000 ohms	3500 ohms	50	100	65 V.
Same	Triode (Screen tied to plate)	275	50,000 ohms	2200 ohms	..	14	65 V.
79	Cascade Triode (2-stage amp.)	265	250,000 ohms	2 V.	..	2100 (for both sections)	65 V.
53, 6A6	..	250	..	3 V.	..	720 (for both sections)	58 V.

CHAPTER TWELVE

Building Radiotelephone Transmitters

CONSTRUCTION OF TYPICAL AUDIO SECTIONS AND ADJUSTMENT FOR PROPER MODULATION

The general design principles outlined in the previous chapter serve as the basis for an almost infinite variety of transmitter combinations. Descriptions of every possible arrangement that might be used for amateur 'phone would fill a book even larger than this one. However, there is a group of established types which includes the combinations most generally adapted to amateur use, with r.f. sections for both the high- and ultra-high frequency 'phone bands as described in Chapters Nine and Fourteen. These will be described as examples. No one combination need be duplicated in its entirety, of course. The speech input circuits may be interchanged to suit the microphone and tubes available, other styles of assembly can be adopted, power tubes of equivalent capability can be substituted. To facilitate individual choice, various of Class-A and Class-B audio combinations are given in Tables I and II, while voltage amplifier data are given in the previous chapter and data for r.f. tubes in grid-bias and suppressor modulated stages, and for Class-B linear amplifier service, are given in the tube tables of Chapter Five. With all this information, an amateur transmitter of almost any conceivable type can be built up.

What Type Transmitter?

● Transmitters are usually distinguished by the method of modulation they use — Class-A plate, Class-B plate, grid-bias or control-grid, or any one of these with Class-B linear amplification and perhaps with controlled-carrier operation. Each has its enthusiastic supporters, and all technically will give equivalent results. The choice is therefore mostly a matter of first cost, which will depend somewhat on the equipment already available. Transmitters of 100-watt or so r.f. output usually can be most economically adapted to Class-B plate modulation, which gives the most watts per dollar. Higher-power r.f. units may be readily adapted to grid-bias modulation at relatively small cost, although the 'phone output will be necessarily reduced to about a quarter of the c.w. code capability. With a power pentode final stage, suppressor-grid modulation is easily applied, with practically the same requirement of reduced output as with grid-bias modulation. Plate modulation might be added later to give full 'phone output, employing the grid modulator in a driver unit for the Class-B modulator. High-level plate and suppressor-grid modulation systems are the most tolerant

FIG. 1201 — AN EFFECTIVE AMATEUR 'PHONE TRANSMITTER
The general-purpose transmitter of Chapter Nine equipped with grid-bias modulator, as described in the following pages.

in adjustment and maintenance. Grid-bias modulation is somewhat more complicated, while the Class-B linear stage with low-level modulation is the least tolerant. The Class-B linear is used by amateurs to only a limited extent, and less than formerly in commercial transmitters.

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 chassis, with rack mounting. Foundation units of the type used for modern receivers are admirably suited. 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 inter-stage 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 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 well 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 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 the high-gain circuits which will be described.

TABLE I—CLASS-A AMPLIFIER AND MODULATOR OPERATING 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*
50	7.5	500	50	100	7500	5.5
2A3 (P.P.)[4]	2.5	300	80	62	3000	15.0
211, 242A, 276A	10.0	1000	65	52	7000	10.0
845	10.0	1000	75	150	7500	23.0
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

With exception noted, 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. For 2 tubes in push-pull, multiply I_b, Load Impedance and Output Watts by 2, taking peak audio grid voltage twice bias value.

[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.

[4] Two tubes in push-pull. Peak audio grid voltage twice bias value.

Plate Modulator Construction

● Class-A modulators for low-power transmitters can be the Class-A drivers of the units described in this chapter; or can be planned for larger tubes in the choke- and transformer-coupling circuits shown in Chapter Eleven, from the operating data given in Table I. Their construction is simple and straightforward, requiring no special description. Assemblies of the same style shown for the Class-B units in this chapter are recommended. Speech-amplifiers for Class-A modulators do not furnish power to the modulator grid circuit, and therefore can be worked out quite readily. The maximum output voltage of the speech-amplifier should be approximately equal to the modulator grid-bias in the case of a single modulator tube or two or more tubes in parallel, and should be approximately twice the Class-A modulator grid bias for tubes in push-pull. Because of their relatively low efficiency, Class-A modulators are seldom used in amateur transmitters at the present time, having been largely superseded by the higher-efficiency Class-B type. (See Table II.)

A 10-Watt Class-B Unit

● A simple and inexpensive Class-B modulator unit suitable for 20- or 25-watt Class-C amplifier input is diagrammed in Fig. 1202. The speech-amplifier is a 53 with both its grids tied together, and both plates also tied together. It operates as a Class-A driver. With single-button microphone input, this driver is adequate to excite the Class-B modulator to its full 10-watt or slightly greater output. Both the driver and the Class-B modulator use the same plate supply, shown below the audio unit in the diagram. In this particular combination, a separate power supply is used for the r.f. section, which is generally good practice in transmitters using Class-B modulation because the varying plate power taken by the modulator causes variation in the supply voltage which might affect the frequency of an oscillator taking its plate power from the same supply. The r.f. section shown may have the constants of similar tube combinations given in Chapter Nine. This modulator could be used with any Class-C amplifier operating with a plate input of 60 ma. or so at a plate voltage approximating 350 volts. With a more sensitive type microphone, a 1- or 2-stage high-gain unit would be used ahead of the 53 driver stage. The no-signal plate current of the modulator is 35 to 40 ma., kicking up to approximately 50 ma. at 100 percent modulation with speech.

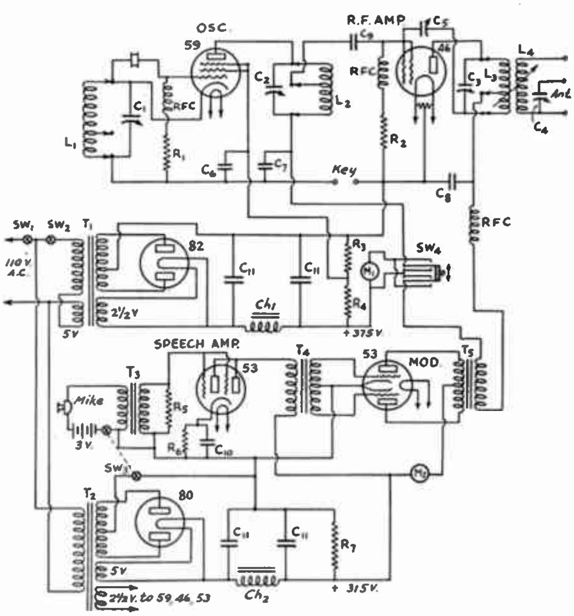


FIG. 1202 — CIRCUIT OF THE 10-WATT 53 MODULATOR UNIT FOR LOW-POWER 'PHONE TRANSMITTERS (W9FVM)

Constants for the r.f. section correspond with designs of Chapter Nine.

C_{10} — 25-volt 10-μfd. electrolytic (Aerovox or similar).
C_{11} — 8-μfd. 500-volt electrolytic condensers (Sprague or similar).
R_5 — 250,000-ohm ½-watt.
R_6 — 1,000-ohm 1-watt.
R_7 — 25,000-ohm 20-watt.
T_1 and T_2 — See text.
T_3 — Single-button microphone transformer.
T_4 — Class-B input (Collins 754X or similar).
T_5 — Class-B output (Collins 740Z or similar).
M_1 — 0–150 d.c. milliammeter.
M_2 — 0–100 d.c. milliammeter.
Ch_1 and Ch_2 — Small replacement-type filter chokes to carry 80 to 100 ma.
Sw_1 and Sw_2 — S.p.s.t. toggle switches.
Sw_3 — D.p.s.t. toggle switch.
Sw_4 — Milliammeter switch, d.p.d.t.

Economy Modulator for 50-Watt Transmitters

● The modulator illustrated in Fig. 1203 and diagrammed in Fig. 1204 is intended especially for speech modulation of a Class-C amplifier operating with a plate input of 140 ma. at 600 volts (approximately 85 watts). Although the modulator tubes have a normal output rating of only 20 or 25 watts, 100 percent speech modulation of this Class-C input is obtained with negligible distortion, following the principles outlined in the preceding chapter. This is accomplished by operating the modulator at slightly higher than usual plate voltage and by proper output transformer ratio (total primary to total secondary turns ratio of 1.15-1). The driver stage requirement of 50 volts peak grid swing is easily delivered by the two-stage speech amplifier with crystal microphone input. The total voltage amplification for the two stages is approximately 1400, adequate for close talking.

The complete assembly is built up on a chassis measuring 7 by 11 by 2 inches. The first-stage 57 is at the rear left corner; midway on the left-hand edge is the second 57 (triode connected) with the 45 driver at the left front. The Class-B input transformer is behind the meter panel, with the 46 modulator tube

FIG. 1203 — THE ECONOMY MODULATOR UNIT CONTAINS A CRYSTAL-MICROPHONE SPEECH AMPLIFIER, DRIVER AND CLASS-B MODULATOR, AS WELL AS A POWER SUPPLY FOR THE LOW-POWER STAGES

While the 46's in the Class-B stage normally would be considered to have an audio output in the vicinity of 20 watts, for speech work they can readily be made to modulate a Class-C input of 80 watts, as explained in the text.

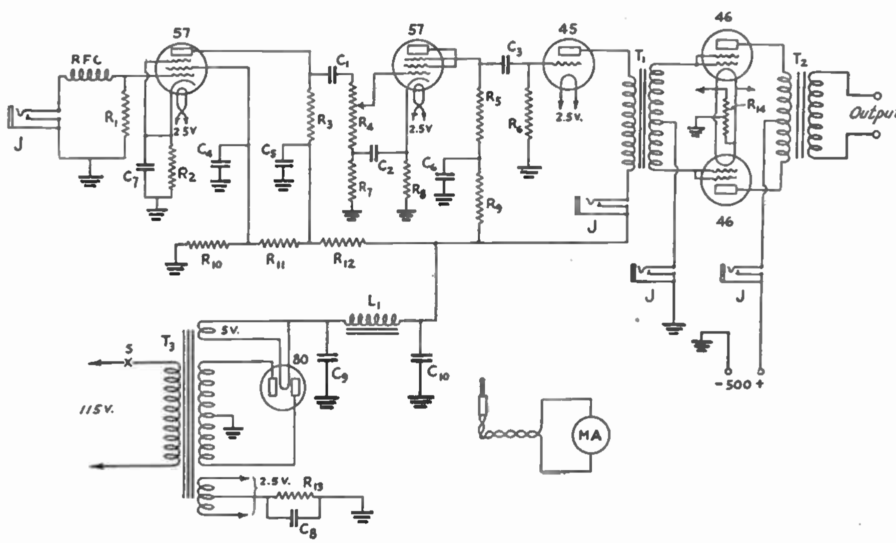


FIG. 1204 — CIRCUIT DIAGRAM OF THE SPEECH AMPLIFIER AND ECONOMY CLASS-B MODULATOR

The power supply furnishes plate and filament power for the first three tubes only; the Class-B stage must be supplied from a separate source. If a power transformer having an additional 2.5-volt winding is used, filaments of the 46's may be heated from the second winding.

R_1 — 5 megohms, ½ watt.
R_2 — 3500 ohms, ½ watt.
R_3 — 250,000 ohms, ½ watt.
R_4 — 500,000-ohm volume control.
R_5 — 50,000 ohms, 1 watt.
R_6 — 0.5 megohm, ½ watt.
R_7 — 0.1 megohm, ½ watt.
R_8 — 2250 ohms, 1 watt.
R_9 — 10,000 ohms, 1 watt.
R_{10} — 50,000 ohms, ½ watt.
R_{11} — 250,000 ohms, ½ watt.
R_{12} — 50,000 ohms, ½ watt.
R_{13} — 1500 ohms, 2 watt.
R_{14} — 20-ohm center-tap resistor.
C_1 — 0.1 μfd., 400-volt.
C_2 — 0.1 μfd.
C_3 — 0.1 μfd., 400-volt.
C_4, C_5, C_6 — 2-μfd. electrolytic, 400-volt.
C_7, C_8 — 10-μfd. electrolytic, 25-volt.
C_9, C_{10} — 8-μfd., electrolytic, 400-volt.
T_1, T_2 — Class-B input and output transformers; (National Type BI and BO respectively). The input transformer should have a turns ratio, total primary to one-half secondary, of 2:1. Output transformer turns ratio should be between 1.05:1 and 1.3:1, total primary to total secondary.
T_3 — Midget power transformer, 275 volts each side center-tap with 5-volt and 2.5-volt windings. (Thordarson type T-5002.)
L — 22-henry, 35-ma. filter choke (Thordarson type T-1892).
J — Single closed-circuit jacks.
MA — 0-200 d.c. milliammeter.
RFC — Short-wave choke (National type 100).

directly behind. The Class-B output transformer is in the rear right corner, the power transformer for the speech-amplifier and driver stages being at the front, beside the 80 rectifier. With the transformers placed as shown, hum pick-up at the input is imperceptible, although different orientation of the power transformer with respect to the output transformer brings the hum up considerably. In a compact assembly of this type, the location of the respective transformers for minimum hum can be checked readily by listening with a pair of 'phones connected to one of the audio transformer windings while moving the transformers about slightly with the amplifier in operation. The small filter, in conjunction with the resistance-capacitance filtering of R_{12} and C_5, is satisfactory. It is especially important in the first stage that the screen voltage be maintained at the proper value. The voltage divider R_{10}-R_{11} serves this purpose. Particular care should be taken to see that the screen voltage is not too high, since this will reduce gain, cause distortion and may even give rise to supersonic oscillation.

With speech modulation of the Class-C amplifier input specified, the plate current should swing no higher than approximately 80 ma. on speech peaks.

FIG. 1205 — THE SPEECH-AMPLIFIER AND 100-WATT CLASS-B MODULATOR

Although this compact unit contains a three-stage speech amplifier, Class-B 800 modulator with all transformers, and a power pack for the speech stages, careful design and construction has made the assembly humless and free from feedback (W4UP).

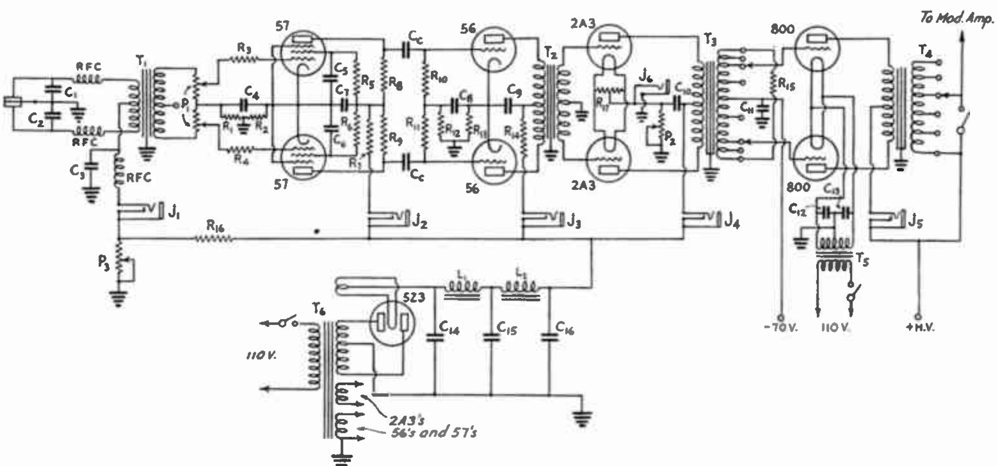


FIG. 1206 — CIRCUIT OF THE 100-WATT AUDIO SECTION

C_1, C_2 — .001 μfd.
C_3 — 25-μfd., 25-volt electrolytic.
C_4, C_5, C_6 — .1 μfd.
C_7 — 8-μfd. electrolytic.
C_8 — .1 μfd.
C_9, C_{10} — 8-μfd. electrolytic.
C_{11}, C_{12}, C_{13} — .1 μfd.
C_{14}, C_{15}, C_{16} — 8-μfd. electrolytics, 500-volt
C — .01-μfd. mica condensers.
R_1 — 100,000 ohms, 1-watt.
R_2 — 1500 ohms, 2-watt.
R_3, R_4 — 50,000 ohms, 1-watt.
R_5, R_6 — 200,000 ohms, 1-watt.
R_7 — 10,000 ohms, 2-watt.
R_8, R_9 — 200,000 ohms, 1-watt.
R_{10}, R_{11} — 500,000 ohms, 1 watt.
R_{12} — 100,000 ohms, 1-watt.
R_{13} — 1500 ohms, 2-watt.
R_{14} — 3000 ohms, 5-watt.
R_{15} — 40,000 ohms, 2-watt.
R_{16} — 50,000 ohms, 2-watt.
P_1 — 250,000-ohm (each section) dual potentiometer.
P_2 — 500-ohm, 10-watt potentiometer.
P_3 — 1000-ohm, 2-watt potentiometer.
J_1 to J_5, inc. — Single circuit-closing jacks.
J_6 — Open-circuit jack.
T_1 — Microphone transformer (W.E.).
T_2 — Audio transformer, 1:3 ratio.
T_3 — Class-B input transformer.
T_4 — Class-B output transformer.
T_5 — 7.5-volt filament transformer.
T_6 — Power transformer, 250 watts, 600 volts c.t.
RFC — 8-mh. r.f. chokes.

Class-B grid current should be between 10 and 20 ma. under corresponding conditions. The Class-C plate current should remain constant, of course. Because of the different voltages on the Class-B and Class-C stages, separate power packs of good regulation are advisable.

A 100-Watt All Push-Pull Audio Section

● The speech-amplifier and modulator unit shown in Fig. 1205 and diagrammed in Fig. 1206 has an audio output capability of 100 watts with double-button carbon microphone input. It employs a number of features to minimize distortion, including push-pull speech amplification. It is designed for use with a Class-C amplifier using 1000-volt tubes, such as a pair of 800's or RK-18's in parallel or push-pull, or a single 100-watt type. By careful adjustment, with speech modulation it also can be used to modulate still higher Class-C input than the usual 200 watts, having been used successfully by its designer (W4UP) to modulate a pair of 261-A tubes in push-pull operating at a plate input of 300 watts (230 ma. at 1300 volts).

As in the smaller unit just described, although a compact assembly is used hum and feed-back are eliminated by careful placement of the components and shielding. Tube shields are used on the input stage and copper braid shields the grid-leads, while resistors such as R_1 and R_2, R_3 and R_4, R_{12} and R_{13}, R_8 and R_9, etc., are paired in individual shield cans with braid covering the entering wires. All these precautions may not be necessary, but they contribute to the over-all stability and distortionless operation that can be attained.

Adjusting taps are shown on the Class-B input and output transformers, although standard types with single pairs of connecting terminals can be used as well. The chassis of the unit is built up on strips of ¾- by 2-inch plywood stock, the top being covered by a piece of 16-gauge aluminum. Battery bias is used for the Class-B modulator stage. The plate power supply should have good regulation (swinging-choke input filter) and be capable of delivering 200 to 250 ma. at 1250 volts to obtain the specified performance. For normal operation, the plate current should kick to a maximum of approximately 100 ma. at 100-percent modulation.

A 250-Watt High-Gain Class-B Unit

● A popular type of modulator in higher-power amateur stations uses a Class-B stage employing 203-A's or 838's. This modulator is suitable for a Class-C stage using either 1000- or 2000-volt tubes of the 100-watt type (203-A, 838, 852, 803 or RK-28). A typical circuit for this size modulator, with a high-quality "Triadyne" 6B5 driver and high-gain pre-amplifier, is shown in Fig. 1208. Fig. 1207 is a rear view of the driver-modulator assembly which also contains the power supply for the pre-amplifier unit.

The speech-amplifier circuit follows the design principles previously outlined and is intended for use with a crystal microphone, gain being controlled at the input to the second stage. The driver is of particular interest, employing 6B5 tubes on which data are given in the tube tables of Chapter Five. This driver also could be used as the modulator for a low-power Class-C stage operating with 40 or 50 watts input, the 6B5 combination having a rated output capability of 20 watts. The pre-amplifier is built as a separately-shielded unit. Power supply connection between the two units is made through the corresponding terminals of the two sockets indicated, using four-prong plugs with a 4-wire cable.

The Class-B output transformer shown would be used with 1000-volt type tubes in the Class-C amplifier. For 2000-volt tubes a transformer of the type having two secondary windings which may be connected in series for this voltage or in parallel for 1000-volt Class-C tubes would be used. If 838 zero-bias tubes are used in the modulator, the plus and minus "C" terminals would be connected together directly. The plate supply for the modulator should be capable of furnishing 350 or more ma. at 1000 or 1250 volts, and of course should have good regulation (10 percent or less).

Plate Modulation of Pentode Class-C Amplifiers

● Pentode-type screen-grid tubes such as the 802, RK-23–25, RK-20, RK-28 and 803 also

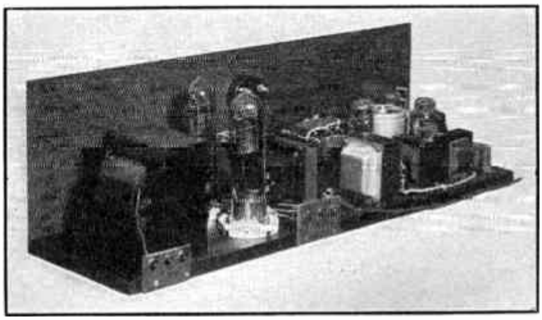


FIG. 1207 — REAR VIEW OF THE 250-WATT DRIVER-MODULATOR UNIT

The Triad 6B5 driver tubes are at the extreme right, the rectifier of the 400-volt driver and pre-amplifier supply towards the center, and the 203-A Class-B stage at the left. Although the equipment appears crowded, hum and feed-back troubles are prevented by careful arrangement (W1BMT-W1BES).

can be used as Class-C modulated amplifiers provided the modulation is applied to both the plate and screen grid. Such use of these tubes is increasing, since they offer the advantages of requiring no neutralization and but small r.f. driving power as compared to triodes of similar capability. Modulation of the screen grid entails consumption of audio power additional to that supplied to the plate circuit by the modulator.

Two methods of feeding the screen grid with the necessary d.c. and modulation voltage are shown in Figs. 1209-A and 1209-B. The dropping-resistor system of 1209-A entails dissipation of audio power as well as d.c. in the dropping resistor *R*. This arrangement is fairly economical with the smaller pentodes (RK-23–25 and 802), but the power loss reaches considerable proportions with the larger types. Two of the smaller pentodes operating at 600 volts can be handled nicely by the "economy" Class-B modulator previously described, the total Class-C current being 84 ma., including both plate and screen input. A carrier output of approximately 40 watts would be obtained.

With the larger pentodes, such as the RK-20, RK-28 and 803, power loss in the screen dropping resistor makes this circuit uneconomical. For these tubes the arrangement of Fig. 1209-B is preferable. This requires a special Class-B output transformer having an additional secondary winding for coupling to the screen

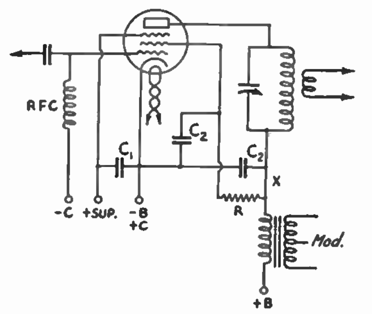


FIG. 1209-A — PENTODE PLATE-MODULATION CIRCUIT WITH SCREEN-DROP RESISTOR

Screen and plate by-passes should be about .001 μfd. The value of the screen dropping resistor, R, is 25,000 ohms for RK-23–25 and 802 tubes.

circuit. This auxiliary winding has approximately 20 percent as many turns as the plate secondary. Transformers of this type are available as standard units. These secondaries

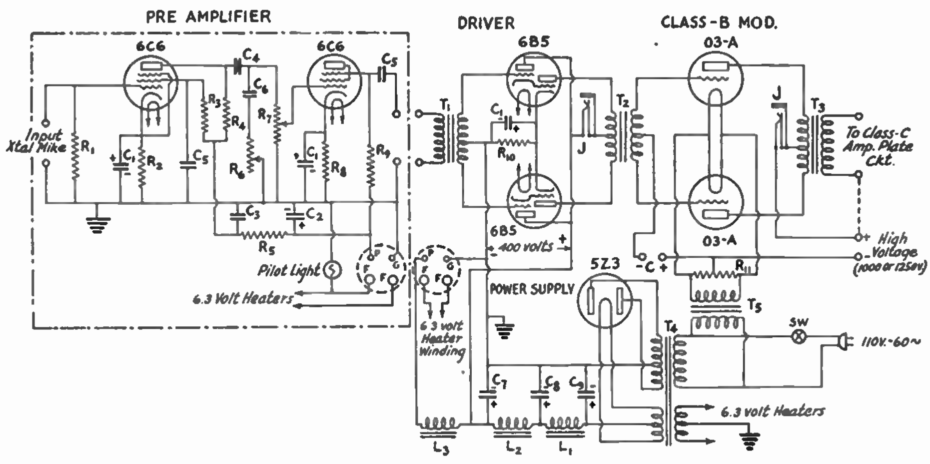


FIG. 1208 — COMPLETE CIRCUIT OF THE 250-WATT DRIVER-MODULATOR AND PRE-AMPLIFIER UNITS

R_1 — 4 megohms.
R_2 — 1000 ohms.
R_3 — 2 megohms.
R_4 — 500,000 ohms.
R_5 — 50,000 ohms.
R_6 — 500,000-ohm tone control.
R_7 — 500,000-ohm volume control.
R_8 — 1000 ohms.
R_9 — 100,000 ohms.
R_{10} — 140 ohms.
R_{11} — 60-ohm center-tapped.
C_1 — 20-μfd. low-voltage electrolytic.
C_2 — 8-μfd. electrolytic.
C_3 — 0.5 μfd.
C_4 — 0.02 μfd.
C_5 — 0.1 μfd.
C_6 — 0.005 μfd.
C_7, C_8, C_9 — Three-section electrolytic.
L_1, L_2 — 100-ma. filter chokes.
L_3 — 20 ma. filter choke.
T_1 — Any good audio step-up transformer, about 3-1 turns ratio.
T_2 — Coto C I 402 Triadyne output transformer.
T_3 — Coto C I 403 Class-B output transformer.
T_4 — Power transformer.
T_5 — 203-A filament transformer.
J — Plate meter jacks.

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

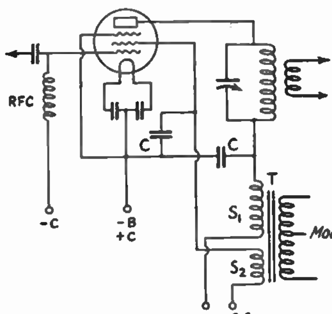


FIG. 1209-B — MODULATION OF PLATE AND SCREEN THROUGH A SPECIAL OUTPUT TRANSFORMER HAVING AN AUXILIARY WINDING

A considerable saving in both d.c. and audio power results from the use of this type of transformer, since the power loss in the screen dropping resistor is eliminated.

neglecting the screen consumption, since it is relatively small compared to the plate load.

The 100-watt modulator previously described can be used with a pair of RK-20's in push-pull or parallel in the Class-C amplifier, plate voltage and current being the same as specified for triodes. A 250-watt modulator such as the one shown in Fig. 1208 will handle a pair of 803's or RK-28's in the Class-C stage, also under the same operating conditions outlined for triodes. Screen voltage can be taken from a separate 400- or 500-volt supply in the transmitter.

Controlled-Carrier Plate Modulation

● The most practical method for controlled-carrier transmission adapted to Class-B modulation is illustrated by the diagrams of Figs. 1210 and 1211. Tracing the control action in Fig. 1210, 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 Class-C amplifier plate circuit resistance remaining practically constant. Condenser C_9 filters off the audio-frequency ripple in this circuit, while the normal audio-frequency output of the modulator is super-imposed on the d.c. flowing in the series circuit in normal fashion. The circuit of Fig. 1211 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. 1210 and R_2 of Fig. 1211 may be used for the same purpose; that is, to pre-load the output circuit of the modulator to reduce the audio peak level.

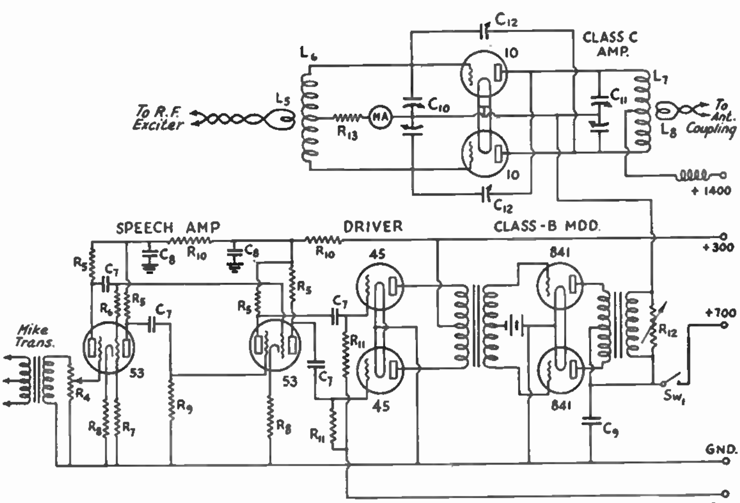


FIG. 1210 — CLASS-B CONTROLLED-CARRIER CIRCUIT FOR 500-VOLT TYPE TUBES (W2CTK)

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} — 8000-ohm 15-watt.

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

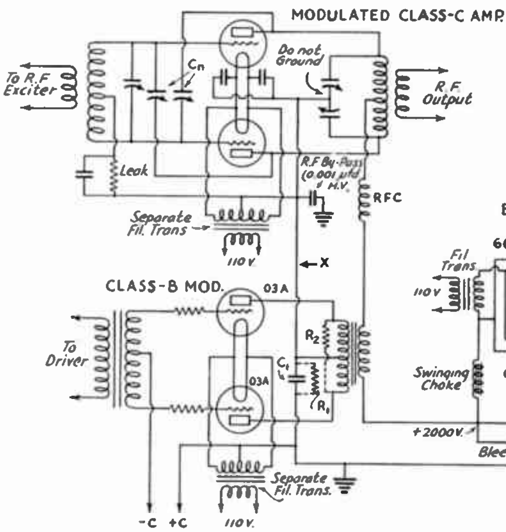


FIG. 1211 — CONTROLLED-CARRIER CIRCUIT FOR 1000-VOLT TUBES (W2HLM)

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 1210, 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. 1211, 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 this type. The adjustment is not especially critical, once the circuits have been tuned in normal procedure. Condensers C_9 of Fig. 1210 and C_1 of Fig. 1211 should have a capacitance of approximately 2 or 3 µfd. No direct ground connection should be made to the Class-C filament circuit.

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 Nine. Neutralization should be exact, because even slight regeneration can cause nonlinear modulation. Tank circuits for Class-C modulated amplifiers should be "medium low-C", having L/C ratios corresponding approximately to the optimum values recommended for c.w. transmitters. Extremely low-C will aggravate harmonic radiation, which may fall outside the amateur bands and attract unfavorable attention of the government monitoring stations.

Class-C modulated amplifiers require somewhat higher excitation than for the same unmodulated output in c.w. telegraph transmission. As in c.w. transmitters, no single figure of grid current can be specified as indicating proper excitation for a given tube. Excitation must be sufficient to maintain the output linear for plate-voltage variation up to twice the mean value. Operating checks, using either cathode-ray oscilloscope or carrier-shift in-

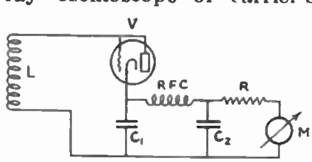


FIG. 1212 — CIRCUIT OF THE SIMPLE DIODE-TYPE CARRIER-SHIFT INDICATOR (W. C. Lent)

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-mfd. 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.

dications, are the most certain. Oscilloscope patterns, obtained with a unit of the type described in Chapter Seventeen, are shown in Fig. 1212. These trapezoidal patterns result with the oscilloscope connected to the transmitter as shown in Fig. 1220. 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. 1213 D, E, and F, which show improper adjustment, and Fig. 1213-G 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.

The carrier-shift indicator is simply a linear rectifier, such as that diagrammed in Fig. 1212, showing flattening of the positive peaks like that illustrated in Fig. 1213-D by a drop in meter reading, or overmodulation as shown in *F* by an upward shift in meter reading.

Grid-Bias Modulated Amplifiers

● The final amplifier circuit of the "general-purpose" transmitter described in Chapter Nine is shown modified for grid-bias modulation in Fig. 1214, while Fig. 1215 gives the circuit for grid-bias modulation of a 100-watt stage using a single 211 tube. The latter is successfully used in a popular manufactured transmitter (Collins 30FX). A simple speech amplifier and modulator unit for use with the amplifier of Fig. 1214 is diagrammed in Fig. 1216. In both arrangements the secondary of the modulation transformer is in series with the grid-bias supply to the modulated amplifier. Grid-bias for the amplifier of Fig. 1214 may be from batteries, a separate bias power pack or can be taken from the power supply for the r.f. exciter stages as shown in Fig. 1215. In this arrangement a separate filament winding is used for the 211 amplifier tube and its center-tap is *not* connected directly to ground. Adjustable bias is taken off a voltage divider across the 400-volt supply so that the modulated-amplifier filament can be biased positive with respect to ground, which is the same thing as biasing the control-grid negative with respect to the filament.

In adjusting a grid-bias modulated amplifier, the grid-bias voltage is initially set slightly more negative than a cut-off value for the particular tube and plate voltage (see tube data in Chapter Five). Next, input tuning and coupling to the r.f. exciter, and antenna coupling and tuning, are adjusted for maximum possible antenna current. Then, leaving all other adjustments alone, the negative grid bias is increased until the plate current drops

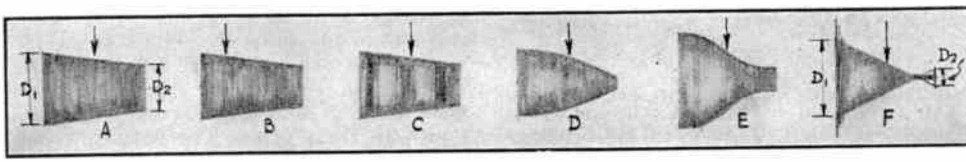


FIG. 1213 — SKETCHES OF TYPICAL TRAPEZOIDAL FIGURES REPRESENTING VARIOUS OPERATING CONDITIONS

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 overmodulation, 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.

FIG. 1213-G — ACTUAL PHOTOGRAPH OF TRAPEZOIDAL FIGURE FOR PROPER 100% MODULATION

off to the proper operating value. This value is given for a number of tubes in the tables of Chapter Five. Generally, it should be the current corresponding to rated plate dissipa-

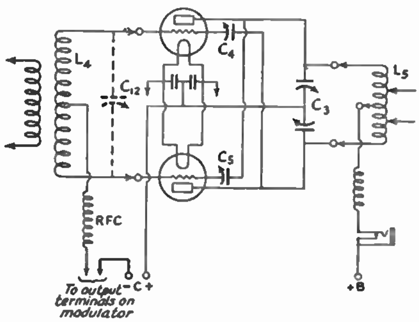


FIG. 1214 — GRID CIRCUIT CHANGES IN THE FINAL AMPLIFIER OF THE GENERAL-PURPOSE TRANSMITTER TO FIT IT FOR GRID-BIAS MODULATION

Legends on components are the same as those given in Chapter Nine.

tion of the amplifier at the particular plate voltage used. When 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

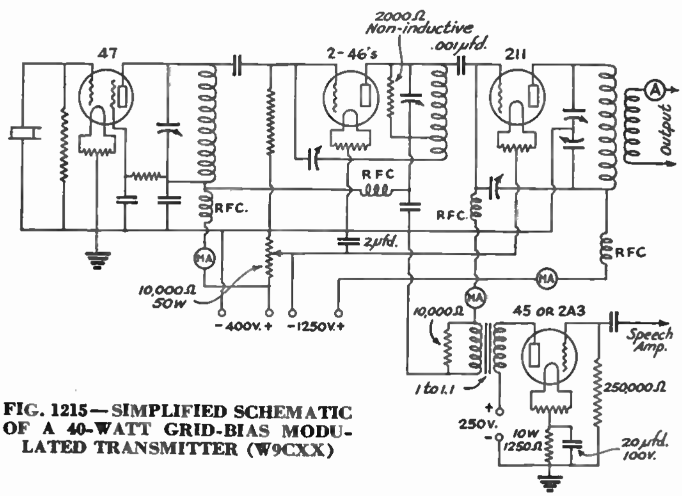


FIG. 1215 — SIMPLIFIED SCHEMATIC OF A 40-WATT GRID-BIAS MODULATED TRANSMITTER (W9CXX)

modulation the antenna current should show rise of not more than 5% 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 Fig. 1217-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. 1217-C. The latter should be corrected by adjustment of coupling to the antenna and variation of the r.f. excitation. *The grid-bias modulator should not be adjusted for maximum efficiency.* In fact, for proper modulation the antenna loading will be somewhat greater than is ordinarily the case, the efficiency being necessarily reduced.

Suppressor-Grid Modulated Amplifiers

● Pentode-type transmitting tubes can be grid-bias modulated as well as triodes, the same adjustment procedure being applicable. However, it is more convenient and usually more desirable to use suppressor-grid modulation with these types. The data of Chapter Five give the recommended ratings for this use of r.f. pentodes, as well as for grid-bias modulation. The suppressor-modulated amplifier behaves much like the grid-bias amplifier just described with respect to excitation and loading. In general, excitation should be somewhat higher and the load coupling somewhat greater than for maximum output conditions in c.w. telegraph operation, with correspondingly reduced efficiency. The oscillograph patterns given for grid-bias modulation in Fig. 1217 are also typical of the suppressor-modulated amplifier for corresponding conditions.

The suppressor-grid modulated amplifier is readily adaptable to controlled-carrier operation employing a circuit arrangement such as that shown in Fig. 1219. The suppressor grid is normally biased excessively negative so that the no-signal carrier output is quite small. A bucking voltage, obtained from a second transformer T_2 of 1:1 ratio and rectified by the bridge arrangement shown with R as the load resistor, reduces the bias in proportion to the audio signal level across the modulator output circuit. The capacitance C across the rectifier load resistor filters out the audio-frequency component in the control circuit and, with R, determines the time constant. In the arrangement used by the designer, R is 4000 ohms and C is 0.1 μfd. Metal-type 6H6 duo-diodes might be used instead of the 25Z5's in the bridge rectifier. The system should first be tested with the suppressor connected directly to the positive side of the rectifier circuit so that audio output from the modulator is not effective. Under this condition, it should be possible to cause the antenna current to swing from a low minimum value to normal full-carrier value by speaking into the microphone, while no voice modulation should be discernible on the carrier. The values of *R* and *C* should be adjusted to give this result, possibly increasing the value of either one. With the circuit normally connected as shown, the action should be fast enough to follow the syllabic variations in speech, but not so fast as to follow the audio-frequency cyclic variations, as previously specified in Chapter Eleven.

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. 1220. The carrier-shift indicator discussed in connection with Class-C amplifiers, and schematically diagrammed in Fig. 1212, is the simplest device for continuous monitoring against overmodulation with constant-carrier transmission, although it will not indicate conditions such as that illustrated by Fig. 1217-B 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 overmodulation by an upward shift in current reading, and flattening of positive peaks (accompanying modulation capability less than 100 percent) by a decrease in current reading. If such carrier shift should be observed at very low modulation levels, with speech input or 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.

With controlled-carrier operation, the carrier-shift indicator is useless because the carrier is continuously varying. The cathode-ray oscilloscope picture also becomes less useful because there is no fixed average reference line. It will show overmodulation on the negative peaks, however. A simple negative-peak indicator which can be used as a suitable substitute is

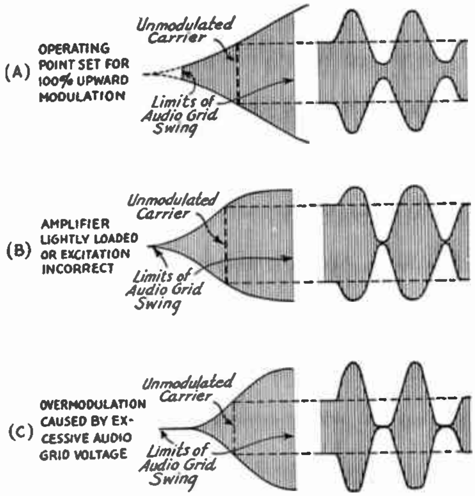


FIG. 1217 — OSCILLOSCOPE PATTERNS REPRESENTING PROPER AND IMPROPER GRID-BIAS OR SUPPRESSOR-GRID MODULATION

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.

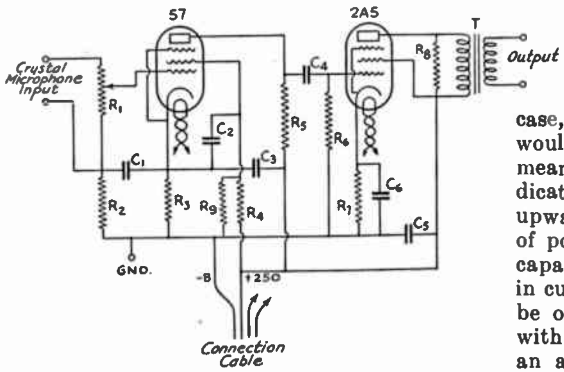


FIG. 1216 — CIRCUIT DIAGRAM OF THE SIMPLE GRID-BIAS OR SUPPRESSOR-GRID MODULATOR SHOWN IN FIG. 1201

C_1 — .1 µfd.
C_2, C_3, C_5 — 2-µfd. electrolytic, 450-volt rating.
C_4 — .1 µfd., 500-volt rating.
C_6 — 10 µfd., 50-volt rating.
R_1 — 500,000-ohm potentiometer.
R_2 — 100,000 ohms, ½ watt.
R_3 — 3500 ohms, ½ watt.
R_4 — 100,000 ohms, ½ watt.
R_5 — 250,000 ohms, ½ watt.
R_6 — 500,000 ohms, ½ watt.
R_7 — 400 ohms, 2 watt.
R_8 — 7500 ohms, 5 watt.
R_9 — 50,000 ohms, ½ watt.
T — Class-B input transformer, ratio approximately 1:1.

A power supply furnishing 2.5 volts at 3 amperes and 180 to 250 volts at 40 milliamperes is required.

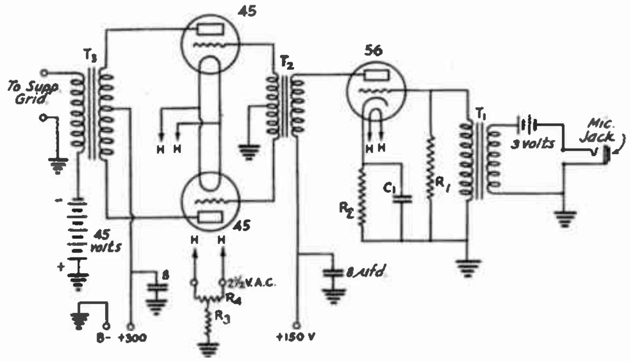


FIG. 1218 — SPEECH AMPLIFIER AND PUSH-PULL MODULATOR CIRCUIT FOR SUPPRESSOR-GRID OR GRID-BIAS MODULATION

T_1 — Single button microphone transformer.
T_2 — Push-pull input transformer.
T_3 — Push-pull output transformer.
R_1 — ¼-megohm metalized grid leak.
R_2 — 2000-ohm 5-watt biasing resistor.
R_3 — 750-ohm 10-watt biasing resistor.
R_4 — Filament center-tap resistor.
C_1 — 0.5-µfd. low-voltage paper by-pass condenser.

diagrammed in Fig. 1221. 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 percent, current will flow through the rectifier circuit, although no current will flow as 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

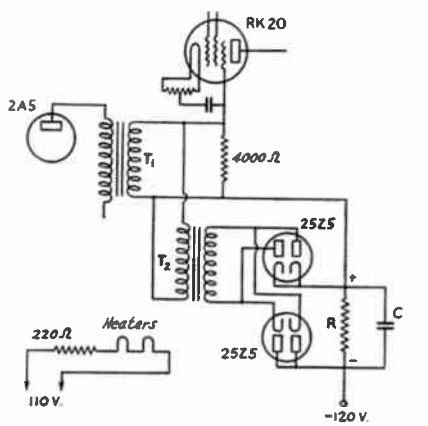


FIG. 1219 — CARRIER CONTROL WITH SUPPRESSOR GRID MODULATION (VE2BC)

Suppressor bias is controlled in accordance with average speech amplitude by means of a bucking circuit, the bucking voltage being obtained by rectifying and filtering part of the audio output of the modulator. Circuit constants are discussed in the text.

(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. Type 45, 80, 10, etc., tubes will be satisfactory for most amateur transmitters using controlled-carrier. The indicator, *M*, may be a low-range milliammeter, or even small glow lamp.

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 a cathode-ray oscilloscope for proper conditions and the corresponding meter readings noted for operating reference. It cannot be emphasized too strongly that improper modulation, with its consequent spurious emissions, must be prevented.

Checking Class-B Linear Amplifiers

As previously mentioned, Class-B linear amplifiers are seldom used in amateur transmitters,

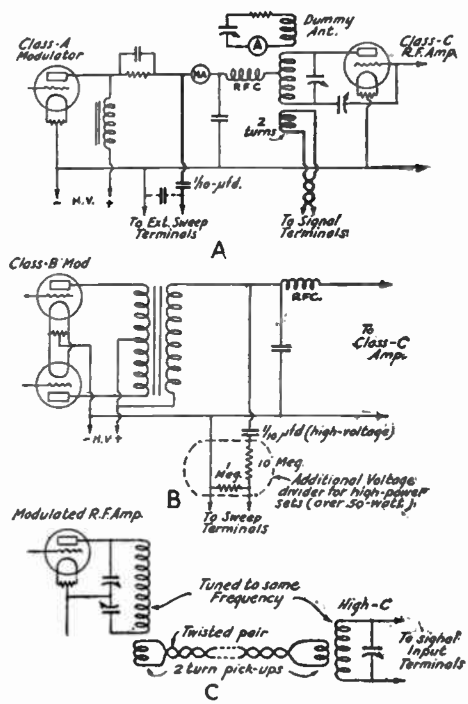


FIG. 1220 — METHODS OF COUPLING THE OSCILLOSCOPE TO 'PHONE TRANSMITTER CIRCUITS (W1HRX-W1BZR)

although they offer some advantages with controlled-carrier transmission. If a linear stage is to be used, it should have a carrier output rating at least several times that of the exciting amplifier. Otherwise, no appreciable gain is to be realized. As compared to the grid-bias or suppressor-grid modulated amplifier, the Class-B linear may have a relatively high-impedance plate load; that is, a lower-C tank circuit. Provision also should be made to give good r.f. excitation voltage regulation, as described in Chapter Eleven. For best linearity, grid bias should be somewhat less than that required for actual plate current cut-off. Zero-bias tubes such as the 838 are well suited, as for Class-B modulators. In operation at rated input, flattening of positive modulation peaks or downward carrier shift indicates too high an output impedance, insufficient negative bias, excessive r.f. excitation, or poor grid-circuit r.f. voltage regulation. Upward carrier shift or flattening of negative modulation cycle peaks usually indicates overmodulation, regeneration, too low an output impedance, excessive negative bias or a combination of these defects.

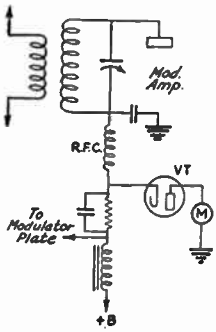


FIG. 1221—SIMPLE NEGATIVE-PEAK OVERMODULATION INDICATOR (W8AGW)

TABLE II—CLASS-B MODULATOR AND DRIVER DATA

Class-B Tubes	*Fil. Volts*	*Plate Volts, E_b*	*Max. Plate Ma., I_b*[1]	*Grid Bias Volts E_c*	*Load Imp., Ohms*[2]	*Tube Output, Watts*[3]	*Input Trans. Turn Ratio (Pri: Sec.)*	*Driver Tubes*	*Driver Plate Volts*
53 or 6A6 (1)	2.5 or 6.3	300	65	0	10,000	10	2.5:1	53 (Class-A)	300
46 (2)	2.5	400	108	0	7000	25	3:1	45 (p.p.)	225
59 (2)	2.5	400	124	0	6000	28	3:1	45 (p.p.)	225
841 (2)	7.5	500	108	−13.5	8000	29	5:1	45 (p.p.)	250
210* (2)	7.5	600	153	−67	8000	57.5	1.6:1	45 (p.p.)	250
801 (2)	7.5	600	130	−75	10,000	45	1.6:1	45 (p.p.)	250
800 (2)	7.5	1000	164	−55	12,500	100	1:1	2A3 (p.p.)	250
RK-18 (2)	7.5	1000	164	−45	12,000	100	2:1	45 (p.p.)	250
RK-31 (2)	7.5	1250	160	0	17,000	140	2:1	45 (p.p.)	250
830-B (2)	10.0	1000	280	−33	10,000	190	1:1.4	2A3 (p.p.)	250
50T (2)	5.25	1500	200	−125	15,000	175	2:1	2A3 (p.p.)	250
203-A* (2)	10.0	1000	366	−40	5800	240	1.6:1	2A3 (p.p.)	250
838 (2)	10.0	1250	320	0	11,200	260	1.6:1	2A3 (p.p.)	250
150T (2)	5.25	2000	400	−165	12,000	500	20-watt driver		

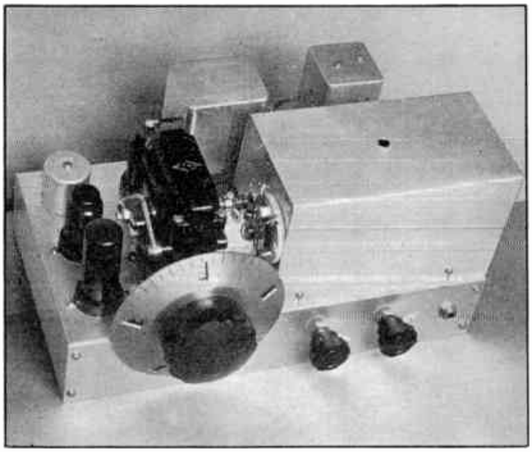
* Graphite anode types. [1] Sinusoidal signal values; speech values are approximately one-half for negatively biased tubes and 80% for zero-bias tubes. [2] Plate-to-plate, both sections or two tubes. [3] Use this power value and plate-to-plate impedance for calculating output transformer ratio by method described in Chapter Eleven.

CHAPTER THIRTEEN

Receivers for the Ultra-High Frequencies

GENERAL ASPECTS OF ULTRA-HIGH FREQUENCY WORKING — SUITABLE RECEIVER TYPES — SUPERREGENERATION — ADVANCED RECEIVERS — BUILDING SUPERREGENERATORS — R.F. AMPLIFIERS — BUILDING "SUPER" RECEIVERS

In amateur work, all frequencies higher than 56 megacycles have become known as the ultra-high frequencies. In this territory, relatively little intensive work was done until a few years ago. Naturally, only a few of its possibilities for amateur communication have so far been revealed. The lower frequencies have been studied and re-studied for so many years that the experienced amateur of today knows fairly well, ahead of time, just what to expect in the way of performance with a given installation at a given time of day, month or year. In this respect, the ultra-high frequencies are different. On them, it is often the unexpected that happens, and because of this, ultra-high frequency workers are frequently provided with thrills over and above those experienced in the normal routine of amateur communication.



AN ULTRA-HIGH FREQUENCY RECEIVER OF ADVANCED DESIGN (SEE FIG. 1321)

The newly-developed system used in this receiver combines the desirable characteristics of the superregenerator, and the superheterodyne. It provides any desired selectivity with extreme sensitivity and noise discrimination.

Equipment Constantly Changing

● Because ultra-high frequency working is still very much in its infancy, it is subject to particularly rapid growth and change. Apparatus considered to be ideal today is quite likely to become antiquated tomorrow. It is therefore absurd to suggest that this chapter should be considered a complete survey of the field or that the equipment illustrated in it is the ultimate. Even as this is being written we can see developments on the horizon which are likely to result in many revisions of our present ideas. Our aim and our only hope is to present the details of well-tried ultra-high frequency equipment, together with the general principles of its operation, knowing that the sincere worker will keep himself abreast of the new developments as they are presented from month to month in *QST*.

What to Expect

● 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, a 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, however, is likely to be extremely "spotty" and remains a field of activity valuable only to the experimenter.

Until recently, 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 later part of 1934, experimental work at A.R.R.L. Headquarters revealed that ultra-high frequency waves were bent very appreciably in the lower atmosphere under certain atmospheric conditions. This work indicated that, on occasions when warm, moist tropical air was overrunning 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.

These circumstances 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. A Headquarters experimental station with such a transmitter set-up, with the antenna approximately 300 feet above sea level has, for example, maintained daily schedules over a distance of about 90 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.

This inability to forecast the range of an ultra-high frequency station is, in the minds of many, the very thing which makes the work of special interest. With equipment being improved every day and a more thorough knowledge of the effect of the atmosphere being gained, 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.

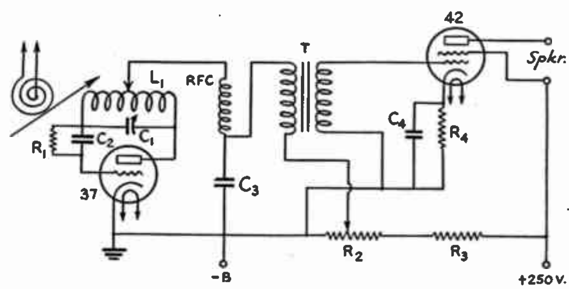


FIG. 1301 — A SIMPLE SELF-QUENCHED SUPERREGENERATIVE RECEIVER

C_1 — 10 or 15 μμfd.
C_2 — 50-μμfd. fixed midget condenser.
C_3 — Between .002 and .006 μfd.; experiment usually necessary to determine best value.
C_4 — 10-μfd. electrolytic low-voltage condenser.
L_1 — 8 self-supporting turns of No. 18 wire, ½-inch inside diameter. Turns spaced diameter of the wire. Best position for tap is usually near center of coil.
RFC — 40 to 50 turns of No. 26 d.c.c. wire on ¼-inch rod, the rod being removed.
R_1 — As high as possible — 20 megohms has been found best in some instances.
R_2 — 50,000-ohm potentiometer.
R_3 — 50,000-ohm 1-watt fixed resistor.
R_4 — 2000-ohm, 1-watt. This value is higher than normal but has been found desirable.
T — Good audio transformer with ratio of 1:3 or less.

All grounds must be brought to a single point on the chassis. The detector tube is mounted horizontally with the plate prong soldered at the junction of the condenser and coil, and just enough space between the grid prong and the other end of the coil to accommodate the midget grid condenser. The receiver should be considered unsatisfactory unless the detector operates with 25 volts or less on its plate. The antenna coil is a 5-turn spiral with adjustable coupling to L_1.

While the early superheterodynes, using autodyne first detectors and very low frequency resistance- or transformer-coupled intermediate amplifiers, proved effective, they fell into disfavor because the performance was not in any way proportional to the complexities. Further, they always made a poor showing in comparison to the superregenerative type in locations where ignition interference was at all severe. More recent superheterodynes using intermediate frequency amplifiers operating between 4 and 10 mc. have shown their value in providing a high order of selectivity. They still suffer, however, from an inability to discriminate against noise.

The most recent receiver development is that resulting from experimental work done at A.R.R.L. Headquarters in combining the superregenerative principles with the superheterodyne. Receivers of this type (to be described later in this chapter) provide any desirable order of selectivity, extreme sensitivity and also possess the excellent a.v.c. action and noise discrimination characteristic of the straight superregenerator.

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. Strangely, the principle has been given very little attention on the part of research engineers, and as a result, the principle of operation is still only partly understood. At the present time, superregeneration is being given very serious consideration in the engineering world and it would appear probable that the principle will play a very big part in receiving equipment of the future.

The general outline of superregenerative action is treated briefly in Chapter Five. The student of the subject anxious to have a more thorough knowledge of theoretical considerations might well study the excellent technical treatment by Ataka in the August 1935 issue of *The Proceedings of the Institute of Radio Engineers.*

From a practical aspect, superregenerative receivers may be divided into two general types. The first, in which the quenching voltage is developed by the detector tube itself — so-called "self-quenched" detectors. Second, the receivers in which a separate oscillator tube is used to generate the quench voltage. The self-quenched receivers have found wide favor in amateur work. Usually, however, they do not equal in performance the separately quenched receivers. The simpler self-quenched types are particularly suited for portable equipment and instances 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 a freedom from howling and generally irregular performance.

Building Self-Quenched Receivers

● The circuit given in Fig. 1301 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 an 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. A feature of considerable importance in this receiver is that the grid leak R_1 runs between the grid and a point connecting to the positive high voltage supply. For reasons which are not yet thoroughly understood, this results in improved selectivity and usually results in a smoother operation than with the leak running to the cathode in the conventional manner.

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 a curiously 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 of placement of by-pass condensers. It is 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 Fig. 1301 is suitable for operation on the 56- and 112-mc. bands. In order to allow operation on 112 mc., however, it is essential to keep the connections between the tuned circuits and the elements of the tubes extremely short. This process is facilitated by mounting the tubes horizontally somewhat in the manner shown in Fig. 1307. In other respects, conventional constructional practice may be used. Should howling be found at the point where the detector goes into superregeneration, it can usually be cured by connecting a resistor of about 250,000 ohms across the secondary of the audio transformer "T".

One very important requirement in this, and all superregenerative receivers, is that the detector grid circuit be loaded very heavily. It is very advisable to provide variable coupling between the antenna coil and the grid coil or to provide means for tuning the antenna circuit. In this way it becomes possible to load the detector so heavily as to prevent it from oscillating. An adjustment of coupling slightly less than this usually provides a very desirable operating point.

A Three-Band Acorn-Tube Receiver

● In Fig. 1302 is illustrated a somewhat similar type of receiver 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. The receiver to be described 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 to that of Fig. 1301 except that the grid leak is shown returned to the cathode. As previously mentioned, a connection of this leak to the other side of the grid condenser often results in improved performance. 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 connection of the condenser in this circuit is indicated in Fig. 1303 and the mechanical arrangement is shown in Fig. 1304. The acorn tube itself is mounted on a socket made with small strips of National Victron. One of the excellent acorn tube sockets now available could, of course, be used instead. It is obvious from the illustration that a special attempt has been

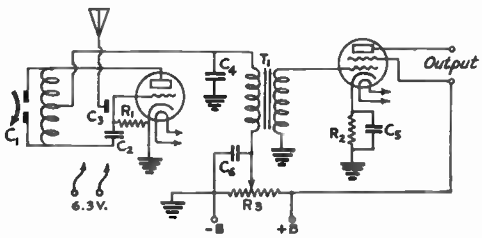


FIG. 1303 — CIRCUIT OF THE SIMPLE THREE-BAND RECEIVER

L_1 — Five turns of No. 14 wire 1/4-inch inside diameter, with turns spaced diameter of wire, for 224 mc. Five similar turns 1/2-inch diameter for 112 mc. Fourteen turns of same diameter for 56 mc.
C_1 — Special split-stator tuning condenser — two rotor and one stator plate — the latter sawed in two.
C_2 — Very small grid condenser (see text).
C_3 — Brass strip 3/16 inch wide mounted close to the exposed surface of C_2 (see Fig. 1304).
C_4 — .002 μfd. fixed condenser.
C_5 — 10 μfd. electrolytic condenser.
C_6 — 1 μfd.
R_1 — 1 to 5 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 audio tube would probably be more appropriate.

Quieter operation may sometimes be obtained by putting a .5 megohm resistor across the transformer secondary.

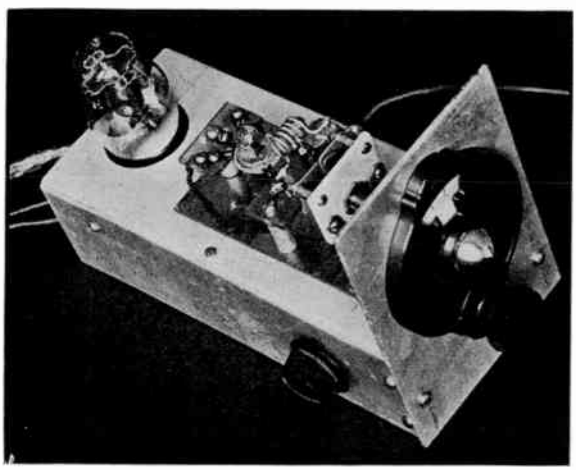
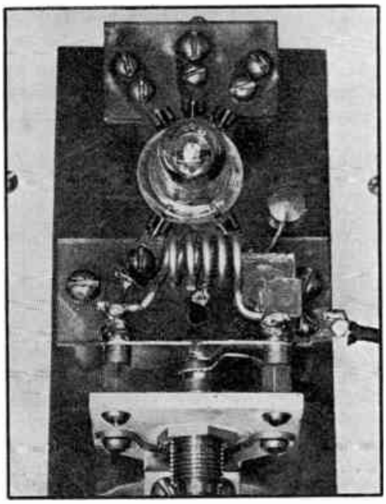


FIG. 1302 — THE THREE-BAND "ACORN" RECEIVER



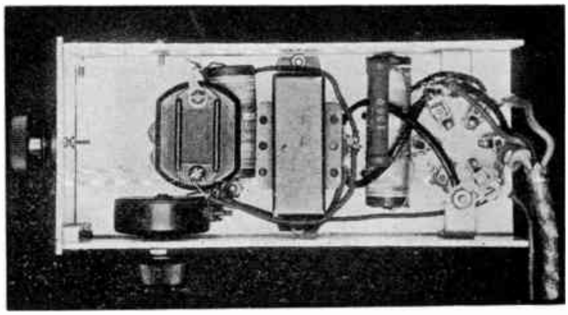


FIG. 1305 — UNDERNEATH THE "ACORN" RECEIVER

All the items not above the chassis channel can be seen in this photograph. The location of the detector voltage control potentiometer is unconventional but convenient.

FIG. 1304 — THE "ACORN" DETECTOR TUBE AND ITS TUNING EQUIPMENT

The grid condenser may be seen immediately to the right of the coil. The brass strip of the antenna coupling condenser can be seen apparently touching the right-hand coil connection.

made to reduce the length of leads in the r.f. circuit. This procedure is very necessary in any tuning unit which is intended for operation on the 112- and 224-mc. bands. The grid condenser C_2 is made with two pieces of light brass or copper about ⅜-inch square cemented with Duco cement to a thin piece of mica. One of the very small midget condensers of 50 μμfd. will serve instead. 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.

Three Detectors — Three Bands

● A novel receiver of particular interest to the experimenter engaged in operation on more than one of the ultra-high frequency bands is that given in Fig. 1306 and illustrated in Figs. 1307 and 1308. The receiver is actually an extension of the circuit given in Fig. 1301 in that the arrangement of the detector tube is very similar. This receiver was built for the particular purpose of observing signals on three different bands at the same time and hence is fitted with three separate potentiometers for the control of detector voltage. Should very rapid change from one band to the other not be essential, a single potentiometer could be used. This would dispense with the second of the two three-way section switches. It will be noted that the antenna is coupled to the detector through small coupling condensers. The padding condensers used for this purpose are operated with the upper leaf pulled at about 45 degrees to the fixed leaf. Adjustment is, of course, essential in each case in order to obtain the right order of

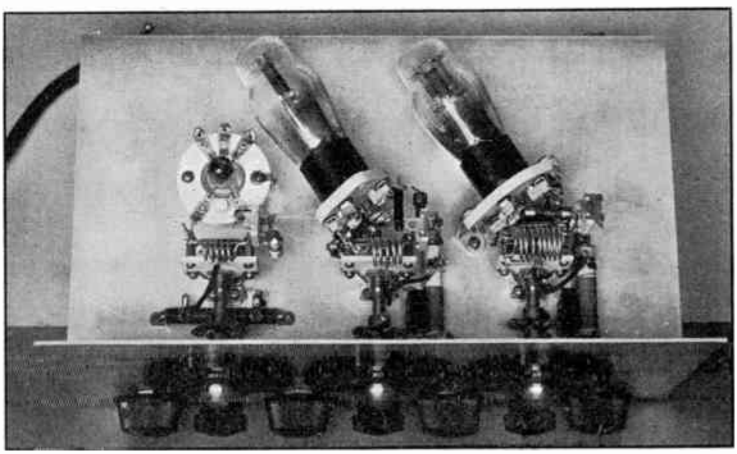


FIG. 1307 — A TOP VIEW OF THE SELF-QUENCHED RECEIVER USING A SEPARATE DETECTOR FOR EACH BAND

The Acorn detector for 224 mc. is at the left, the remaining detectors operating on 112 and 56 mc. The horizontal mounting of the Type 37 tubes and their placement at an angle greatly reduce the length of leads between the tube terminals and the tuned circuit.

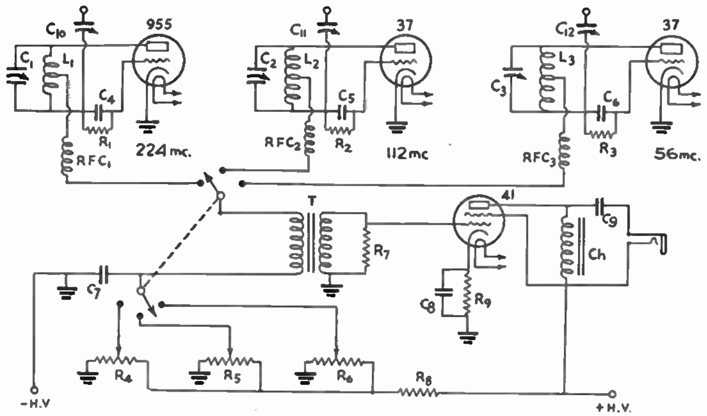


FIG. 1306 — WIRING OF THE THREE-BAND RECEIVER WITH SEPARATE DETECTOR UNITS

L_1 — Five turns of No. 14 wire ¼-inch inside diameter turns spaced about twice the diameter of wire. (For 224 mc.)

L_2 — Five turns of same wire 7/16-inch inside diameter with slightly less spacing. (For 112 mc.)

L_3 — Eight turns of same wire ½-inch inside diameter with spacing about equal to diameter of the wire. (For 56 mc.)

C_1 — Cardwell Type ZV5 TS split stator Trim-Air condenser.

C_2 — Cardwell Type ZR15 condenser with stator plates split.

C_3 — Cardwell Type ZR15 condenser without modifications.

$C_{4, 5, 6}$ — 100 μμfd. fixed midget condensers.

C_7 — .1 μfd. 400-volt paper-type condenser.

C_8 — 10 μfd. low voltage electrolytic condenser.

C_9 — 1 μfd. 400-volt paper type condenser.

$C_{10, 11, 12}$ — National M 30 padding condensers.

$R_{1, 2, 3}$ — 5 megohm, ½-watt fixed resistors.

$R_{4, 5, 6}$ — 100,000-ohm potentiometers.

R_7 — .25 megohm ½-watt resistor (A lower value may be found necessary in some cases of bad "fringe howl").

R_8 — 50,000-ohm ½-watt fixed resistor.

R_9 — 600-ohm 5-watt resistor.

RFC_1 — 30 turns of No. 30 double-silk-covered wire on former ¼-inch diameter.

RFC_2 — 20 turns of similar wire on ⅜-inch diameter former.

RFC_3 — 35 turns of similar wire on ⅜-inch diameter former. Experiment with these values for the r.f. chokes may be necessary if severe "dead-spot" trouble is encountered.

antenna coupling. It will also be noted that an acorn tube is used for the 224-mc. band but that Type 37 tubes serve for 112 and 56 mc. The latter tubes are mounted horizontally in order to allow the shortest possible connections between the tube terminals and the tuned circuits. In a receiver of this type, considerable care must be taken with the adjustment of the taps on the tuning coil and with the size of the r.f. chokes. It is by no means simple to obtain smooth operation on the three widely-separated bands with this type of circuit.

Receivers With Separate Quenched 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. 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 it has been shown that 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 entirely suited for 56-mc. and 112-mc. operation. A slight increase in the quench frequency may be found desirable for 224-mc. operation and work at still higher frequencies. Fig. 1309 is probably the most effective of the various circuits available and, because it has performed so splendidly in practice, we will use

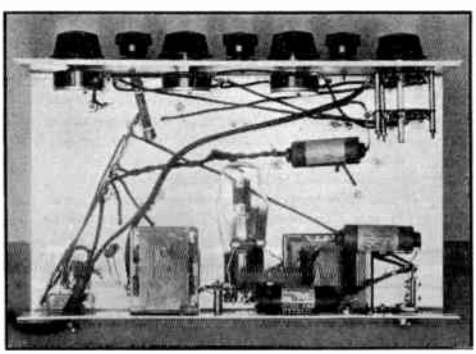


FIG. 1308 — SHOWING THE ARRANGEMENT OF THE AUDIO TRANSFORMER, DETECTOR VOLTAGE-CONTROL POTENTIOMETERS AND WIRING OF THE THREE-BAND RECEIVER

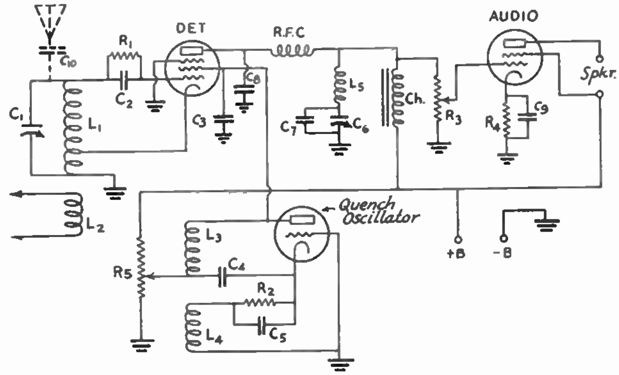


FIG. 1309 — ONE OF THE MOST SATISFACTORY GENERAL TYPES OF SEPARATELY-QUENCHED SUPER-REGENERATIVE CIRCUITS

This arrangement of an r.f. pentode detector with separate quench oscillator is both tolerant in its adjustment and effective in its operation. It is strongly recommended for operation with acorn, metal or normal glass tubes on any frequency for which the detector tube is suited.

The following are average values for the components but are naturally subject to minor variations in individual cases:

L_1 — For 954 detector tube. Nine turns of bare or tinned No. 14 wire ½-inch inside diameter with turns spaced to occupy 1 inch of length for 56–60 mc. Four turns of similar wire with slightly greater turn spacing for 112 mc. Four turns of similar wire ¼-inch inside diameter with similar spacing for 224 mc. These coils are suited for use with a tuning condenser of small mechanical size and about 15 μμfd. capacity. Trouble will be had in reaching 224 mc. unless the r.f. wiring is extremely short.

L_1 — For conventional tubes. Eight turns of No. 14 wire ½" inside diameter with turns spaced to occupy 1 inch for 56 mc. Four similar turns with about twice the turn spacing for 112 mc.

L_2 — Subject to variation to suit the antenna and frequency used. About four ½-inch turns will usually be effective.

L_3, L_4 — Windings of National quench oscillator coil unit. In this circuit, the coil connections should be reversed — putting the coil intended for the grid circuit in the plate circuit.

L_5 — National Type R90 choke. (Inductance 90 millihenrys.)

C_1 — 15 μμfds. a suitable value for 56- or 112-mc. operation. The unit should be small mechanically. A split-stator condenser is useful for the very high frequencies. See Figs. 1303 and 1304.

C_2 — 100 μμfds. a good average value.

C_3 — .002 μfd. fixed condenser located near the detector screen terminal.

C_4 — .1 μfd. 400-volt paper type condenser.

C_5 — .1 μfd. paper condenser — low-voltage type suitable.

C_6 — 150 μμfd. or larger mica trimmer condenser.

C_7 — 250 to 350 μμfd. fixed midget condenser. These two condensers serve to tune the quench filter to resonance. Their size depends on the inductance of L_5 and the actual quench frequency.

C_8 — 500 μμfd. fixed midget condenser.

C_9 — 10 μfd. electrolytic low-voltage condenser.

C_{10} — (If used instead of L_2) Small two-plote leaf-type trimming condenser.

R_1 — 5-megohm half-watt resistor.

R_2 — 2000 ohms for 37 or similar tube.

R_3 — 500,000-ohm potentiometer.

R_4 — 600 ohms for 41 tube. Consult tube tables.

R_5 — 100,000-ohm potentiometer. A 25,000-ohm resistor is often useful when connected between the top of this potentiometer and the positive high-voltage lead. This resistor makes it impossible to put excessive voltage on the detector screen and limits the load on R_5.

R.F.C. — Subject to variation in individual sets. A National Type R90 is usually effective.

Ch. — Any good coupling choke designed for the plate circuit of a screen-grid detector.

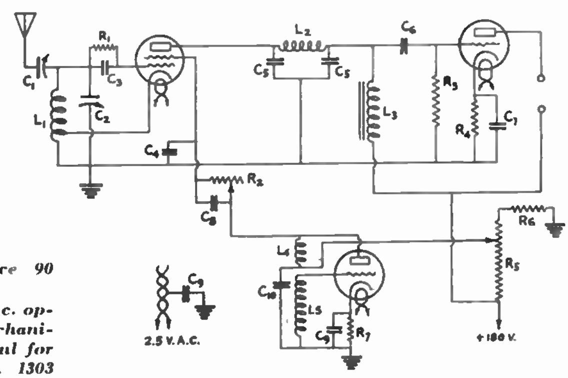


FIG. 1310 — AN ALTERNATIVE CIRCUIT FOR THE THREE-TUBE 56-MC. RECEIVER

C_1 — Very small compression type mica trimmer condenser.

C_2 — 15-μμfd. variable condenser.

C_3 — 100 μμfd. condenser.

C_4 — .001- to .002-μfd. condenser.

C_5 — .001-μfd. condenser.

C_7 — 5-μfd. or more.

C_8 — .5-μfd. or more.

C_9 — .01-μfd. or more.

C_{10} — .5-μfd. or more.

R_1 — ½-watt, 5 megohm.

R_2 — 50,000-ohm rheostat.

R_4 — 2,000 ohm, 1 watt.

R_5 — 12,000-ohm voltage divider.

R_6 — 50,000-ohm 2-watt resistor.

R_7 — 2,000-ohm, 1 watt.

L_1 — Detector coil. Two turns, 1-inch diameter. Tap one-quarter turn from grounded end.

L_2 — 90 millihenry r.f. choke.

L_3, C_6, R_3 — Parts of National S101 coupling unit.

L_4, L_5 — National quench oscillator coils.

The 57, 36 or 77 would suit for the detector, 56's or 37's being used for the other tubes. A 2A5 or 41 audio tube and would be useful for speaker operation.

it as representative of good practice. In this circuit the quench voltage is introduced into the screen circuit of the screen-grid detector. It will be noted that the grid of the quench oscillator is grounded and that since the plate of the oscillator is connected directly to the screen of the detector, the condenser C_3 serves as a tuning condenser across both quench oscillator coils. A further feature of the circuit is that by adjustment of the potentiometer R_5 the voltage on the quench oscillator and the screen of the detector are varied simultaneously. This, at first glance, would appear to make adjustment of conditions in the detector circuit difficult. In practice, however, this is not so. The connection of the quench oscillator to the screen of the detector (which serves as the anode of the signal-frequency portion of the circuit) readily provides the high quench voltage necessary. Adjustment of the cathode tap on L_1 and variation of the antenna coupling then readily allows a setting in the detector circuit which results in superregenerative action with a normally high screen voltage. The procedure is to adjust the cathode tap on L_1 until smooth superregenerative action is had across the band with no antenna connection. Then the antenna is coupled and the setting of R_5 increased until the receiver can be held just on the edge of superregeneration with R_5 at about ⅔ of its full setting. A further feature of this circuit is the filter circuit provided by L_5, C_7 and C_6. These components tune to the quench frequency and filter out the quench voltage before it has an opportunity to reach the grid circuit of the audio tube. While the receiver may be operated without this filter, there is always the possibility that the audio tube will be loaded considerably with quench voltage. This, of course, impairs the operation of the audio tube and prevents it from performing in normal fashion.

The layout of receivers of this type may well follow the practice already discussed for self-quenched detectors as far as the detector and audio tubes are concerned. The location of the quench oscillator and the wiring of its circuit is not of particular importance in view of the low frequency being handled. This general type of circuit is suitable for operation on any of the three bands — an acorn tube being desirable for 112- or 224-mc. operation.

Fig. 1310 shows an alternative method of connecting the quench oscillator to the detector as well as several other minor circuit modifications. In this case a separate voltage control is inserted in the screen lead of the

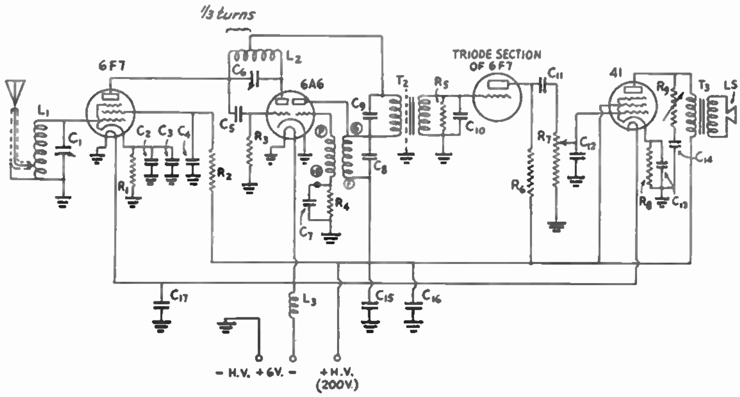


FIG. 1311 — CIRCUIT OF THE POLICE-TYPE SUPERREGENERATIVE RECEIVER

L_1 — R.f. coil. For 30-mc. range, 12 turns No. 12 enameled on ½-inch diameter Mycalex dowel, turns spaced diameter of wire. Tap adjusted to suit antenna used. Total turns reduced approximately ½ for 56-mc. band.
L_2 — Detector coil. For 30-mc. range, 9 turns No. 12 enameled on ¾-inch diameter Mycalex dowel, turns spaced diameter of wire. Approximately ½ as many turns for 56 mc.
L_3 — Filament choke. 22 turns No. 16 enameled closewound on ⅝-inch diameter bakelite dowel.
C_1 and C_6 — 50-μμfd. or smaller midget tuning capacitors (Hammarlund APC).
C_2 — 0.006-μfd. cathode r.f. by-pass.
C_3 — 1-μfd. cathode a.f. by-pass.
C_4 — 0.006-μfd. screen-grid by-pass.
C_5 — 50-μμfd. mica grid capacitor for detector.
C_7 — 0.006-μfd. quench oscillator grid capacitor.
C_8 — 0.002-μfd. fixed, quench oscillator plate tuning capacitor.
C_9 — 0.006-μfd. audio primary by-pass.
C_{10} — 500-μμfd. audio secondary by-pass.
C_{11} — 0.02-μfd. audio grid coupling capacitor.
C_{12} — 0.001-μfd. audio grid by-pass.
C_{13} — 8-μfd. audio cathode by-pass.
C_{14} — 0.05-μfd. tone-control capacitor.
C_{15} — 4-μfd. plate supply audio by-pass.
C_{16} — 0.006-μfd. plate supply r.f. by-pass.
C_{17} — 0.006-μfd. filament supply r.f. by-pass.
T_1 — Quench frequency oscillation transformer (National Type ORS connected as shown by circled letters).
T_2 — Interstage audio transformer with static shield between windings. Connect by trial for best audio quality.
T_3 — Pentode output transformer. (Included in speaker.)
R_1 — 500-ohm ½-watt cathode bias resistor.
R_2 — 100,000-ohm ½-watt screen-grid resistor.
R_3 — 2-megohm ½-watt detector grid leak.
R_4 — 10,000-ohm ½-watt quench oscillator grid leak.
R_5 — 100,000-ohm ½-watt audio transformer load resistor.
R_6 — 50,000-ohm ½-watt audio plate load resistor.
R_7 — 100,000-ohm variable volume control.
R_8 — 500-ohm ½-watt audio cathode bias resistor.
R_9 — 25,000-ohm variable tone control.

detector, thus permitting variation of the screen voltage without affecting voltage on the quench oscillator. This arrangement has also proved thoroughly effective in practice.

Superregenerative Receivers With R.F. Amplifiers

● One important disadvantage of the simple superregenerative receivers just described is that they are capable of severe radiation. Also, as we have already stated, they are extremely unselective. Prevention of the radiation and some improvement in selectivity is made possible by adding an r.f. amplifier stage ahead of the superregenerative detector. Fig. 1311 is an excellent example of circuit design in a receiver of this type. It is the circuit used in the General Electric ultra-high-frequency police receiver. It will be seen that the r.f. amplifier is the pentode section of a 6F7 tube — the triode section of this tube being used as the first of the two audio amplifiers. A further novel feature is that one section of a 6A6 is used as the detector — the other section serving as the quench oscillator. In this particular arrangement of the detector the same voltage is applied to the quench oscillator and the detector itself. For amateur work, it is probable that a potentiometer in the high voltage supply to the quench and detector tubes would be of some value in providing optimum adjustment over the wide range of frequencies to be covered. The dotted line running through the audio transformer T_2 represents an electrostatic shield between the transformer windings. Some difficulty may be had in securing a transformer fitted with such a shield — the purpose of which is to reduce the amount of quench voltage passed along to the audio system. An alternative would be the use of a quench voltage filter such as that shown in Fig. 1309.

FIG. 1312 — A MOBILE RECEIVER EMPLOYING THE CIRCUIT GIVEN IN FIG. 1311
The tube shields have been removed.

Fig. 1313 is presented as a typical example of the use of the 954 acorn pentode tube as an r.f. amplifier. In this particular example it is used in conjunction with a 995 acorn self-quenched detector. Obviously, however, the same general arrangement could be used with a separately quenched detector of either triode or pentode types. The receiver is built in two sections — the upper box, containing the r.f. amplifier and detector, and the lower inverted "U" chassis containing the audio stage and miscellaneous wiring. The 954 is mounted in the detector compartment with the grid end of the tube projecting through the partition. A short piece of tubing squeezed into the hole in the partition improves the shielding at this point. The tuning condensers are mounted in each compartment and interconnected with flexible coupling. The coils are mounted directly on the condensers. All r.f. bypass condensers are returned to a single point on the partition alongside the 954 amplifier tube.

The most important adjustments are in the location of the grid and plate taps for the 954 and in lining up the two coils so that satisfactory tracking is obtained. The adjustable antenna condenser is an aid in this tracking adjustment. Even though an r.f. amplifier of this type is capable of giving a very appreciable gain at frequencies even as high as 224 mc., this gain is not usually accompanied by any increase in the strength of stronger signals. The gain is made evident, though, by the way in which weak carriers push down the characteristic noise produced by the detector.

It is not very well understood by many ultra-high frequency workers that this superregenerative noise, when the detector is operating correctly, is of a very low level and that the receiver can be operated in a superregenerative condition even when the noise is substantially inaudible. There is no excuse for the terrific hissing which is so often tolerated.

Planning Other Combinations

● This review of several types of superregenerative receivers obviously covers but a small fragment of the field. The ultra-high frequency worker, as he gains experience, will find it readily possible to combine many of the minor circuit details in order to provide a receiver which suits his particular fancy. We would reiterate a firm recommendation that, in receivers where space is not a very important consideration, a separate quench tube be used. In the adjustment of any of the receivers it should not be thought that a loud hissing noise in the output is proof of satisfactory operation. This, indeed, is very far from the truth. High sensitivity and good signal-noise ratio can be obtained only by loading the input of the

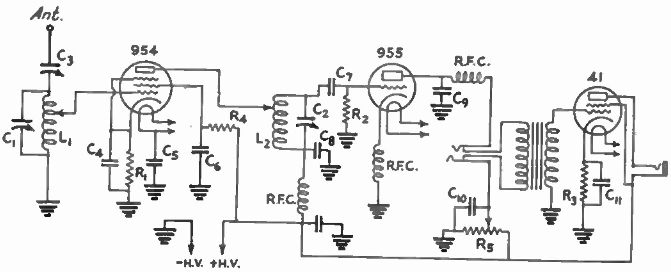


FIG. 1313 — THE CIRCUIT OF THE RECEIVER WITH 954 R. F. AMPLIFIER

C_1, C_2 — 15-μμfd. Cardwell Trim-Air condensers. These cover an unnecessarily wide frequency band. Some workers will prefer to remove one or even two of the three rotor plates.
C_3 — 30-μμfd. leaf type trimmer condenser.
$C_{4, 5, 6}$ — 250-μμfd. fixed midget condensers.
C_7 — 100-μμfd. fixed midget.
C_8 — 250-μμfd. fixed midget.
C_9 — .001-μfd. fixed midget.
C_{10} — .5-μfd. fixed condenser.
C_{11} — 2-μfd. low voltage electrolytic condenser.
C_{12} — .001-μfd. fixed midget (number not marked on diagram).
R_1 — 1500-ohm half-watt resistor.
R_2 — 1-megohm half-watt resistor.
R_3 — 600-ohm 1-watt resistor.
R_4 — 100,000-ohm half-watt resistor.
R_5 — 100,000-ohm potentiometer.
L_1, L_2 — Eight turns of No. 14 bare wire ½-inch inside diameter. The location of the taps can be determined only by experiment. In the original receiver the grid tap is two turns from the end, the plate tap one turn. Experimental coils for the 112-mc. band had three ½-inch diameter turns. In this case the taps were adjusted to within a fraction of a turn.
R.F.C. — 25 turns of No. 28 d.s.c. wire on ¼-inch diameter bakelite rod.

detector very heavily — then operating the receiver on the fringe of the superregenerative condition. A well-adjusted receiver will slide in and out of the superregenerative condition without any thumps, squeals or other irregularities. The self-quenched detector will usually produce louder signals as the voltage on the detector is increased. It is a very good plan, however, to operate the detector with very low voltage even though the signal output may not be of the highest level available.

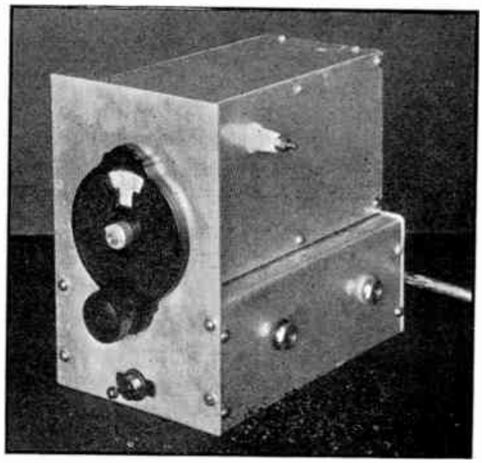


FIG. 1314 — A GENERAL VIEW OF THE PENTODE-ACORN RECEIVER

Representing a tasty problem for the skilled set builder, this receiver is capable of a high order of performance. The acorn r.f. amplifier plays the major rôle.

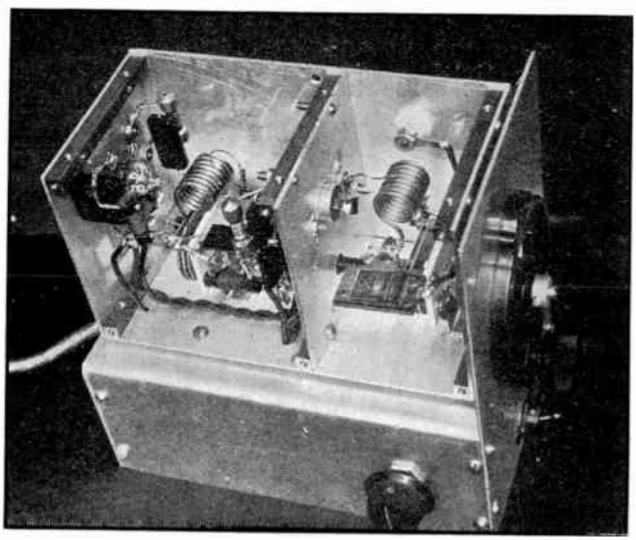


FIG. 1315 — A SIDE VIEW OF THE RECEIVER SHOWING THE ARRANGEMENT INSIDE THE SHIELD BOX

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. Further, it is considered that the use of tuned circuits ahead of a superregenerative receiver, operated at the frequency on which the detector is operating, handicaps the operation of the detector, particularly with respect to its ability to discriminate against noise. The obvious method of obtaining high selectivity is to adopt the superheterodyne principle, changing the signal frequency to a lower one, then passing it through a selective amplifier operating at the low frequency. Early superheterodynes, in the interests of simplicity, used an autodyne first detector together with an intermediate frequency amplifier operating on about 30 kc. This type of superheterodyne remains an effective one even to-day but it has an inherent defect in that the signal tunes in two places — each point being 30 kc. removed from the actual signal frequency. A much more effective superheterodyne is provided by the use of a separate oscillator tube operating in conjunction with the first detector to provide an intermediate frequency somewhere between 1500 and 10,000 kc. In this way, single-spot tuning is obtained, while the selectivity and gain of the intermediate frequency amplifier can be held at reasonable values. Two important disadvantages are seen in this type of receiver for amateur work, the first being an inherent inability to discriminate against the man-made noise which constitutes such a severe problem on the ultra-high frequencies. The second disadvantage is the difficulty of building an intermediate frequency amplifier with sufficiently high gain while still retaining the essential stability.

Practical experience with many receivers of this type leads us to suggest that the straight superheterodyne be used only in cases where interference from noise is a problem of no consequence. This state of affairs is likely to prevail when the location of the station is well removed from highways and from electrical machinery. A further suggestion resulting from practical experience is that the amateur be content to use, as the intermediate frequency amplifier, a not-too-selective broadcast receiver operating at the high-frequency end of the broadcast band. The construction of the complete receiver will then only rotate around the circuits operating on the signal frequency.

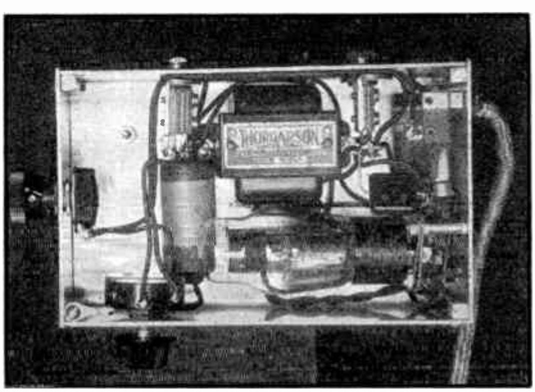


FIG. 1316 — THE UNDER SIDE OF THE PENTODE-ACORN RECEIVER

The audio equipment is tossed in helter-skelter, providing just enough room for the detector voltage control and the output jacks. The location of the potentiometer has proved to be more convenient in actual operation than the conventional one.

Building a 56-mc. Superhet Adaptor

Fig. 1317 is the circuit of the converter unit illustrated in Fig. 1318. It is designed for use with a broadcast receiver operating as the intermediate frequency amplifier and contains a preselector, a first detector and its companion oscillator. The illustration of the converter shows the manner in which the r.f. amplifier is mounted horizontally in order that the connection between the amplifier plate and the grid circuit of the detector may be kept as short as possible, and in order to facilitate the important business of isolating the grid and plate circuit of the r.f. tube. It will be noted that screen-grid injection is used in the first detector. It is obviously possible to exploit other methods of coupling the oscillator either to the control grid or the suppressor grid of the 6C6. A review of the general considerations in converter design given in Chapter Six will reveal almost endless possibilities in the way of circuit arrangement. Because the screen of the detector is connected across the tuned circuit of the oscillator, this circuit is loaded somewhat by the screen-to-ground capacity. Condensers C_4 and C_5 serve to load the two other tuned circuits in similar fashion in order that the three circuits will track. Additional precautions would have to be taken in order to secure perfect tracking over a wide range of frequencies, but with the arrangement shown it is readily possible to obtain effective tracking over the 56- to 60-mc. band. A more advanced type of converter suitable for the same work is that described later and shown in Fig. 1320.

The Super-infragenerator Receiver

While the superheterodyne receiver provides a ready solution to the problem of selectivity it fails to give us a universally valuable receiver simply because of its undue response to noise. The most recent development at A.R.R.L. Headquarters is an entirely new type of receiver in which all the valuable features of the super-regenerative receiver are combined with those of the superheterodyne. Experimental receivers of this type are, at this writing, only just emerging from the laboratory but their performance has been so satisfactory in preliminary trials that we are led to present comprehensive details. It is certain, of course, that this basic type of receiver will be subject to many modifications in the early future and it is therefore suggested that the interested reader should follow developments as they are recorded from time to time in *QST*.

In the new 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.

The frequency sequence diagram of Fig. 1319 will make the arrangement clearer. In this diagram, the first converter unit comprises a pre-selector, an oscillator and a mixer tube. In this unit, the incoming fre-

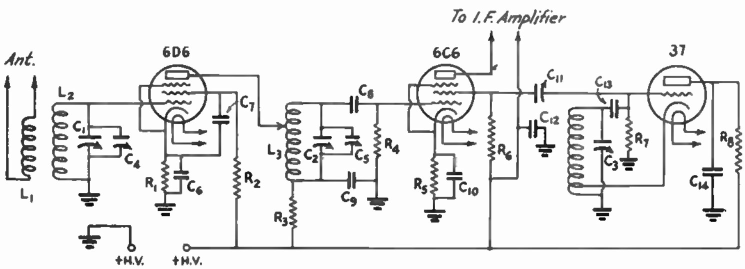


FIG. 1317 — A GLASS-TUBE INPUT CONVERTER SUITABLE FOR THE 56-MC. SUPERHETERODYNE

L_1 — Seven turns of No. 16 enameled wire with very slight turn spacing. Inside diameter 3/8 inch.
$L_{2, 3, 4}$ — Each eight turns 7/16-inch inside diameter of No. 14 tinned wire. Turns spaced to occupy one inch.
$C_{1, 2, 3}$ — 15 μμfd. Cardwell Trim-Air condensers.
$C_{4, 5}$ — National M30 mica padding condensers.
$C_{6, 7}$ — .002 μfd. midget fixed condensers.
C_8 — 100 μμfd. midget condenser.
C_9 — .001 μfd. midget condenser.
C_{10} — .01 μfd. paper-type condenser.
C_{11} — National M30 padding condenser.
C_{12} — .01 μfd. paper-type condenser.
C_{13} — 100 μμfd. midget condenser.
C_{14} — .001-μfd. midget condenser.
R_1 — 300-ohm half-watt resistor.
R_2 — 100,000-ohm half-watt resistor.
R_3 — 2000-ohm half-watt resistor.
R_4 — 1-megohm half-watt resistor.
R_5 — 50,000-ohm half-watt resistor.
R_6 — 100,000-ohm half-watt.
R_7 — 50,000-ohm half-watt.
R_8 — 25,000-ohm half-watt.

Experiment with values of C_{11}, R_5 and R_8 may be necessary to get most effective converter operation.

When the output of the converter is to feed into the antenna-ground terminals of a broadcast chassis, a transformer should be connected between the output of the 6C6 and the broadcast receiver input. The primary may be 70 close-wound turns of No. 30 d.s.c. wire tuned with a 150 μμfd. mica padding condenser. The secondary winding, wound close to the "B plus" end of the primary, should be about 20 similar turns. The optimum size will depend on the individual broadcast set used.

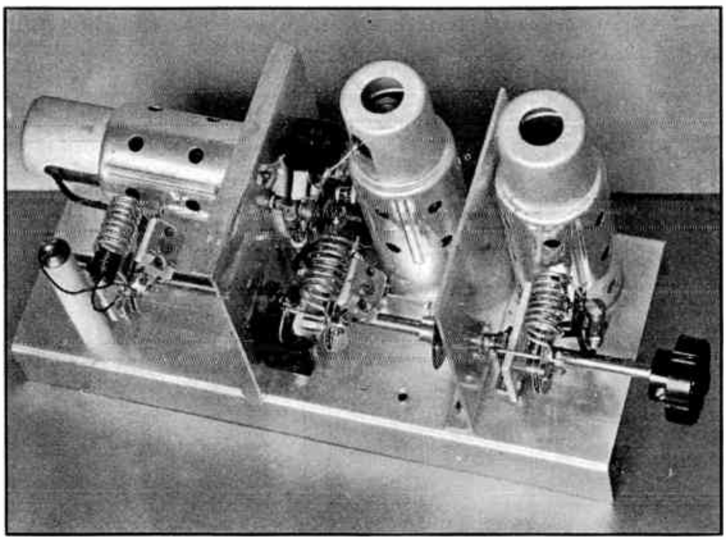


FIG. 1318 — THE GLASS-TUBE CONVERTER UNIT

The chassis is of folded aluminium and measures 10 by 4 by 1 inches. The partitions are 3¾ inches high. The unit is designed to be mounted behind the same panel as the intermediate frequency amplifier which, as suggested in the text, may well be a broadly tuning broadcast receiver. Needless to say, a good vernier dial will be essential on the converter.

quency is amplified very considerably by the pre-selector stage, fed to the mixer tube and there converted to a low-intermediate frequency of the order of 1500 kc. (1.5 mc.). The second converter unit consists of the tuned circuits necessary to provide the desired selectivity together with a second oscillator and mixer tube. The frequency of the oscillator in this second converter unit is such that the output frequency from the mixer is of the order of 22.5 megacycles. This second or high-i.f. is fed directly to the superregenerative third detector. The modulation components then pass to the audio amplifier. As is indicated on the diagram, the first converter unit serves to provide appreciable gain, an improved signal-noise ratio and the suppression of images. The second converter has as its only function the provision of the required selectivity. The superregenerative third detector is, of course, the heart and lungs of the receiver, providing, as it does, enormous gain, effective suppression of ignition noises and the like, together with a very high order of automatic-volume-control action.

Building an S.I.G. Receiver

● For the advanced worker, the metal tube receiver shown in Figs. 1320 to 1323 will provide an interesting constructional job. It is obviously a complex receiver (though not as complicated as some straight superheterodynes) but it is perfectly straightforward in its circuit arrangement and in the general process of adjustment and operation. It is essential, however, that the builder should have a very clear understanding of the manner in which the receiver operates.

Fig. 1320 reveals the input converter unit as being very similar to that already shown in Fig. 1317. It is, indeed, a perfectly conventional input converter, fitted with acorn tubes in order that it may be operated on the higher frequency bands. The components of this unit are mounted on a shallow folded aluminum chassis which, as shown in Fig. 1322 is separate from the main chassis. The three acorn tube sockets are mounted on vertical partitions immediately alongside the three tuning condensers and all leads are kept very short and direct. In the completed receiver this unit is covered with a folded aluminum dust cover which also serves as a shield. This can be seen in the illustration given at the beginning of this chapter. Trimmer condensers are used in parallel with the tuning condensers of the r.f. and detector grid circuit in order to compensate for the loading effect of the suppressor grid on the oscillator tuned circuit.

The main chassis of the receiver, which measures 12 x 6½ x 2¼ inches, carries the two intermediate frequency sections of the circuit and the audio equipment. In Fig. 1322 the i.f. transformer, into which the first detector feeds, is shown at the upper right. It consists of a remodelled Tobe Type T1 intermediate frequency transformer which, in its original form, had three tuned units each fitted with coils made up of three separate windings connected in series. In order to permit the transformer to be tuned to 1500 kc., two sections of each coil unit are removed, the remaining single coils being spaced approximately 1¼ inches apart. The result is a transformer which gives about as much selectivity as can be used at the present time. Doubtless special 1500-kc. transformers will be available in the early future. A variable selectivity transformer of this general type would be of considerable benefit in this receiver. The oscillator unit at the lower left of Fig. 1321 is tuned to approximately 21 mc. and operates in conjunction with the mixer tube above it to produce the high-i.f. of 22.5 megacycles. The superregenerative 6J7 tube is tuned to this frequency. The oscillator tube shown below this detector in the diagram provides the quench voltage. The audio frequency section of the circuit is quite conventional.

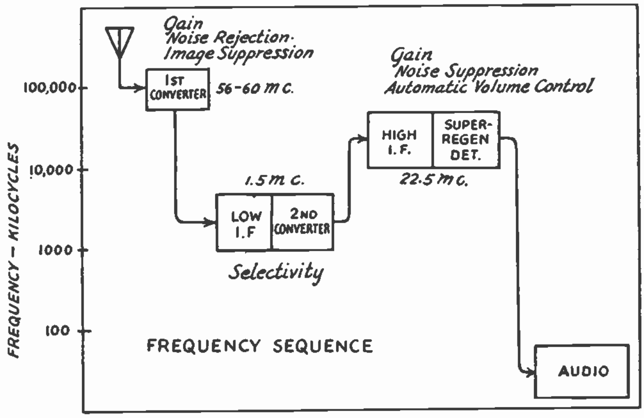


FIG. 1319 — ILLUSTRATING THE PRINCIPLE USED IN THE SUPER-INFRAGENERATOR RECEIVER

Having constructed and wired the receiver, the first procedure is to operate the superregenerative third detector and the audio tube alone. The cathode tap on L_7 is adjusted so that smooth superregenerative action is obtained and the remaining two tubes of this unit are then inserted in their sockets. At this stage, the second oscillator tube is tuned by means of C_{15} in order to determine whether or not it can be placed on the same frequency as that on which the superregenerative detector is operating. Now, an antenna is connected to the grid of the 6L7 tube and C_{15} is varied slowly until some broadcast station signal is heard. The difference-frequency between the second oscillator and the third detector may then be determined by identifying the broadcast station. Usually, under these conditions, the sensitivity of the receiver is very great and it should be possible to pick up many miscellaneous signals. A weak one will serve to allow adjustment of the primary L_6 of the input circuit to the third detector. This primary should be very closely coupled to L_7 — the increasing coupling being carried to the point where the third detector will only superregenerate toward the maximum setting of the potentiometer R_{16}. Excessive coupling is, however, possible at this point. Such a condition will not allow the second oscillator to be tuned to a frequency 1500 kc. different from that of the third detector. Experiment will soon reveal the optimum adjustment. A weak broadcast signal near the high frequency end of the broadcast band may now serve to allow tuning of the intermediate-frequency transformer by connecting the antenna, preferably through a very small capacity, to the input winding of the transformer. The exact intermediate frequency used is not of any particular consequence providing it is not that of some very powerful local broadcasting station.

Having tuned at least two of the circuits of the i.f. transformer, the input converter unit may now be connected. By loosening the flexible coupling on the oscillator condenser, and rotating only the condensers across the r.f. and detector grid circuits, it should now be possible to receive background noise or, preferably, the signal from a superregenerative receiver or a special modulated test oscillator. Now, the primary of the i.f. transformer should be tuned carefully and the padding condensers on the input tuned circuits also adjusted. Needless to say, a modulated test oscillator operating both on 1500 kc. and also the ultra-high frequency range is of great value in the alignment of the receiver. The use of such test oscillator is not absolutely essential, however.

Having lined up the input circuits and the i.f. transformer, experiments may now be undertaken with the setting of the second oscillator. It will be possible to find two settings of C_{15} at which the receiver is operable. The settings, of course, are each 1500 kc. removed from the frequency of the third detector. It may be found that one of the settings gives a better signal than the other. Likewise, in the input converter unit it is possible to tune the oscillator either on the low frequency or high frequency side of the signal frequency. Usually, the high setting is to be preferred.

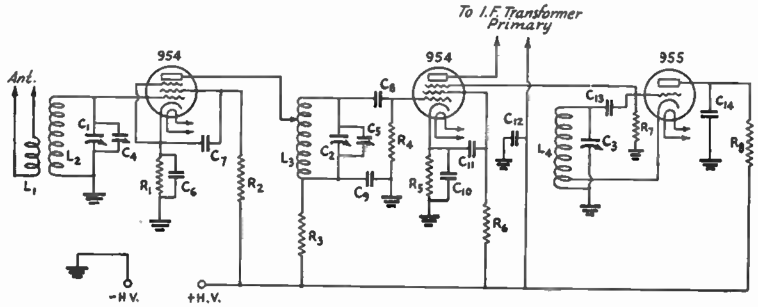


FIG. 1320 — WIRING OF THE ACORN INPUT UNIT OF THE SUPER-INFRAGENERATOR RECEIVER

L_1 — Seven turns of No. 15 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.

$C_{10, 11, 12}$ — .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.

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.

Now comes the all-important setting of the second intermediate frequency. The ideal method, of course, is to measure this frequency with a frequency meter. Since few amateurs are likely to possess frequency meters tuning in this range, it will usually be necessary to accomplish the tuning by cut-and-try. The general procedure is to find a high i.f. which will produce no serious beats as the receiver is tuned across the band. When a strong beat is located somewhere within the limits of the band, C_{15} and C_{16} are both turned in the same direction by a slight amount, the test oscillator signal recovered and a further search being made for the beat. Two or three tests of this type will soon reveal the direction in which the interferring beats are moving and will indicate the direction C_{15} and C_{16} should be tuned in order to place the beats beyond the tuning range of the receiver.

The original model illustrated has shown a very excellent performance and it is certain that the discriminating amateur, particularly if he experiences severe interference, will be well repaid for any effort spent on this type of equipment.

Possible Modifications

● In the receiver described, no attempt was made to "simplify" the layout by using double-purpose tubes. It is the view of many workers that, while double-purpose tubes reduce the number of sockets in the receiver, they do not mean any appreciable simplification of the circuit nor of the process of adjustment. Rather do they tend to increase the

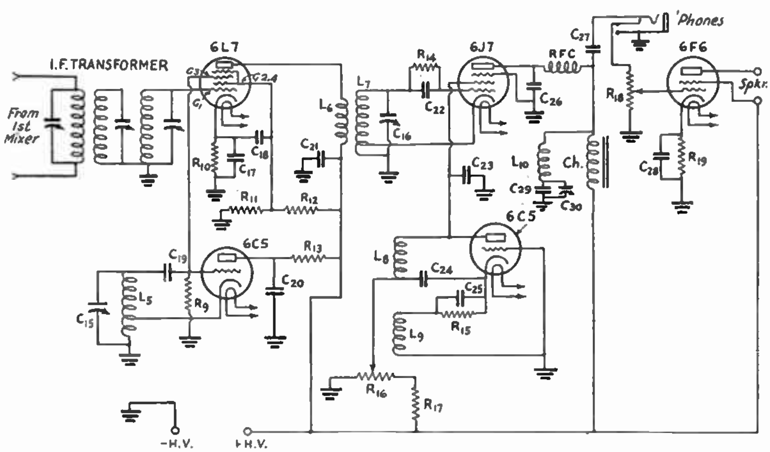


FIG. 1321 — THE WIRING OF THE INTERMEDIATE-FREQUENCY SECTION

L_5 — Eight close-wound turns of No. 22 double-silk-covered wire on a ½-inch diameter former. A National R39 former of this size was used in the original set. Cathode tap is 2 turns up from the grounded end of coil.
L_6 — Twenty close-wound turns of No. 30 d.s.c. wire on a National ½-inch diameter R39 coil form. This coil is wedged into L_7 with small pieces of celluloid and the assembly made firm with "Duco" cement or acetone. See text for details of adjustment.
L_7 — Ten turns of No. 14 bare or tinned wire ¾-inch inside diameter with turns spaced diameter of wire. Cathode tap at about third turn from grounded end.
$L_{8, 9}$ — Windings of National quench oscillator unit. Improved performance is had in this circuit by using the small coil in the grid circuit. The "P" lug is therefore connected to the tube grid, the "G" terminal going to the tube plate.
$C_{15, 16}$ — Hammarlund AT75 75 μμfd.
C_{17} — .01 μfd. 200-volt paper-type condenser.
C_{18} — .01 μfd. 400-volt paper-type condenser.
C_{19} — 100 μμfd. fixed midget condenser.
C_{20} — 1000 μμfd. fixed midget.
C_{21} — .01 μfd. 400-volt paper-type condenser.
C_{22} — 100 μμfd. midget fixed condenser.
C_{23} — .002 μfd. fixed midget condenser.
C_{24} — .1 μfd. 400-volt paper-type condenser.
C_{25} — .1 μfd. low-voltage paper-type condenser.
C_{26} — 1000 μμfd. fixed midget.
C_{27} — .1 μfd. 400-volt paper-type condenser.
C_{28} — 10 μfd. electrolytic condenser.
R_9 — 50,000-ohm half-watt resistor.
R_{10} — 350-ohm half-watt resistor.
R_{11} — 50,000-ohm 1-watt resistor.
R_{12} — 15,000-ohm 2-watt resistor.
R_{13} — 100,000-ohm half-watt resistor.
R_{14} — 5-megohm half-watt resistor.
R_{15} — 2000-ohm half-watt resistor.
R_{16} — 100,000-ohm potentiometer.
R_{17} — 50,000-ohm half-watt resistor.
R_{18} — 500,000-ohm potentiometer.
R_{19} — 600-ohm 5-watt resistor.
I.F. Transformer — See text for details.
R.F.C. — National Type R90 choke.

L_{10}, C_{29} and C_{30} comprise the quench frequency filter — a very desirable but not essential addition. L_{10} is a National Type R90 choke (90 millihenrys). C_{30} is a 150 μμfd. or larger mica padding condenser while C_{29} is a fixed condenser of 250 μμfd. The filter is tuned with a rectifier type voltmeter across the output of the set until minimum reading is obtained with no signal input to the set. C_{15} and L_5 are mounted on the oscillator tube socket and covered with a small shield can.

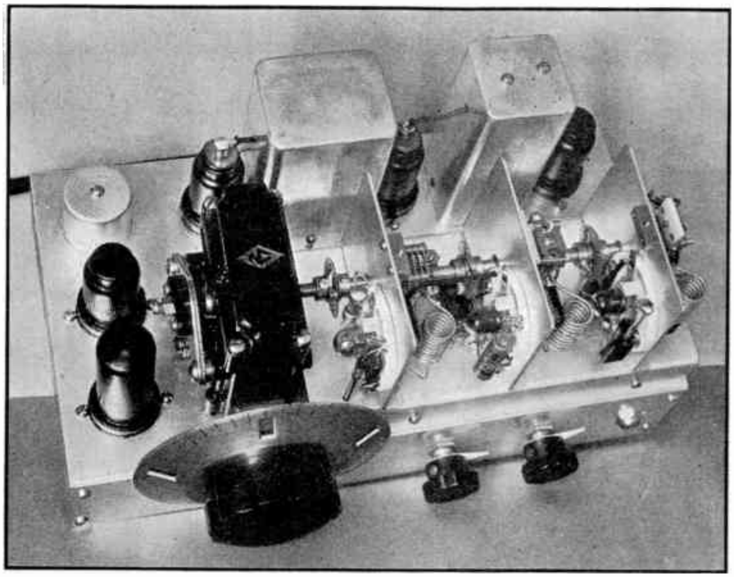


FIG. 1322 — THE NEW RECEIVER WITH THE SHIELD COVER REMOVED

On the partitions, reading left to right, are the first oscillator, first detector and input r.f. stage. Reading from right to left, along the rear of the set, are located the second oscillator; low-i.f. transformer; second converter; superregen. input coil; superregen. detector; quench oscillator coil; quench oscillator and audio amplifier tubes.

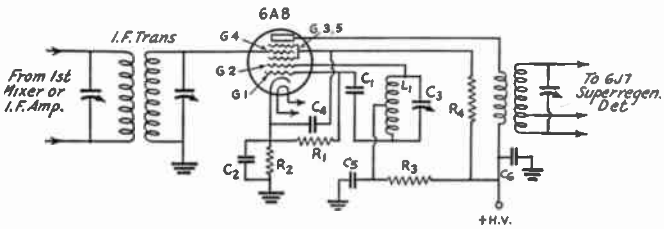


FIG. 1323 — A SUGGESTED CIRCUIT FOR THE 6A8 CONVERTER

R_1 — 50,000-ohm half-watt resistor.
R_2 — 250-ohm half-watt resistor.
R_3 — 20,000-ohm half-watt resistor.
R_4 — 50,000-ohm half-watt resistor.
C_1 — 100 μμfd. midget condenser.
C_2 — .01 μfd. paper-type condenser.
C_3 — 75 μμfd. oscillator tuning condenser.
C_4 — .01 μfd. paper-type condenser.
C_5 — .001 μfd. midget condenser.
C_6 — .01 μfd. paper-type condenser.
L_1 — Eight close-wound turns of No. 22 d.s.c. wire on half-inch diameter former. Top at approximately the center of coil.

operating difficulties. Nevertheless, one possible modification of value would be to use the Type 6A8 tube as the second converter. Fig. 1323 illustrates the manner in which the tube would be wired.

Another modification of value is the addition of an i.f. amplifier operating at the low intermediate frequency. Such an amplifier would provide the receiver with still greater gain and in some instances this may result in a higher useable sensitivity. This amplifier could be used in conjunction with a pair of double-tuned i.f. transformers and could be connected in accordance with the circuit given in Fig. 1324. An amplifier of this type would be invaluable in instances where a conventional glass or metal tube had to be used as the preselector in the first converter unit. In the receiver described, this preselector tube provides an appreciable gain and has the duty of offsetting, by its gain, the negative gain obtained in the first two converters. Should the gain on the first tube of the receiver be cut in half, for instance, the overall sensitivity of the receiver would be impaired. In this case, the proposed i.f. amplifier would immediately restore or, for that matter, better the original gain.

Future Developments

● We would emphasize again that the entire field of ultra-high frequency working is in a state of extreme flux. New developments are appearing almost every day and equipment which is now modern is likely to be superseded in the very early future.

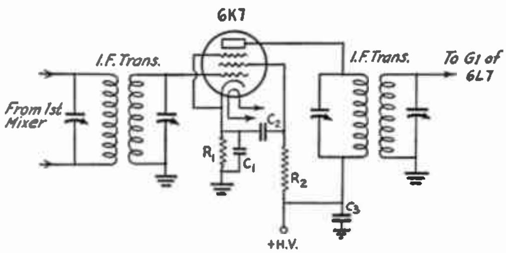


FIG. 1324 — WIRING OF THE SUGGESTED I.F. AMPLIFIER

R_1 — 350-ohm half-watt resistor.
R_2 — 100,000-ohm half-watt resistor.
$C_{1,2,3}$ — .01 μfd. paper-type condensers.

CHAPTER FOURTEEN

Ultra-High-Frequency Transmitters

THE SIMPLEST CIRCUITS — FREQUENCY STABILITY CONSIDERATIONS—LINEAR OSCILLATORS—SHORT-LINE-CONTROLLED OSCILLATORS — OSCILLATOR-AMPLIFIER TRANSMITTERS

TRANSMITTER practice on the ultra-high frequencies differs quite considerably from that followed on the lower frequencies. One important reason for this is that conventional transmitting tubes are very poor amplifiers at frequencies of 56 mc. or above. It is actually possible to use a relatively low-frequency controlling oscillator and to follow it with a series of harmonic amplifiers until the desired ultra-high frequency is reached. However, the efficiency obtained in the amplifiers at the ultra-high frequency end of the transmitter is usually extremely low and such a set-up would represent a very considerable expenditure of time and money. In the early days of ultra-high frequency working, common practice was to use a simple oscillator circuit for the transmitter, then modulating the oscillator directly. Transmitters of this type, indeed, are still widely used today but, unless special precautions are taken, they exhibit very serious frequency modulation which causes their signal to occupy an unnecessarily wide band of frequencies and which prohibits the use of even a reasonably selective receiver. The trend, today, is toward the use of stabilized oscillators of one form or another, or oscillator-amplifier transmitters. In the latter case, the best stations employ a crystal-controlled oscillator but reasonable freedom from frequency modulation can be obtained even by the use of a simple oscillator and amplifier both operating on the same frequency.

Before proceeding with the details of actual transmitting circuits, it would be well to outline the frequency bands in which these transmitters are to operate and to submit some general suggestions with respect to the problem of determining the frequency at which the transmitter is operating.

Finding the Bands

● On the ultra-high frequencies the amateur has available the territory between 56 and 60 mc. and also all the frequencies higher than 110 mc. In order to facilitate contact and communication in the enormously extensive territory higher than 110 mc., however, it has been suggested that the amateur endeavor to operate in bands related harmonically with the 56-mc. band. The so-called ultra-ultra high frequency bands to which particular attention is being given are therefore 112 to 120 mc.; 224 to 240 mc. and 448 to 480 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. 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 wave-length simultaneously.

The 56-mc. band covers from 5.357 to 5 meters. This means that the harmonically related 112-mc. band will be from 2.678 to 2.5 meters while the next band down — the 224-mc. band — will be from 1.339 to 1.25 meters.

The future will certainly see amateur activity on the frequencies higher than these but, at the moment, most of the interest is concentrated in exploring the wide "wastes" between 5 and 1.25 meters.

The methods of frequency measurement and checking described in Chapter Seventeen are, generally speaking, unsuited for the ultra-high frequencies. Fortunately, simpler (though probably less accurate) methods are available.

The simplest method is merely to cut the antenna wire to 95 per cent. of the actual wave-length desired, then tuning the transmitter until the antenna is operating most effectively. This scheme is, of course, extremely approximate and would serve only as a preliminary measure.

The next simple 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, of even on 5 meters, the problem is readily solved if a linear type oscillator is used. With this type of oscillator (to be described later) 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 consists of two No. 18 bare copper wires spaced about two 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 wave-length being measured. An alternative sliding bridge — useful when the oscillator has plenty of output — is a flashlamp 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 readily checked by comparing harmonics produced by oscillators on harmonically related lower frequency bands.

Simple Oscillator Circuits

● One of the simplest and most practical circuits for experimental work is that shown in Fig. 1401. It is the type of circuit which can be set up in quick time and hence is of especial value to the experimenter. However, in common with all similar circuit arrangements, the inherent stability is of a low order. When modulation is applied, the output frequency will change in accordance with the modulation voltage and, as a result, the signal will occupy a wide band of frequencies. The circuit is therefore not recommended for ultra-high frequency communication purposes except in instances where the equipment *must* be kept as compact and light-weight as possible.

A further simple circuit particularly suited for single-tube operation is that shown in Fig. 1402. This particular circuit is suited for

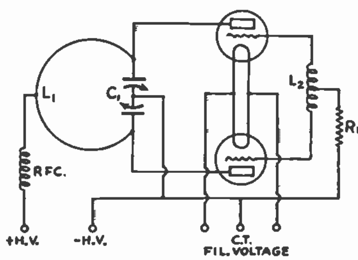


FIG. 1401 — A SIMPLE 56-MC. OSCILLATOR CIRCUIT

L_1 — Single turn of ¼-inch copper tubing, 4 inches in diameter, mounted on stator terminals of tank condenser.

L_2 — 4 turns No. 14 enamelled antenna wire, 1" in diameter, and about 2" in length. Turns are squeezed together or separated until set oscillates with minimum plate current at the desired frequency of operation.

C_1 — National split-stator condenser, Type TMP-100. Net maximum capacity (sections in series) 100 μμfd.

RFC — 18 turns of No. 24 d.c.c. on ½-inch wooden dowel, 1/16-inch spacing between turns.

R_1 — 10,000-ohm non-inductive grid-leak 5-watt size or larger.

These constants are for Type 10 tubes. Slight modification of L_2 may be necessary when Type 45, 71-A or 801 tubes are used. A tank tuning condenser of lower voltage rating would be satisfactory for the smaller tubes. A receiver type condenser may be used when the plate voltage does not exceed 250 or 300 volts.

experimental work, with conventional tubes, on frequencies even as high as 224 mc. The frequency stability of this type of circuit, though, is also very poor.

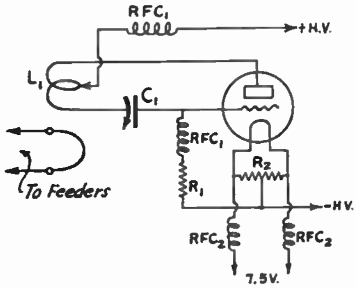


FIG. 1402 — CIRCUIT SUITABLE FOR EXPERIMENT ON 112 OR 224 MC.

The W.E. 304A has been used with this circuit on 224 mc. Other types of tubes will require modification of the constants suggested.

C_1 — National Type NC800 condenser.

L_1 — Single turn tank coil of very small copper tubing or No. 12 gauge wire. Actual length of conductor in one experimental transmitter for 224 mc. was 7 inches — the turn 1-inch diameter.

R_1 — 20,000 10-watt resistor.

R_2 — 50- or 100-ohm center-tapped resistor.

RFC_1 — 15 turns of No. 18 wire wound on a pencil — the turns being pulled apart slightly.

RFC_2 — About 10 turns of the filament leads wound on a pencil.

Linear Oscillator Circuits

● The circuits just described, and many similar to them, are satisfactory for experimental work on the u.h.f. bands. However, they become increasingly unsatisfactory as the frequency is increased. Another type of circuit, admirably suited for all the bands mentioned, and having considerably greater inherent frequency stability, is that of Fig. 1403. It is one of a large group of so-called "linear" oscillators. In Fig. 1403, the conductors L_1 and L_2 are made of such dimensions that the entire length of each conductor — including the elements and leads within the tube — correspond to a half wavelength. The plate and grid feeds are then connected at the nodal point in the electrical center of the system. The conductors may be made of No. 14 wire but a great improvement in performance is made possible by using large diameter copper tubing — the two conductors being spaced approximately the diameter of the tubing.

Several methods of coupling the feeder system are possible. That indicated is one possibility. In this case, the tuned feeders of a Zepp system are clipped on the plate rod, one on each side of the nodal point. Variation of the spacing of the two clips then permits variation of the coupling to the feeder. Untuned feeders may be attached in the same manner, the spacing of the clips being varied to give the necessary impedance match.

In this type of oscillator, the adjustment of the length of the rods is the one very important matter. It is probably a good scheme to start out with rods a full half-wave long, then cutting them down until the desired wavelength is reached. The actual length of the rods will depend upon the type of oscillator tube used.

The mounting of the rods is another important matter. Probably the simplest method is to support them between two stand-off insulators on a strip of good insulating material.

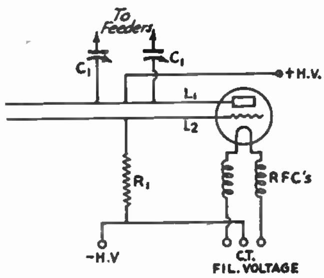


FIG. 1403 — AN OSCILLATOR CIRCUIT SUITED FOR THE VERY HIGH FREQUENCIES

L_1, L_2 — Copper rods or tubes slightly less than a half-wave long. Tubing ½-inch outside diameter spaced 1 inch between centers is suggested though smaller or larger conductors will serve.

C_1 — Feeder tuning condensers. Three-plate midgets would be satisfactory for 2½ meters or below. Condensers several times this capacity would serve for 5 meters.

R_1 — Grid-leak of resistance and power rating to suit oscillator tube. 25,000 ohms is a good average value.

RFC's — About 25 turns of No. 14 wire ⅝-inch diameter with turns spaced the diameter of the wire. These chokes are absolutely essential.

Almost any of the usual triodes will operate in this circuit down to at least 2¼ meters. The Type 800 or W.E. 304A are suggested for satisfactory performance at 1¼ meters.

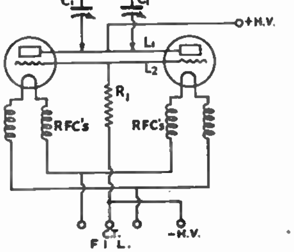


FIG. 1404 — A PUSH-PULL VERSION OF THE LINEAR OSCILLATOR

The same values may be used as given under Fig. 1403. The length of the rods must be reduced, however, to allow for the loading effect of the second tube.

The support should preferably be at the nodal point.

A Push-Pull Linear Oscillator

● The circuit of Fig. 1404 shows how the linear oscillator may be adapted for push-pull

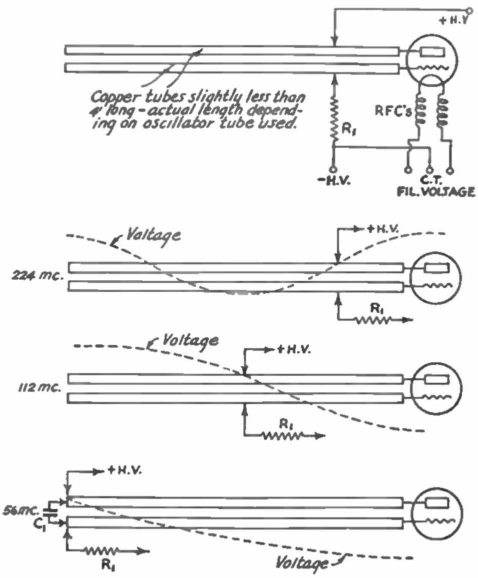


FIG. 1405 — A THREE-BAND ULTRA-HIGH-FREQUENCY TRANSMITTER

The rods are of ½-inch copper tubing spaced 1 inch center to center. Their length is slightly less than a full wave at 1¼ meters. The actual length is determined by the type of tube used. With a W.E. 304A, the rods are 113 centimeters (about 34 inches) long. They would be slightly shorter for the 800 and most of the smaller tubes. An adjustable bridging condenser of about 25 μμfds. between the grid and plate feed points may be found desirable on 112 and 224 mc.

working. Instead of having one end of the half-wave lines open, they are connected to the grid and plate of a second tube. This means, of course, that the actual length of the rods will be decreased to allow for the loading provided by the second tube. The full length of each rod will be twice the distance from the node to the tube terminals in Fig. 1403. The nodal point, where plate and grid feeds are attached, will now be in the center of the system. The antenna feed methods may be the same as those previously mentioned.

Setting up a Linear Oscillator

● The construction and tuning of transmitters of the type just mentioned is very simple. The only essential need is to develop the habit of visualizing the voltage distribution along the rods so that the actual operating conditions in the circuit can be determined rapidly. The most suitable tubes for these circuits, and for the 2½ and 1¼ meter bands, are probably the 800 and the W.E. 304A. Other tubes such as the 45, 10 or 37 have been shown to be effective but a little more difficulty may be had in obtaining stable operation and reasonably long tube life.

The use of a plate current meter is, of course, essential. If the circuit is oscillating, this meter will show current fluctuations when the rods are touched with a pencil or screwdriver at points other than the voltage nodes. This very method, indeed, is probably the best one to reveal the actual location of the nodes. Another practical way of locating the best position for the plate and grid feed clips is to move the clips until the plate current drops to a minimum value.

A Three-Band Transmitter

● Fig. 1405 illustrates a transmitter of this general type suited for operation on the 5, 2½ and 1¼-meter bands. It is similar to the arrangement of Fig. 1403, being identical, in fact, when the set is operated on 2½ meters. The plate and grid conductors are made a full-wave long at 1¼ meters and the circuit

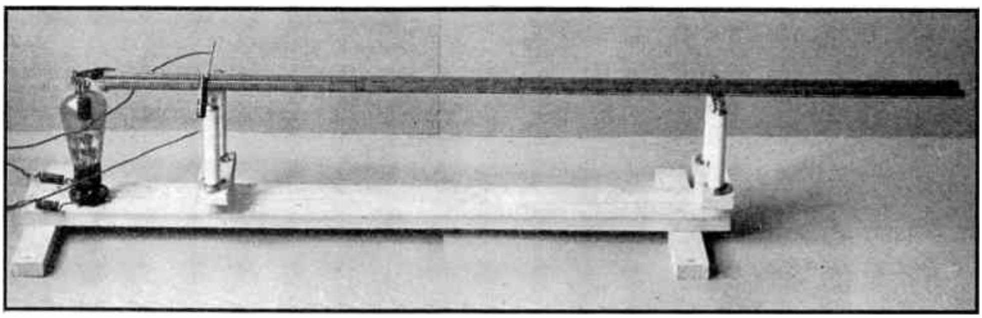


FIG. 1406 — AN EXPERIMENTAL SET-UP OF THE CIRCUIT OF FIG. 1405

The pipes of the resonant line are supported on small pieces of National Victron, these, in turn, being supported by the stand-off insulators. The tube is the W.E. 304A.

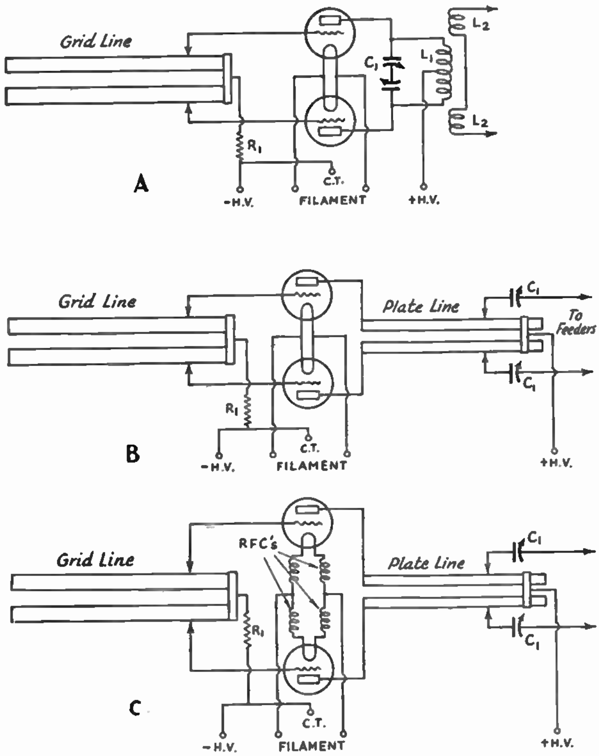


FIG. 1407 — THREE BASIC CIRCUITS FOR THE SHORT-LINE-CONTROLLED OSCILLATOR

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 — Approximately three turns of 1/8-inch copper tubing, turns 2 inches diameter for 56 mc. A single turn 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 — Usually necessary only on 112 and 224 mc.

Approximately 15 turns of No. 14 wire 1/2-inch inside diameter for 112 mc. Seven similar turns for 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 four feet for 56-mc. band; 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.

will oscillate at that wave length when the plate and grid-feed clips are connected one quarter-wave (at 1¼ meters) from the tube elements. Sliding the feed clips out near the center of the rods will put them one quarter-wave (at 2½ meters) from the open end and the system will then operate at 2½ meters. For 5-meter operation, the feed clips are run down to the ends of the rods and a by-pass condenser is clipped across them. Since the entire rod length is one quarter-wave at 5 meters the node will be at the far end and the system will oscillate at 5 meters. It will be necessary, of course, to change the location of the antenna feeder clips when changing from one band to another. On the 2½ and 1¼ meter bands they may be on either side of the plate feed connection. On 5 meters, one feeder may be clipped on the plate rod near the feed end, the other feeder opposite it on the grid rod.

Short-Line Control

● In the circuits just discussed, improved stability is made possible by the use of high-Q 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 very 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. It is also interesting to note that Q is proportional to the square root of the frequency and, unlike conventional tuned circuits, therefore *increases* with frequency. A line made up of copper tubing of about 4 inches in diameter has, at 60 mc., a Q of more than 6000. Such a line is therefore capable of providing a selectivity performance comparable with that of a crystal-controlled oscillator. Tubing of such dimensions is, though, quite expensive, and current amateur practice is to use conductors of 1-inch diameter or less. Such a line does not provide the highest possible order of selectivity but it allows quite a tremendous improvement over oscillators not fitted with this type of frequency control.

Fig. 1407 illustrates three practical arrangements of push-pull oscillators employing short-line frequency control. The controlling element, marked "grid line" on the diagram consists of a pair of copper pipes slightly less

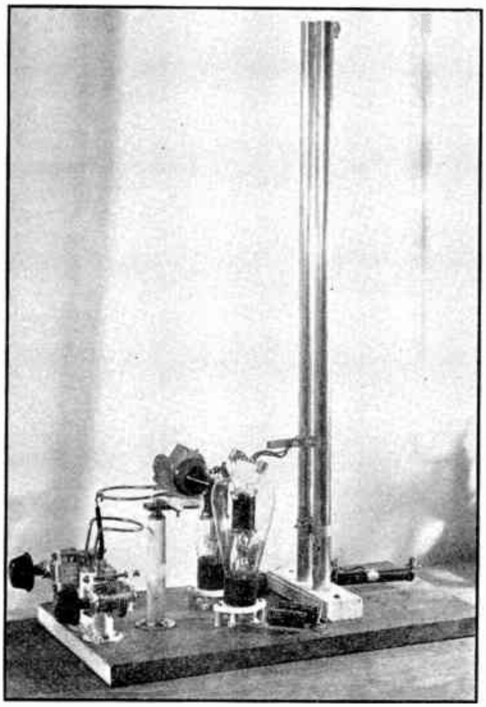


FIG. 1408 — A TRANSMITTER FOR 112-MC. OPERATION USING CIRCUIT "A" OF FIG. 1407

The antenna coil in this case is a single turn. The two series feeder tuning condensers can be seen at the left. Type 800 tubes are shown.

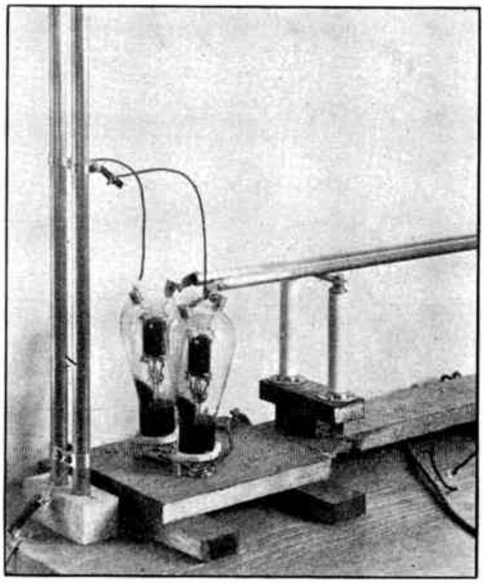


FIG. 1409 — THE TUBE END OF A TRANSMITTER EMPLOYING THE CIRCUIT "B" OF FIG. 1407 AND OPERATING ON 56 MC.

The mounting of the grid line in this example is not ideal because of the long grid leads. It is better, when possible, to drop the line over the edge of the bench in the manner shown in Fig. 1413. While Type 800 tubes are shown, the arrangement is equally suited for tubes of lower power.

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 effective 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. 1407, 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 the grid taps approach the bridge the greater will be the stability and the longer will the line be for a given frequency.

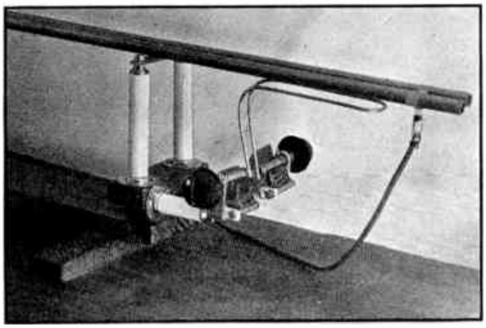


FIG. 1410 — THE FAR END OF THE PLATE LINE OF THE TRANSMITTER SHOWN IN FIG. 1409

The antenna coupling "hairpin" is mounted on the two series feeder tuning condensers. The high-voltage feed line drops down from the bridge on the line. The hairpin coupling has been found somewhat more convenient to adjust than the sliding contacts shown in Fig. 1407.

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.

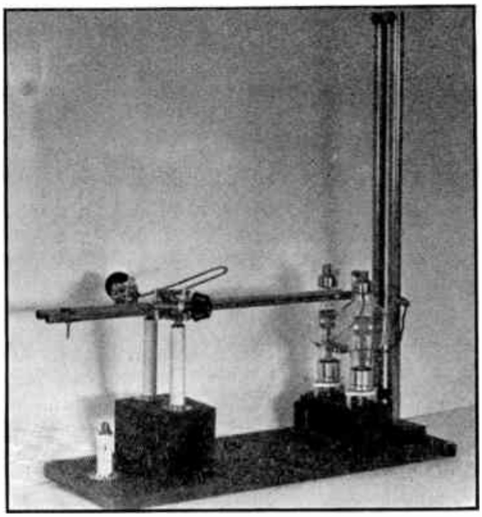


FIG. 1411 — A 112-MC. TRANSMITTER EMPLOYING THE CIRCUIT "C" OF FIG. 1407

Eimac 50T tubes are used in this set-up.

The antenna may be coupled in the manner shown in Fig. 1407 at "B" and "C" or it may be coupled inductively with a "hairpin" antenna coil such as that illustrated in Fig. 1410.

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. 1407.

The transmitters illustrated all employ medium sized tubes. It should be understood that these identical circuits are equally suited for use with the smaller tubes — the only necessary modifications being in the mounting of the tubes themselves and in the circuit adjustment. With tubes such as the Type 45 it will be found that the grid taps can be placed very close to the bridge end of the line. This particular adjustment will vary greatly with the type of tube used.

Concentric Lines

● In commercial practice the "open" type of line just described is rarely used. Instead, concentric lines are employed. Such lines have many advantages, particularly for single-tube oscillators, but they are usually somewhat more difficult to construct and adjust.

Fig. 1412 shows one simple single-tube circuit with a concentric short-line controlling element. In such a line, the length of the inner conductor determines the resonant frequency (aside from the loading effect of the tube) and it is therefore convenient to provide a telescoping section at the upper end of the inner con-

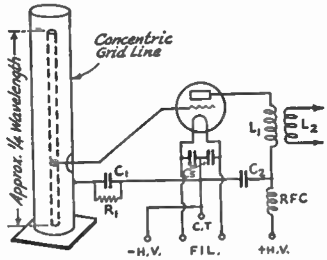


FIG. 1412 — A TYPICAL SINGLE-TUBE TRANSMITTER WITH A CONCENTRIC GRID LINE

C_1 — 100 μμfd. receiving type condenser.
C_2 — 500 μμfd. high-voltage condenser.
C_3 — Filament by-pass condensers — 500 μμfd. low voltage.
R_1 — 10,000 to 50,000 ohms depending on tube used.
L_1 — Size will depend greatly on type of tube and length of leads. Six turns of 1/8-inch copper tubing 1 1/2-inch diameter suggested for first trial on 56 mc.
L_2 — Two or three similar turns.

The inner conductor will be slightly less than 4 feet long for 56-mc. band operation; a few inches less than 2 feet for 112 mc.

ductor for frequency adjustment. It is also convenient to drill several fairly large holes in the outer conductor in order to allow adjustment of the grid tap. It will be noted that no

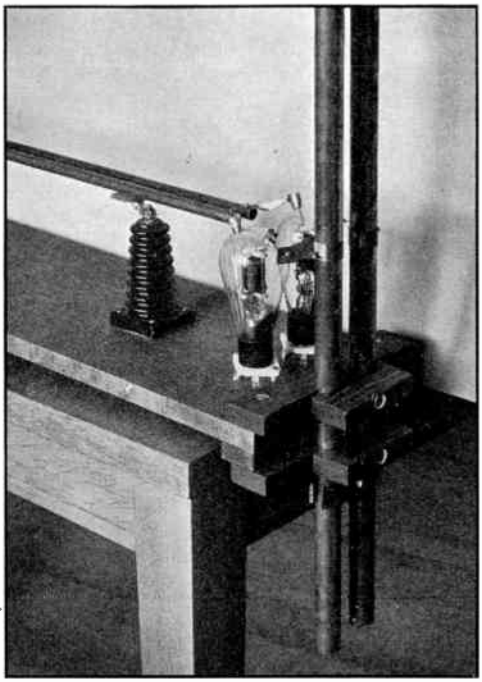


FIG. 1413 — A TYPICAL OSCILLATOR ASSEMBLY FOR A TRANSMITTER EMPLOYING THE CIRCUIT OF FIG. 1415

This mounting of the grid line is an excellent one for straight oscillator transmitters using short-line control. Dry wood is sufficient insulation at the low-voltage end of the line, though in this particular case small pieces of National Victron were used as "packing" between the wood clamps and the copper pipes. The same arrangement is equally suited to lower powered tubes.

tuning condenser is indicated across the plate coil L_1. By avoiding any tank condenser and by tuning the coil itself (together with the tube capacities) to the required frequency, better controlling action of the short line is usually obtained.

In determining the spacing of the conductors in both the open and concentric resonant lines, the following ratios 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.

Oscillator-Amplifiers With Short-Line Control

A splendid improvement in the frequency stability of the transmitter and a consequent great reduction in frequency modulation is made possible by using a short-line controlled oscillator driving a modulated amplifier stage. Providing a separate power supply is used to drive the oscillator of such a transmitter, excellent freedom from frequency modulation can be obtained.

The arrangement of a transmitter of this type is shown in Fig. 1415. This transmitter is similar to those already described except that the hairpin output "coil" is tuned to resonance and provides excitation for the grids of the push-pull amplifier tubes. These tubes are neutralized in the conventional manner and

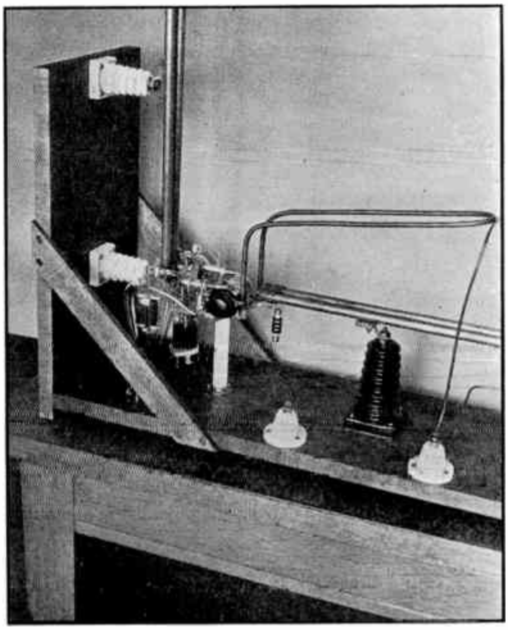


FIG. 1414 — THE AMPLIFIER END OF THE LINEAR OSCILLATOR-AMPLIFIER TRANSMITTER SHOWN IN FIG. 1413

The neutralizing and grid tuning condensers are all mounted together on a Victron shelf supported on a single stand-off insulator. The plate line goes vertically out of the picture at the left. At its upper end, the antenna coupling components are mounted.

are provided with a linear tank circuit. This arrangement is capable of a fine performance and is strongly recommended to the amateur anxious to produce a signal substantially free from frequency modulation. In the transmitter

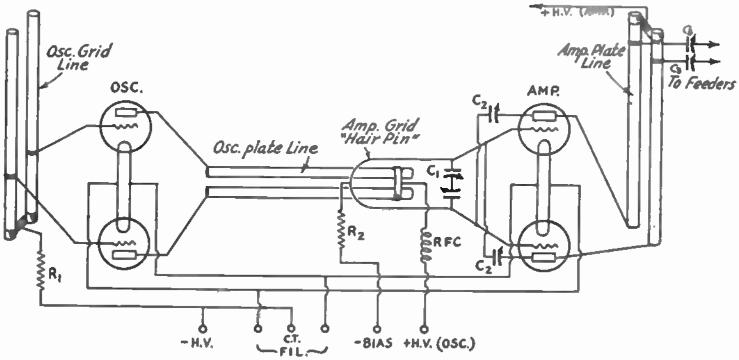


FIG. 1415 — CIRCUIT LAYOUT FOR A LINEAR OSCILLATOR-AMPLIFIER TRANSMITTER WITH SHORT-LINE CONTROL

C_1 — Split stator receiver-type condenser of approximately 50 μμfds. per section.
C_2 — Cardwell Type NA-4-NS remodelled to give one stator and one rotor plate or National NC800 (for Type 800 tubes). Neutralizing condensers of lower voltage rating may be used for smaller tubes.
C_3 — 75 μμfd. receiver type condensers.
R_1 — 10,000 to 50,000 ohms depending on tubes used.
R_2 — 10,000 ohms usually appropriate.
The grid hairpin in the transmitter illustrated is 10 inches long and 2 inches wide.

illustrated, Type 800 tubes are used for both the oscillators and amplifiers. Obviously, these tubes could be replaced by others of lower or higher power rating without any other important change in the circuit. Generally speaking, it is good practice to use the same tubes in the oscillator as in the amplifier, or at least tubes having the same power capabilities. The adjustment of such a transmitter, with respect to neutralization and excitation, will be carried out exactly in accordance with the principles given in Chapter VIII.

Oscillator-Amplifiers With Conventional Tank Circuits

In many instances, particularly when the transmitter must be built in a restricted place, it is impractical to use short lines in the transmitter. Fortunately, it is still possible to obtain entirely satisfactory performance with the more conventional type of tank circuit.

Fig. 1416 illustrates a very low-powered oscillator-amplifier of this type in which screen-grid tubes are used to avoid the necessity of neutralization. Several types of screen-grid tubes are available for this type of work and the circuit arrangement has many useful applications. This particular transmitter has a very low power output but may well be used as an exciter unit for one or more additional amplifier stages using more powerful tubes.

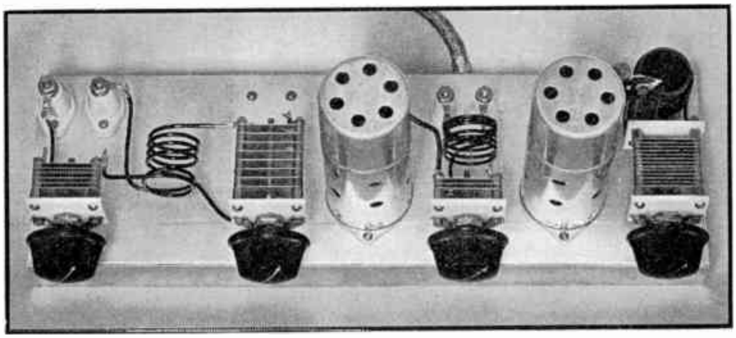
Two Type 58 or 6D6 tubes are used in the transmitter proper, one as an electron-coupled oscillator-doubler and the second as the 56-mc. amplifier. The latter tube is, of course, the tube modulated.

A top view of the transmitter is given in Fig. 1416. The physical layout, it will be observed, almost exactly follows the circuit diagram of Fig. 1417. The metal chassis is made of aluminum and measures 13 by 4 inches, with ¾-inch vertical sides.

The tuning condensers are mounted on brackets supplied for the purpose. The oscillator tuning condenser C_4 is provided with mounting brackets at both ends so that this condenser will be quite solidly mounted. The double mounting helps to prevent frequency changes arising as the result of vibration. For the same reason the oscillator coil L_5,

FIG. 1416 — A SIMPLIFIED HIGH-STABILITY 56-MC. TRANSMITTER

Type 58 receiving tubes show their splendid capabilities as transmitters in this rig. An unusually high order of stability under modulation is attained by the circuit design and layout.



which is just behind C_4, is wound on a form instead of "on air" as are the other coils.

The oscillator plate-coupling coil L_4 is mounted on two feed-through stand-off insulators at the rear edge of the chassis behind C_3. This coil is placed so that its axis coincides with that of L_3, and is about ¼-inch away from it. Its connections run down through the insulators to the under side of the chassis.

Any of the new pentode-type low-power transmitting tubes may be employed in a circuit of this type. Minor changes in coil sizes may be necessary, however.

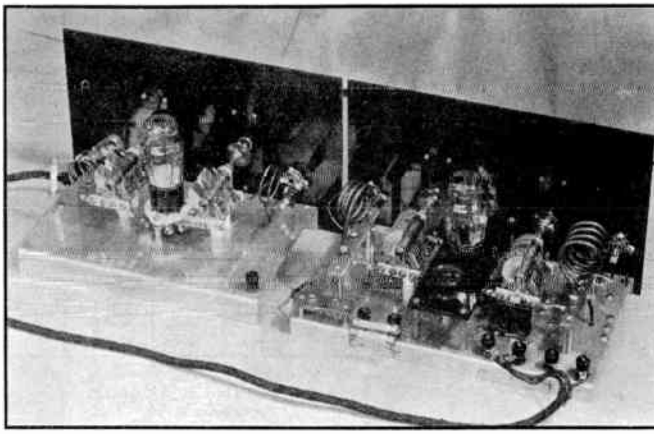


FIG. 1418 — A REAR VIEW OF THE SIMPLE OSCILLATOR-AMPLIFIER TRANSMITTER USING TRIODES

The neutralizing condensers are mounted on the same bakelite strip which supports the amplifier tube. Since the photograph was taken, plug-in coils have been fitted to the oscillator also.

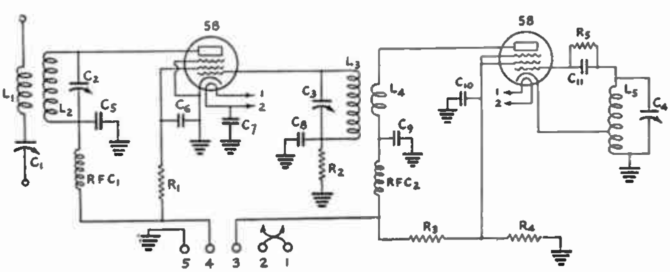


FIG. 1417 — CIRCUIT DIAGRAM OF THE LOW-POWER OSCILLATOR-AMPLIFIER TRANSMITTER

C_1 — 50-μμfd. (Cardwell Trim-Air Type RT-50).
C_2 — 30-μμfd. (Cardwell Trim-Air Type XT-30).
C_3 — 25-μμfd. (Cardwell Trim-Air Type RT-25).
C_4 — 140-μμfd. (Cardwell Trim-Air Type RT-140).
C_5 to C_{10} incl. — 250-μμfd. midget mica condensers.
C_{11} — 100-μμfd. mica condenser.
R_1 — 50,000-ohm 1-watt resistor.
R_2 — 25,000-ohm 1-watt resistor.
R_3 — 50,000-ohm 20-watt resistor.
R_4 — 50,000-ohm 2-watt resistor.
R_5 — 25,000-ohm 1-watt resistor.
RFC_1, RFC_2 — National Type 100 chokes.
L_1 — 2 turns No. 12 enamelled wire, coil diameter ⅞ inch.
L_2 — 4 turns No. 12 enamelled wire, coil diameter ⅞ inch, length ⅝ inch.
L_3 — 3½ turns No. 12 enamelled wire, coil diameter ⅞ inch, length ½ inch.
L_4 — 3 turns No. 12 enamelled wire, coil diameter ⅞ inch, length ¾ inch.
L_5 — 5½ turns No. 12 enamelled wire, on 1-inch diameter (National) coil form, length ⅞ inch; tapped 1½ turns from ground end.

Terminals 1 and 2 connect to the heater voltage supply. Terminal 3 is supplied with 250 volts for the oscillator supply while terminal 4 connects to the modulator and high voltage positive. A maximum plate voltage of 300 is suggested. Terminal 5 is connected to the negative high voltage.

Using Twin-Triode Tubes in the Oscillator-Amplifier

● A novel and particularly effective transmitter is illustrated in Figs. 1418 and 1419. The Type 53 tube at the right-hand side of the circuit is the oscillator arranged in a tuned-grid tuned-plate circuit. Its plate tank is inductively coupled to the tuned grid circuit of the amplifier stage in which a similar tube is used. The amplifier tubes are neutralized in the conventional manner.

The transmitter shown in Fig. 1418, using this circuit, is arranged in the form of two units and the coupling between the oscillator and amplifier is varied by sliding the units themselves.

Almost any of the popular transmitting tubes may be arranged in circuits of this type for 56-mc. operation, and providing the basic principles of transmitter adjustment treated in Chapter VIII are observed, effective performance should be had just so long as the oscillator has a power output closely comparable with that expected from the amplifier. On frequencies higher than 60 mc., it becomes increasingly difficult to obtain excitation for the amplifier and it is suggested that only very experienced workers should attempt the oscillator-amplifier type of transmitter if operation is to be expected on the 112-mc. band. For the very high frequencies, the simple short-line controlled oscillators are recommended.

Modulation Requirements

● We have made no mention, so far, of the modulator requirements for these transmitters. The subject, of course, is of very wide scope and, since modulator practice differs in no respect from that observed on the low frequencies, we would suggest that appropriate modulator equipment be chosen only after a close study of Chapters Eleven and Twelve.

For the very low-powered transmitters, the modulator may be simplified by using an audio pentode tube (such as the 41 or 42) as a Class-A speech-amplifier-modulator. A good single button microphone and microphone transformer will excite such a tube satisfactorily without any intermediate speech amplifier.

The Transceiver

● In the earlier days of u.h.f. work, when most of the activity was with portable equipment, a reduction of weight and general simplification was made by using the same tubes for transmission as for reception. The so-called "transceivers" built around this idea are still very much worth-while for portable and mobile work but they are frowned upon as equipment for the fixed station in a populous center because of their ability to cause severe radiation when operating in the receiving position. Some of the later types of transceivers are provided with means for reducing the plate voltage in the receiving position and therefore do not offend as seriously. Generally speaking, it is less expensive to purchase a complete transceiver than to build one.

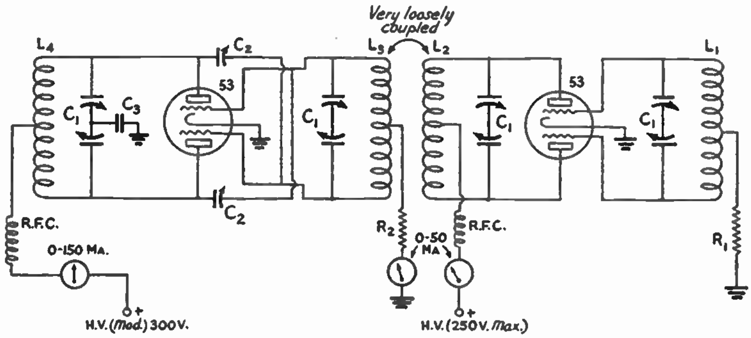


FIG. 1419 — CIRCUIT OF THE OSCILLATOR-AMPLIFIER TRANSMITTER USING DUAL TRIODES

The antenna may be coupled with a conventional split antenna coil or by tapping the feeders on L_4.

C_1 — National STD 50 split-stator condenser.
C_2 — National STD type with 1 rotor and 1 stator double-spaced.
C_3 — .01-μfd. fixed condenser.
For five meters:
L_1 — 3 turns 1" diameter.
L_2 — 1½ turns 1⅛" diameter.
L_3 — 2½ turns 1⅛" diameter.
L_4 — 4 turns 1⅛" diameter.
L_2 and L_3 are inductively coupled at least three inches apart.
RFC — National Type 100 chokes.
R_1 — 2000-ohm, 1-watt resistor.
R_2 — 1500-ohm, 1-watt resistor.

Antenna Systems

● The same general principles of design must be observed in planning u.h.f. antennas as in planning antennas for the lower frequencies. Even the directive array is fundamentally the same (except for its dimensions) on the u.h.f. or the lower frequencies. It is therefore suggested that Chapter Sixteen be studied thoroughly before the details of any u.h.f. antenna system are decided upon.

A final firm suggestion is that a directive array should be used for u.h.f. working whenever possible. Using a directive array is an exceedingly inexpensive way of getting a substantial increase in effective transmitted power.

CHAPTER FIFTEEN

Design and Construction of Power Supply Equipment

RECTIFIERS — FILTERS — PRACTICAL PLATE AND FILAMENT SUPPLY FOR TRANSMITTERS AND RECEIVERS — VOLTAGE DIVIDERS — TRANSMITTER BIASING VOLTAGE SUPPLY — TRANSFORMER AND FILTER CHOKE CONSTRUCTION — PORTABLE AND INDEPENDENT SYSTEMS

FULLY as important as the transmitter itself is the apparatus which supplies the power to the tube filaments and plates. The operation of a well-designed transmitter can be spoiled by a poor power supply. Although the power supply involves only the use of simple apparatus in most cases, good design and adjustment will be well rewarded by improvement in the signal and in the over-all effectiveness of the transmitter.

In this chapter we shall consider various types of power supplies for both transmitters and receivers. 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 worthy of careful consideration. We shall discuss first the plate supply for the transmitter.

> 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 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 30,000 kc. This requirement is designed to ensure that the emitted signal will be "pure d.c." on the five 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.

The output of dry-cell or storage batteries is ideal for the transmitter because it is steady, pure direct current. Except for very low-power transmitters, however, the battery cost is a great deal more than the cost of other power supply apparatus of the same voltage output; furthermore, the current that can be taken from the batteries is extremely limited if reasonable battery life is to be secured. Not more than 30 milliamperes should be taken continuously from standard-size "B" batteries; at this discharge rate the life of the battery should be approximately 200 hours. The heavy-duty batteries can stand higher discharge rates and will last longer. Because of their cost and relatively short life,

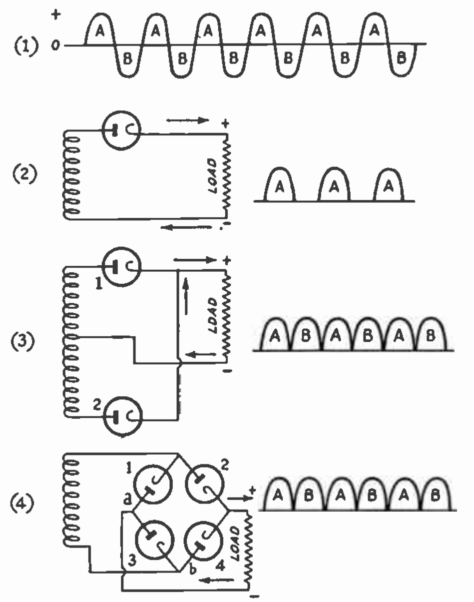


FIG. 1501 — FUNDAMENTAL RECTIFIER CIRCUITS
At (1) is the conventional representation of the a.c. wave; (2) shows a half-wave rectifier; at (3) is the full-wave center-tap system; and (4) is the "bridge" rectifier. The output wave form with each type of rectifier is shown at the right.

batteries are used chiefly for portable transmitters—particularly with ultra-high frequency equipment — and in locations where no other source of power is available, such as on farms.

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.

The Rectifier-Filter 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 in the chapter and for the moment we will limit the discussion to the rectifier.

An understanding of how a rectifier functions may be obtained by studying Fig. 1501. At (1) is a typical a.c. wave, in which the polarity of the current and voltage goes through a complete reversal once 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 continually. 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 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.

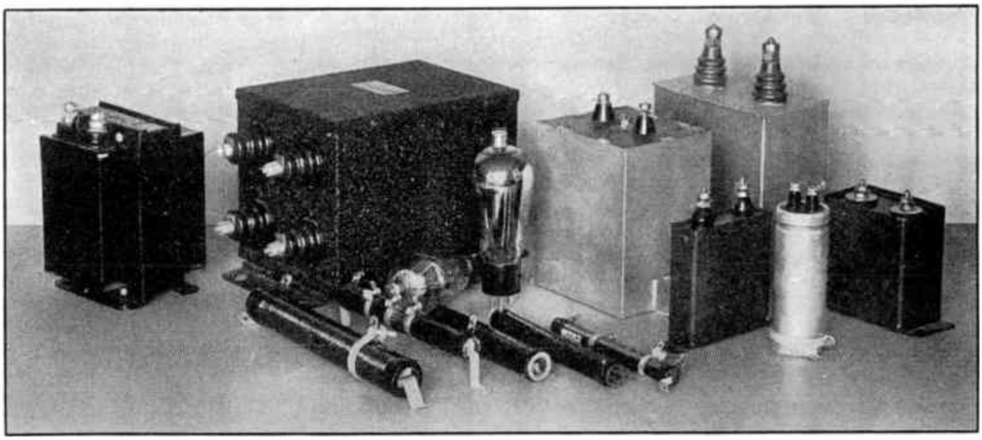
If the transformer has no center-tap, or if the total voltage it furnishes is the same as the desired output voltage, scheme (4), known as the "bridge" rectifier, may be used to obtain full-wave rectification. Its operation is as follows: When the upper end of the winding is positive, current can flow 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. 1501. 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 today 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.



Chokes, transformers, condensers, rectifiers and resistors — the essentials of all power supply systems.

Operating Limits of Rectifiers

● Two factors determine the safe operating limits of 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. 1501, 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, 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. The bridge circuit, however, 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 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.

Standard types of rectifier tubes are listed in the table, 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.

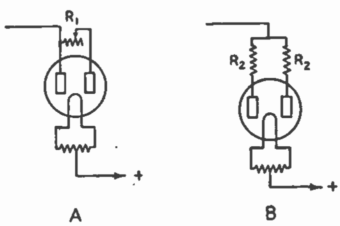


FIG. 1502 — METHODS OF BALANCING FULL-WAVE RECTIFIER PLATE CURRENTS WHEN PLATES ARE CONNECTED IN PARALLEL. R_1 MAY BE AN ORDINARY 30-OHM FILAMENT RHEOSTAT. R_2 SHOULD BE 50 TO 100 OHMS

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 will be found with 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 rectifiers the filament power always should be applied for at least 30 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

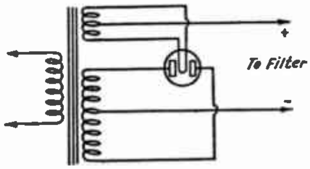


FIG. 1503 — HOW FULL-WAVE TUBE RECTIFIERS ARE CONNECTED

This diagram can be used with Type 80, 82 and 83 rectifier tubes.

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.

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 the series with the plates of the rectifier tubes as shown in Fig. 1502. 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*.

Rectifier Circuits

● The elementary rectifier circuits of Fig. 1501 are shown in practical form in Figs. 1503 and 1504. Fig. 1503 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 Fig. 1504, half-wave rectifier tubes being used in both cases. In the practical circuits, it can be seen that while a single filament transformer will suffice for both tubes in the center-tap circuit, the bridge circuit requires the use of three separate filament transformers; the filaments of one pair of tubes can be connected together, but the filaments of the other two tubes are at different potentials and must have separate sources of filament-heating power.

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

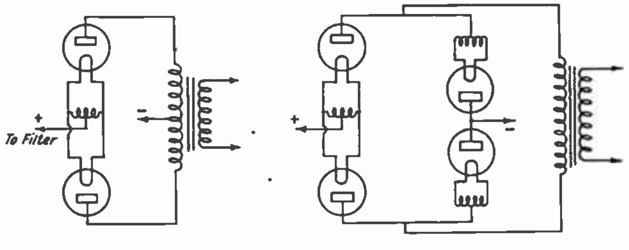


FIG. 1504 — CENTER-TAP AND BRIDGE RECTIFIER CIRCUITS

In both circuits, the peak inverse voltage is equal to the total secondary voltage of the transformer multiplied by 1.4. Therefore, twice as much voltage can be obtained from the bridge as from the center-tap rectifier without exceeding the tube ratings. The tubes will pass the same load current in both cases.

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.

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 oscillator-amplifier transmitters, good voltage regulation is still desirable because it tends to reduce key thumps.

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.

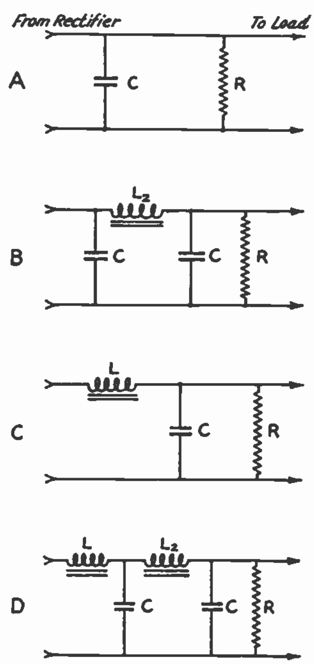


FIG. 1505 — FILTERS

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.

1501) 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" (percent. 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.

Types of Filters

● Inductance and capacity can be combined in various ways to act as a filter. Four representative arrangements are given in Fig. 1505. 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* (the "brute force" filter) is a popular one; with suitable values of *L* and *C* the smoothing will be adequate for most amateur purposes. 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.

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 gotten economically with the single-section filter. Because of the many advantages of choke-input filters, they will be given detailed consideration in this chapter.

Designing the Plate Supply

● As suggested before, the ripple voltage tolerable in the output of the power supply will depend upon the type of service. We can take .25% or less as standard for radiotelephony. The percent. ripple allowable for c.w. telegraphy will, however, 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 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.

To illustrate the method of designing a plate supply, let us go through a specific problem. Suppose that two 203-A tubes are to be supplied 1000 volts of 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. 1505-C will represent the most economical design; for 1% or less ripple two sections, Fig. 1505-D, should be used. For our particular problem, then, a single-section filter will suffice. The percent. ripple will depend upon the product of the choke inductance and condenser capacity; the following formula gives the ripple percentage directly:

$$\%\text{ ripple} = \frac{100}{LC}$$

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.

To maintain the output voltage at a constant value, it is necessary to have some load on the plate-supply system at all times. 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. 1505, is used. Since it is desirable to keep down the amount of power dissipated in the bleeder, a fairly high resistance is ordinarily used; usual practice is to make the bleeder take 10% or less of the full load current. The bleeder resistance will therefore 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 only one-tenth 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 whose inductance varies from the critical value at no load to the optimum value at full load; such chokes are available from manufacturers.

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 percent. ripple. We have previously determined that the product of inductance and capacity must be at least 20 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.

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. The resonance frequency will be equal to

$$f_{res.} = \frac{159}{\sqrt{LC}}$$

where L is in henrys and C in microfarads, and should be well below the supply-line frequency. In our example, the resonance frequency by 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 ensure having 1000 volts at the power supply terminals under full-load current.

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

$$\text{Sec. VA} = \text{Total } E_{rms} \times I \times .75$$

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.

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. 1505-D. The percent. ripple for a two-section filter is found by the following formula:

$$\% \text{ Ripple} = \frac{650}{L_1 L_2 (C_1 + C_2)^2}$$

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 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 is 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 percent. ripple with a condenser-input filter, but experience has shown that a filter of the type shown in Fig. 1505-B will have excellent smoothing if each condenser is 2 to 8 μfd. and if the choke has an inductance (commercial rating) of 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 continuously 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.

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 adequate for 50 cycles as well.

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*.

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

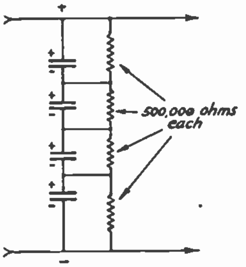


FIG. 1506—HOW EQUALIZING RESISTORS ARE USED WITH FILTER CONDENSERS CONNECTED IN SERIES FOR HIGH VOLTAGES

for a given size and cost, but cannot be made in single units for very high voltages, 500 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. When condensers are connected in series all the units of the string should have the same capacity so the voltage will divide equally between them. As a further assurance that each condenser in the string will take a proportionate share of the voltage, resistors may be connected across the individual units as shown in Fig. 1506. Each of the resistors should be 500,000 ohms, and should be rated to dissipate one or two watts.

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. 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 always should be purchased from reputable manufacturers; 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 time, but eventually will "blow" and have to be replaced. Failure of a high-voltage condenser may also mean the destruction of the rectifier tubes.

The Filament Supply

● The second 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 winding is 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

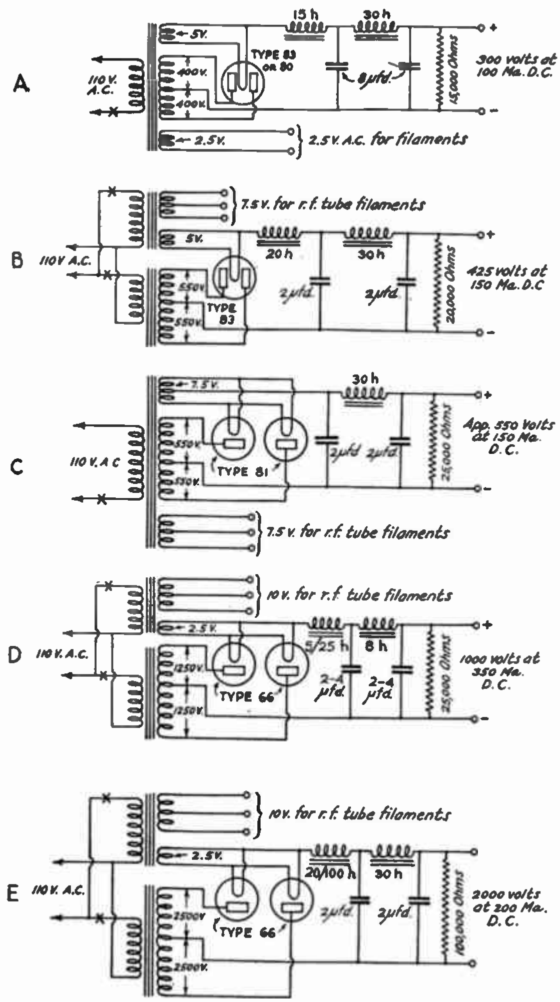


FIG. 1507 — REPRESENTATIVE POWER-SUPPLY ARRANGEMENTS FOR DIFFERENT TYPES OF TRANSMITTING TUBES

All these diagrams will give adequately-filtered d.c. output for the different classes of service. They are explained more 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.

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. 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 Type 10.

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.

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

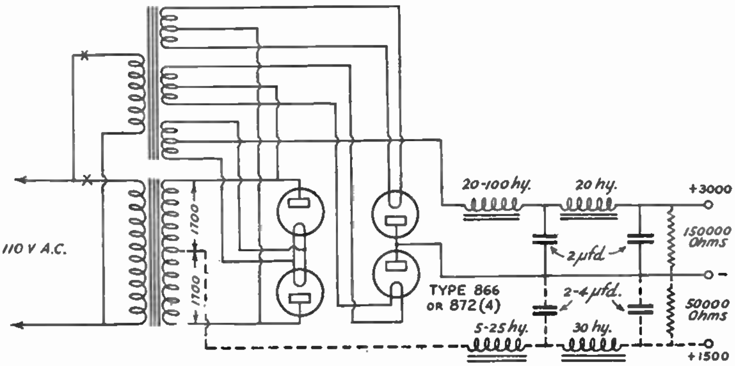


FIG. 1508 — HIGH POWER BRIDGE RECTIFIER CIRCUIT. WHEN THE CENTER-TAP FILTER SHOWN IN DOTTED LINES IS USED, A TAP AT HALF MAXIMUM VOLTAGE WITH GOOD REGULATION IS PROVIDED. THE TOTAL CURRENT DRAWN FROM BOTH TAPS SHOULD NOT EXCEED 300 MA. FOR 866'S OR 1600 MA. FOR 872'S

the type of rectifier and filter best suited to his needs. As a guide in construction, however, Fig. 1507 shows a number of rectifier-filter combinations to give various output voltages and currents. All will give adequately-filtered direct current to the transmitting tubes, 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 so that 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.

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, which means that electrolytic condensers cannot be used unless two of them are put in series to replace the single condensers shown. The condensers need not have 8 μfd. capacity each, but this is a standard size with electrolytic condensers and is recommended.

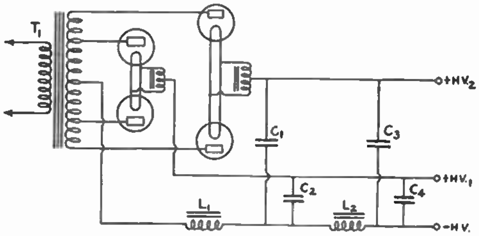


FIG. 1509 — A POWER SUPPLY CIRCUIT IN WHICH A SINGLE TRANSFORMER AND SET OF FILTER CHOKES IS MADE TO SERVE FOR DIFFERENT VOLTAGES

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.

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 Type 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 Type 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 *E* is suitable for use with one or two 852 or 860 tubes. With the filter values shown the ripple will be .25% or less.

The circuit of Fig. 1508 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 852's, 150-T's, one or two 861'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 resistance. This same principle may be applied with benefit to lower voltage supplies. The 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. 1509 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.

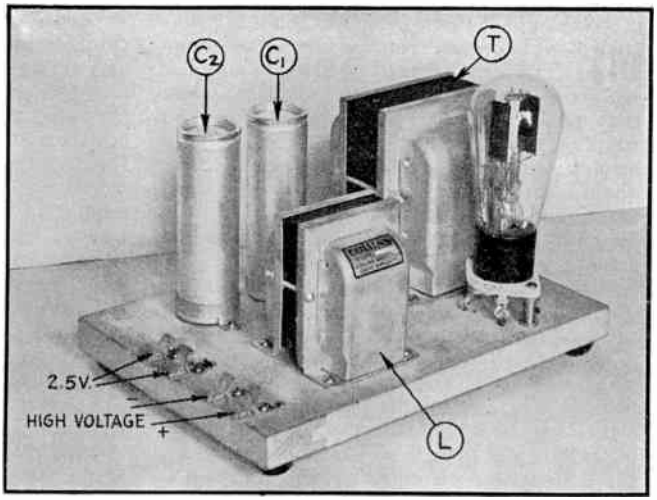


FIG. 1510 — A 350-VOLT POWER SUPPLY, OF INEXPENSIVE CONSTRUCTION, SUITABLE FOR THE LOW-POWER TRANSMITTER

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 ordinary 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 possible to keep the carrier free from hum.

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.

Fig. 1510 is a photograph of a power supply suitable for use with a low-power transmitter. Its circuit diagram, Fig. 1511 will be seen to be similar to *A* in Fig. 1507 with the exception of the fact that the input choke to the filter is omitted and that no bleeder resistance is used. The filter condensers are electrolytics having a capacity of 8 μfd. each. The power transformer should deliver not more than 350 volts each side of the center tap to avoid damaging the condenser.

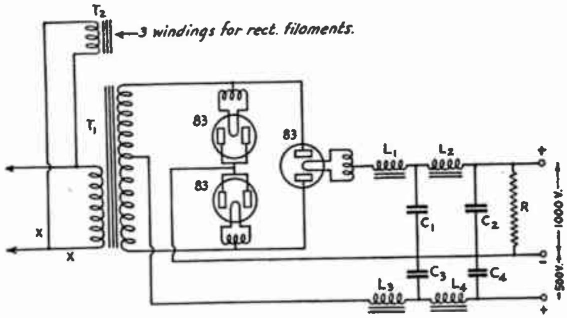


FIG. 1512 — A DUPLEX PLATE SUPPLY CIRCUIT

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 — 2μfd., 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.

Electrolytic condensers have inherent leakage and the charge accumulated on them will dissipate itself in a short time, which is the reason why the bleeder can be dispensed with. If paper condensers are used a bleeder of about 20,000 to 30,000 ohms should be connected across the output of the filter. This power supply will deliver approximately 350 volts with a load of 100 milliamperes.

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.

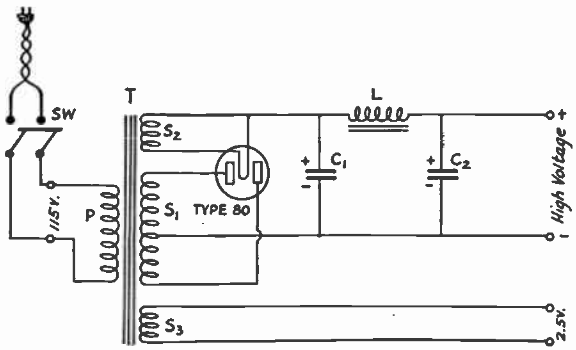


FIG. 1511 — WIRING DIAGRAM OF THE POWER SUPPLY SHOWN IN FIG. 1510

T — Power transformer; high-voltage winding, S_1, 350 volts each side of center tap; rectifier filament winding, S_2, 5 volts; transmitting-tube filament winding, S_3, 2.5 volts. Transformers of this type are sold for broadcast-receiver purposes,
L — Filter choke, commercial inductance rating 20 to 30 henrys, current-carrying capacity 100 ma.
C_1, C_2 — 8-μfd. electrolytic filter condensers rated at 500 volts peak.

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. 1512. 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 transformer to furnish 500 volts for the low-power stages of the transmitter. A total of 250 milliamperes (or slightly 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. Such a power supply will operate either the exciter unit and RK-18 amplifier or the three-tube transmitter described in the chapter on transmitters.

With the filter values indicated in Fig. 1512 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 4 μfd. will bring the ripple down to 3%. It is best to use the two-section 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.

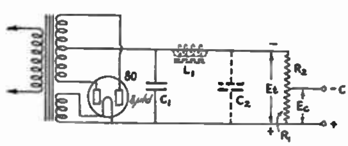


FIG. 1513 — A PRACTICAL CIRCUIT FOR THE "C" SUPPLY

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, E_c, 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).

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.

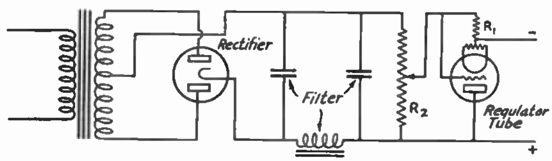


FIG. 1514 — CIRCUIT OF THE AUTOMATIC VACUUM-TUBE REGULATOR AS APPLIED TO A BIAS- OR PLATE-SUPPLY POWER PACK

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 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. 1513 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 overbiased. 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 milliamperes, 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. 1514. 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 resistance, 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.

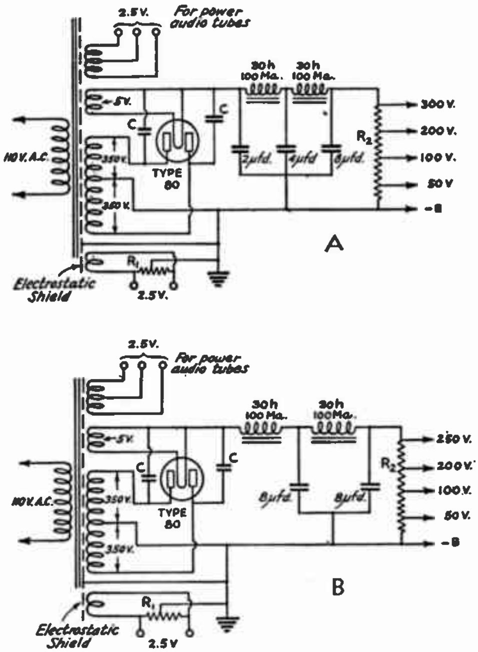


FIG. 1515 — WIRING DIAGRAMS FOR RECEIVER POWER SUPPLIES

Condenser C should be a mica condenser of about .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.

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.

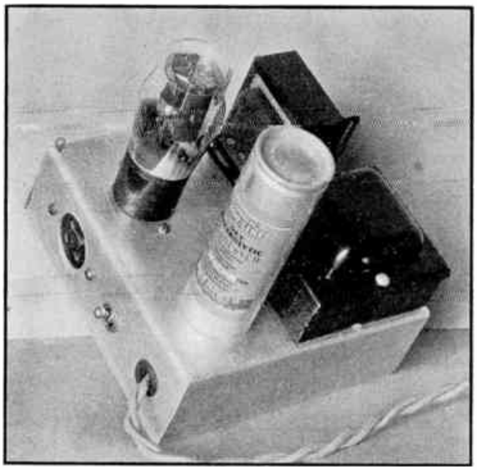


FIG. 1516 — LOW-POWER RECEIVER POWER SUPPLY

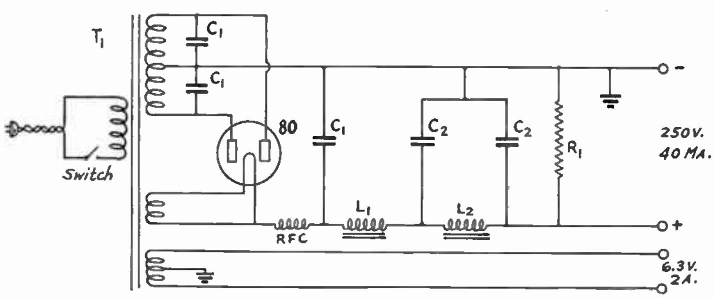


FIG. 1517 — A LOW-CURRENT POWER SUPPLY FOR REGENERATIVE OR T.R.F. RECEIVERS

T_1 — 275-volt 40-ma. plate winding, 6.3-volt 2-amp. heater winding, 5-volt 2-amp. rectifier winding.
L_1–L_2 — 30-henry 40-ma. chokes.
C_1 — .005-μfd. 400-volt tubular paper condenser.
C_2 — Dual 8 μfd. 450-volt electrolytic condensers.
R_1 — 50,000 ohm 10 watt resistor.
RFC — Receiving type r.f. choke.
2.5-volt heater windings may be substituted, subject to receiver requirements.

If additional taps are necessary, a regulator tube with its separate filament transformer will be required for each tap.

Receiver Power Supplies

● Power supplies for a.c.-operated receivers do not differ materially from those used with transmitters except that the voltages are lower and all ripple must be eliminated. 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. 1515-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. 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. 1515-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. 1515-B is recommended on this score; it will be especially valuable if the reciver 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

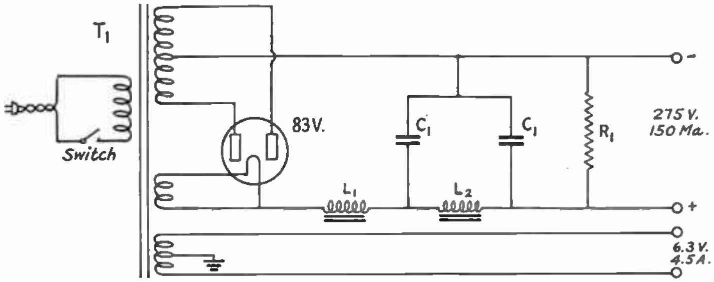


FIG. 1518 — A POWER PACK FOR SUPERHETERODYNE RECEIVERS, WITH SUFFICIENT RESERVE FOR SPEAKER FIELD SUPPLY

T_1 — 300-volt 150-ma. plate winding, 6.3-volt 4.5 amp. heater winding, 5-volt 2-amp. rectifier winding.
L_1 — 10-henry 150-ma. choke.
L_2 — 20-henry 150-ma. choke.
C_1 — Dual 8 μfd. 450-volt electrolytic condensers.
R_1 — 50,000 ohm 10 watt resistor.
2.5-volt heater windings may be substituted, subject to receiver requirements.

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.

Voltage Dividers

● In addition to the voltages shown in Fig. 1507, 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. 1507-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. 1520. 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. 1507-D calls for a bleeder current of 40 ma. (1000 volts divided by 25,000 ohms); the lower section therefore is equal to

$$\frac{350}{.04} = 8750 \text{ ohms.}$$

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

$$\frac{500}{.13} = 3850 \text{ ohms.}$$

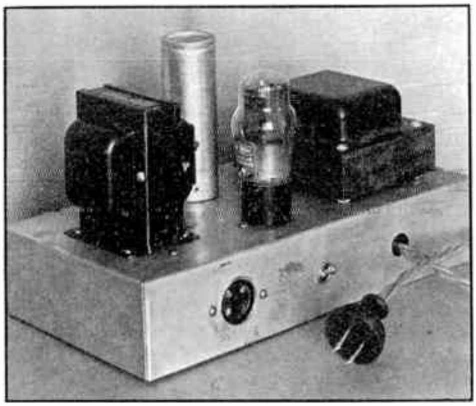


FIG. 1519 — A HEAVY-DUTY RECEIVER POWER-SUPPLY

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

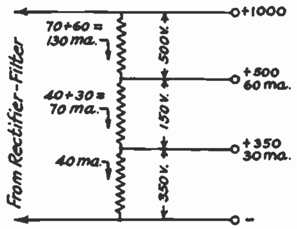


FIG. 1520 — VOLTAGE DIVIDER COMPUTATIONS CAN BE MADE BY PLOTTING THE VOLTAGE DROPS AND CURRENT DIVISION IN A DIAGRAM SIMILAR TO THIS ONE

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.

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.

Portable and Independent Power Supply

● The problem of power supply for a portable transmitter or one which must be operated where a commercial power line is not available is usually difficult to solve. In fact, independent power supply can usually be provided for only transmitters of low power requirements except at appreciable expense.

As mentioned previously, a series of 45 volt dry batteries totaling 250 to 350 volts may be used to provide plate voltage for low power transmitters. If reasonable battery life is to be expected, the total current load should not exceed a value of about 30 ma. for continuous operation from standard size batteries. In telegraph service this limit might be extended to perhaps 50 ma. Dry batteries are used most frequently for portable transmitters although they are also used successfully in permanent installations of low power.

A series of small "test tube" type storage cells with total voltage outputs of 200 to 500 volts have been used in the past and many may be found in service at the present time. Their disadvantages are that they require means for frequent recharging and they are more or less "messy" to handle. The maximum current which may be drawn with reasonable battery service is limited to 50 or 60 ma. They may be charged by connecting the cells in series-parallel from a 32 volt power plant or from a 110-volt d.c. line.

The increasing use of automobile radio receivers has brought about a revival of the "buzzer" type of transformer to obtain power at a voltage suitable for the plates of tubes from a low-voltage d.c. source such as a storage battery. In its modern form the vibrator-transformer consists of a specially-designed transformer combined with a vibrating interrupter; when the unit is connected to a 6-volt 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. Transformers of this type usually deliver about 200 volts and are obtainable in current ratings up to about 50 ma. Rectifier tube types 1, 1-V, and 84 are commonly used in this type of plate supply.

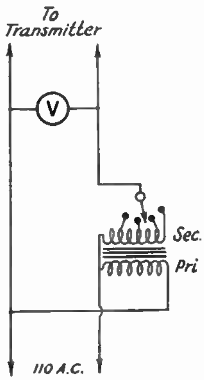


FIG. 1521 — SIMPLE METHOD OF CORRECTING CHANGES IN LINE VOLTAGE. THE TOY TRANSFORMER WITH TAPPED SECONDARY MAY BE CONNECTED SO AS TO INCREASE OR DECREASE LINE VOLTAGE AS DESCRIBED IN THE TEXT

Power supplies of this type can be obtained at reasonable cost and will be suitable for transmitters of very low power. Amateurs who have no a.c. have occasionally built higher-voltage power supplies operating on the same principle. A system using 6-volt batteries and Ford spark coils was described in the June, 1932, and June, 1934 issues of *QST*. A home-made transformer for use with 32-volt farm-lighting plants was described in the June, 1933, issue.

The most dependable type of independent power source is the high voltage d.c. generator or the a.c. rotary converter operating from 110, 32, 12 or 6 volts storage batteries. These are now available with a variety of output voltages and power ratings. They are comparatively expensive, however, and, of course, the storage battery providing the driving power must be recharged frequently.

Some amateurs have been successful in charging two or three 6 volt storage batteries by means of a small d.c. generator driven by a windmill. Such a charging system is described in the issue of *QST* for March 1934.

The only way by which the charging of storage batteries may be eliminated is by the use of a gasoline engine-driven generator. Power plants of this type are available in a variety of power ratings but, of course, are quite expensive.

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. 1521. 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 polarity 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 polarity of the two windings of the toy trans-

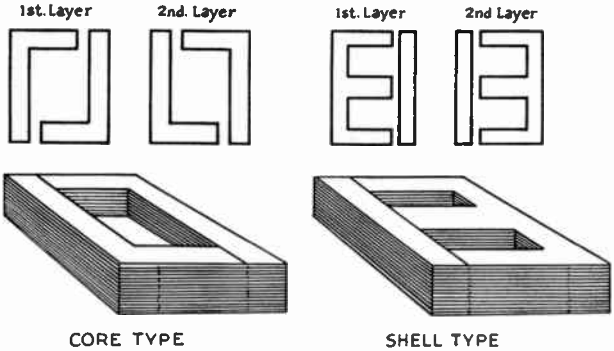


FIG. 1522 — TYPES OF TRANSFORMER CORES, SHOWING THE SHAPES OF LAMINATIONS

former 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.

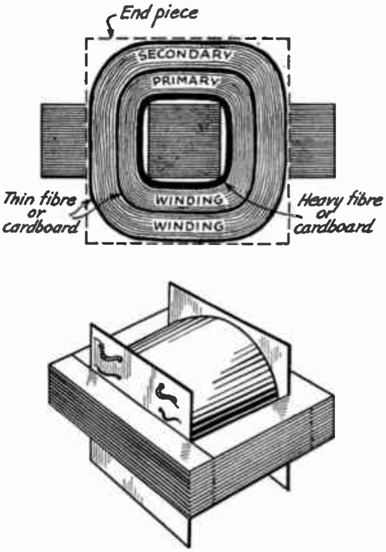


FIG. 1523 — A CONVENIENT METHOD OF ASSEMBLING THE WINDINGS ON A SHELL TYPE CORE

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.

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. 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:

$$\text{No. primary turns} = (7.5)\left(\frac{E}{A}\right)$$

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 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

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"

DESIGN DATA FOR INDUCTANCE COILS WITH IRON CORES. *Weight of Steel taken as 480 $\frac{lbs}{cu.ft.}$ = 0.28 $\frac{pounds}{cubic\ inches}$*

Wire	Core Size Cross Section	Inductance Henrys	Equiv Gap (G)	*Actual 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.		0.5	.040"	.017"	1/64"	1600	6500	0.42"	0.28"	3.0	400	82.5	1.0 oz	1/2 x 1.6"	1/2 x .50"	0.30
		1.0	.041	.019		2300	9000	0.50	0.33	3.2	615	127.0	1.5 "	1/2 x 1.7	1/2 x .55	0.31
	1/2 x 1/2	5.0	.043	.023		5200	20000	0.75	0.50	3.8	1670	345.0	4.0 "	1/2 x 1.92	1/2 x .75	0.37
		10.0	.046	.030	1/32"	7600	27000	0.90	0.60	4.2	2640	545.0	6.5 "	1/2 x 2.1	1/2 x .85	0.41
		15.0	.048	.035		9500	32000	1.00	0.68	4.5	3510	725.0	8.5 "	1/2 x 2.2	1/2 x .85	0.43
		5.0	.043"	.023		3500	13000	0.62"	0.42"	4.5	1310	271	3.25 oz	3/4 x 2.4	3/4 x .75	1.0
		10.0	.046	.030		5000	18000	0.73	0.49	4.75	2000	411	5.0 "	3/4 x 2.5	3/4 x .75	1.0
	3/4 x 3/4	15.0	.048	.035		6300	21000	0.82	0.55	5.0	2630	544	6.5 "	3/4 x 2.6	3/4 x .75	1.05
		20.0	.052	.044	3/64"	7600	24000	0.91	0.60	5.2	3280	678	8.0 "	3/4 x 2.7	3/4 x .85	1.1
		50.0	.070	.100	7/64"	14000	33000	1.25	0.83	6.0	7000	1445	1 LB 1 "	3/4 x 30	3/4 x 1.0	1.25
		10.0	.046"	.030	1/32"	3800	14000	0.64"	0.43"	5.6	1760	364	4.25 oz	1 x 3.0	1 x .75	2.1
		15.0	.048	.035		4800	16000	0.69	0.49	5.8	2310	478	5.5 "	1 x 30	1 x .75	2.1
	1 x 1	20.0	.052	.044	3/64"	5700	18000	0.78	0.52	5.9	2800	580	6.75 "	1 x 3.1	1 x .75	2.2
		50.0	.070	.100	7/64"	11000	25000	1.10	0.75	6.7	6130	1270	15.0 "	1 x 3.5	1 x 1.0	2.5
		100.0	.100	.250	1/4"	18000	29000	1.40	0.93	7.4	11000	2280	1 LB 10 "	1 x 3.8	1 x 1.1	2.75
	2 x 2	100.0	.100"	.250	1/4"	8900	14000	0.97"	0.65"	10.4	7700	1590	1 LB 3 oz	2 x 5.5	2 x 1.0	14.5
All wound with No 30 enamelled wire. 103 ohms per 1000 ft. 3287 ft. per lb. Carrying Capacity 0.10 amps.		0.5	.040"	.017	1/64"	1600	13000	0.55"	0.38"	3.4	450	46	2.2 oz	1/2 x 1.6	1/2 x 0.63	0.31
	1/2 x 1/2	1.0	.041	.019		2300	18000	0.66	0.45	3.6	700	72	3.5 "	1/2 x 1.75	1/2 x 0.70	0.35
		50	.043	.023		5200	39000	1.00	0.68	4.5	1950	200	9.5 "	1/2 x 2.10	1/2 x 0.95	0.43
		1.0	.041"	.019		1500	12000	0.53"	0.37"	4.3	540	56	2.7 oz	3/4 x 2.10	3/4 x 0.63	0.87
	3/4 x 3/4	5.0	.043	.023		3500	26000	0.83	0.56	5.0	1470	151	7.2 "	3/4 x 2.5	3/4 x 0.80	1.05
		10.0	.046	.030	1/32"	5000	35000	1.00	0.67	5.4	2250	230	11.0 "	3/4 x 2.6	3/4 x 0.95	1.12
		5.0	.043"	.023		2600	20000	0.71"	0.49"	5.8	1250	130	6.1 oz	1 x 2.8	1 x 0.75	2.0
	1 x 1	10.0	.046	.030	1/32"	3800	27000	0.86	0.58	6.1	1940	200	9.5 "	1 x 3.0	1 x 0.85	2.2
		15.0	.048.	.035		4800	32000	0.96	0.65	6.4	2550	260	12.5 "	1 x 3.1	1 x 0.90	2.25
		10.0	.046"	.030	1/32"	1900	13000	0.60"	0.42"	9.5	1500	160	7.5 oz	2 x 4.66	2 x 0.60	11.5
		15.0	.048	.035		2400	16000	0.68	0.46	9.7	1900	200	9.5 "	2 x 4.75	2 x 0.66	12.3
	2 x 2	20.0	.052	.044	3/64"	2900	18000	0.75	0.51	9.8	2400	250	11.5 "	2 x 4.85	2 x 0.75	12.5
		50.0	.070	.100	7/64"	5300	24000	1.00	0.70	10.5	4600	480	1 LB 6.5 "	2 x 5.50	2 x 0.95	14.0
		100.0	.100	.250	1/4"	8900	28000	1.33	0.90	11.2	8300	860	2 LB 8 "	2 x 5.90	2 x 1.15	16.0
All wound with No. 26 enamelled wire 40.75 ohms per 1000 ft. 1300 ft. per lb Carrying Capacity 0.25 amps	1/2 x 1/2	0.5	.040"	.017	1/64"	1600	32000	0.90"	0.60"	4.2	550	22.5	7 oz	1/2 x 2	1/2 x .85	0.40
		1.0	.082	.120	1/8"	3200	32000	1.30	0.85	5.1	1350	55	1 LB 1 "	1/2 x 2.5	1/2 x 1.10	0.50
	3/4 x 3/4	0.5	.040"	.017	1/64"	1000	21000	0.72"	0.46"	4.7	390	16	5 oz	3/4 x 2.3	3/4 x 0.71	0.96
		1.0	.041	.019		1500	30000	0.90	0.58	5.1	640	26	8 "	3/4 x 2.5	3/4 x 0.83	1.05
	1 x 1	1.0	.041"	.019		1100	22000	0.75"	0.50"	5.8	530	22	6.5 oz	1 x 2.9	1 x 0.75	2.10
		5.0	.086	.170	11/64"	3700	35000	1.40	0.92	7.3	2260	92	1 LB 12 "	1 x 3.6	1 x 1.20	2.7
		5.0	.043"	.023	1/4"	1300	23000	0.82"	0.53"	9.7	1050	43	13 oz	2 x 4.9	2 x 0.80	12.7
	2 x 2	10.0	.050	.040	1/64"	2000	32000	1.05	0.68	10.5	1750	71	1 LB 6 "	2 x 5.2	2 x 1.0	13.8
		15.0	.096	.200	13/64"	3300	28000	1.35	0.86	11.1	3060	125	2 " 6 "	2 x 5.5	2 x 1.1	14.7
		20.0	.104	.280	9/32"	4000	32000	1.43	0.95	11.5	3820	156	2 " 15 "	2 x 5.6	2 x 1.2	15.2
		10.0	.046"	.030		1300	22000	0.81"	0.53"	14.0	1510	62	1 LB 3 oz	3 x 6.9	3 x 0.8	39
		15.0	.048	.035		1600	26000	0.90	0.60	14.2	1900	77	1 " 7 "	3 x 7.0	3 x 0.85	40
	3 x 3	20.0	.052	.044	3/64"	1900	30000	1.00	0.65	14.4	2300	93	1 " 12 "	3 x 7.1	3 x 0.9	41
		50.0	.140	.330	1/3"	5000	28000	1.60	1.10	15.9	6600	270	5 " 2 "	3 x 7.8	3 x 1.35	46
		100.0	.200	.600	19/32"	8400	34000	2.10	1.40	17.0	12000	485	9 " 3 "	3 x 8.3	3 x 1.65	50
All wound with No. 23 enamelled wire 20.32 ohms per 1000 ft. 648.4 ft per lb. Carrying Capacity 0.50 Amps.	1/2 x 1/2	0.5	0.16"	.35	11/32"	3200	32000	1.80"	1.20"	6.4	1700	35	2 LB 10 oz	1/2 x 3	1/2 x 1.45	0.62
	3/4 x 3/4	0.5	0.08"	.170	11/64"	1480	30000	1.25"	.83"	6.0	735	15	1 LB 2 oz	3/4 x 2.9	3/4 x 1.1	1.26
		1.0	0.16	.35	11/32"	3000	30000	1.75	1.20	7.2	1800	37	2 " 13 "	3/4 x 3.5	3/4 x 1.5	1.6
		0.5	0.04"	.02	1/64"	800	32000	0.90"	0.60"	6.2	410	8.5	0 LB 10 oz	1 x 3.0	1 x 0.85	2.2
	1 x 1	1.0	0.082	.17	11/64"	1600	31000	1.30	0.85	7.1	945	19	1 " 8 "	1 x 3.5	1 x 1.0	2.5
		5.0	0.387	.75	3/4"	7800	32000	2.90	1.90	11.0	7000	143	10 " 14 "	1 x 5.2	1 x 2.2	4.2
		1.0	0.041"	.019		560	22000	0.75"	0.50"	9.8	460	9.4	0 LB 12 oz	2 x 4.9	2 x 0.75	12.7
	2 x 2	5.0	0.086	.17	11/64"	1800	32000	1.35	0.90	11.3	1700	35	2 " 10 "	2 x 5.5	2 x 1.15	15.0
		10.0	0.184	.40	13/32"	3800	33000	2.00	1.30	12.8	4100	83	6 " 6 "	2 x 6.2	2 x 1.5	17.3
		5.0	0.043"	.023		860	30000	1.00"	0.60"	14.2	1000	21	1 LB 10 oz	3 x 7.1	3 x 0.85	40.0
		10.0	0.092	.20	13/64"	1840	31500	1.40	0.92	15.3	2350	48	3 " 10 "	3 x 7.5	3 x 1.15	43.5
	3 x 3	15.0	0.130	.30	19/64"	2620	32000	1.65	1.10	16.0	3500	71	5 " 7 "	3 x 7.8	3 x 1.4	46.0
		20.0	0.175	.38	3/8"	3500	32000	1.90	1.25	16.6	4850	99	7 " 8 "	3 x 8.1	3 x 1.5	48.0
		50.0	0.432	.80	13/16"	8700	32000	3.00	2.00	19.2	14000	282	21 " 8 "	3 x 9.3	3 x 2.3	58.0
		100.0	0.900	1.50	1 1/2"	16700	31500	4.10	2.80	22.0	31000	620	47 " 5 "	3 x 10.5	3 x 3.1	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.

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 inches 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 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. 1522. 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. 1523 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 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. 1522 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 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

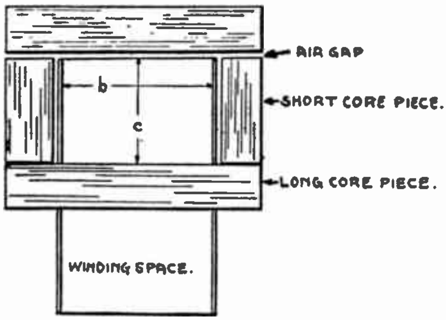


FIG. 1524 — CORE ARRANGEMENT FOR FILTER CHOKE COILS
The dimensions b and c refer to the full-page table.

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. 1524. The core may be built of straight pieces, as shown, or from L-shaped laminations of the type shown in Fig. 1522.

The table 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. 1524. The arrangement of core and winding should be that of the diagram, also.

CHAPTER SIXTEEN

Antennas

TYPES OF ANTENNAS — FEEDER SYSTEMS — IMPEDANCE MATCHING — DIRECTIVE ARRAYS — ANTENNAS FOR THE ULTRA-HIGH FREQUENCIES

THE antenna systems used by amateurs are of two types, called "Marconi" and "Hertz" antennas after the men who first applied them to radio communication. The Marconi antenna, which may be a single wire, vertical or part vertical and part horizontal, is connected to the ground through coupling and tuning apparatus; in its performance the ground plays an essential part. The Hertz antenna is a single wire suspended above the earth; the earth plays no part in the mechanism of radiation from the Hertz antenna, although it has a profound effect on its practical performance. For short-wave work the Hertz antenna is used almost exclusively; however, at the lower amateur frequencies, particularly in the 1715–2000-kc. band, space limitations sometimes preclude its use by amateurs and the grounded antenna must be substituted.

The fundamental principles on which antennas operate have already been discussed in Chapter Four. A complete understanding of these principles is, of course, of great value to the amateur interested in planning his own antenna system and in getting the best possible performance from it.

Contrary to usual practice throughout this *Handbook*, in this chapter we shall find it more convenient to speak in terms of wavelength than in terms of frequency. At the same time, however, the relationship between frequency and wavelength should be kept in mind continually.

The Grounded Antenna

● The important points about the grounded antenna are three: its length, height and the ground connection. To be most effective, the antenna should be as high as possible and the ground connection should have low r.f. resistance.

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 natural wavelength of a bent grounded antenna is approximately 4.2 times its actual length. It is not necessary to make a highly-accurate calculation when figuring the length of a grounded antenna because the tuning apparatus inserted at the base will compensate for discrepancies between the natural wavelength and the transmitter wavelength or frequency. For example, an antenna for 1900 kc. (158 meters wavelength) should be 158/4.2 or 37.6 meters long, corresponding to a length of 124 feet. This length, it should be noted, is the *total* length from the far end of the antenna to the ground connection.

Hertz Antennas

● The natural wavelength of a Hertz antenna depends primarily upon its length and secondarily upon such factors as may operate to change the distributed constants of the wire from those it would have in space. The natural wavelength is approximately twice the length of the wire, as explained in Chapter Four. In practice the natural wavelength of the wire will be somewhat greater than twice the physical length, partly because electromagnetic waves do not travel quite as fast on wires as they do in space, and partly because the antenna is in proximity to other objects, including the antenna poles, guy wires and insulators, all of which increase the distributed capacity and thereby increase the wavelength of the antenna. Because of the varying nature of these extraneous effects, the natural period of a given length of wire will differ with different surroundings. If the antenna is reasonably clear of other objects and is well off the ground, its natural wavelength will be between 2.07 and 2.1 times its actual length.

The following formulas can be used for figuring antenna length:

Length (feet) = 1.56 × wavelength in meters.
Length (meters) = 0.475 × wavelength in meters.

$$\textbf{Length (feet)} = \frac{468{,}000}{\text{Freq. (kc.)}} = \frac{468}{\text{Freq. (mc.)}}.$$

$$\textbf{Length (meters)} = \frac{142{,}500}{\text{Freq. (kc.)}} = \frac{142.5}{\text{Freq. (mc.)}}.$$

The lengths given by the formulas are for half-wave antennas — the minimum length that can be used for the frequency or wavelength in question. As explained in Chapter Four, the wire may be any integral multiple of a half wave in length, so long as a whole number of complete standing waves can appear on it. Thus an antenna having a length double that given by the formulas will have two half waves on it; it is known as a full-wave or second harmonic antenna. The fact that the antenna may be any number of half waves long makes it possible to use the same antenna for work in several bands, since a full-wave (second-harmonic) antenna for one band will be a half-wave (fundamental) antenna on the next lower-frequency band, two full waves long (fourth harmonic) on the next higher-frequency band, and so on.

Directional Effects of Hertz Antennas

● The direction or directions in which the greatest amount of radio-frequency energy is radiated from a Hertz antenna varies with its length (measured in wavelengths), its height above ground, and the character of the ground and surrounding objects. If the antenna were in free space, i.e., remote from ground and other objects, its directional characteristic would be as shown in Fig. 1601. Although shown plane, these figures should be imagined as being rotated about the line of the antenna as an axis, since the radiation characteristic is three-dimensional. Thus the radiation characteristic of a half-wave antenna will resemble a doughnut in shape, with the axis of the wire running through the hole; the full-wave characteristic will resemble two cones point to point, etc.

Angle of Radiation

● When the antenna is suspended above the ground its directional characteristic is changed because some of the energy radiated toward the ground is reflected back into space. The reflected energy reinforces the original space radiation at certain angles in the plane perpendicular to earth and cancels it in others. The ground therefore affects the *angle of radiation*, discussed in Chapter Five. The effect of the ground depends upon the position of the antenna with respect to earth (vertical, horizontal, etc.,) its height above ground, and the characteristics of the ground itself. If the ground is a good "electrical mirror" the vertical radiation will be reinforced and the horizontal radiation cancelled when a horizontal

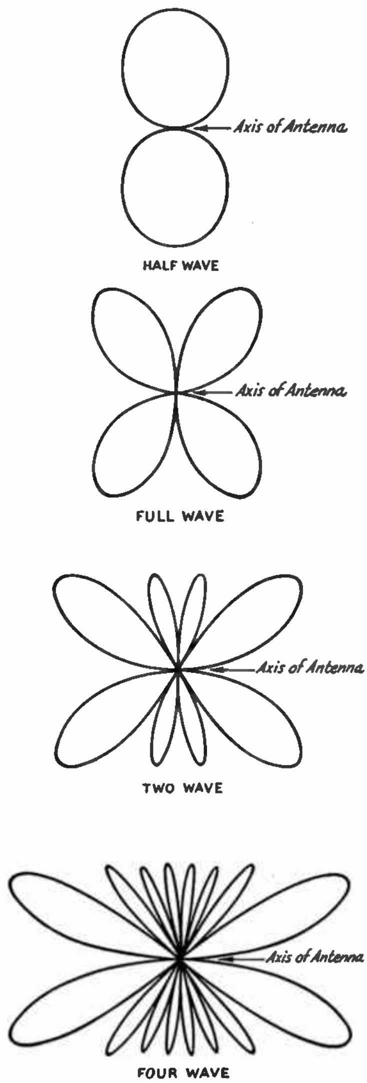


FIG. 1601 — CROSS-SECTIONS OF SPACE DIRECTIONAL PATTERNS OF HERTZ ANTENNAS

The lobes are drawn to scale, and are based on the assumption that the same power is supplied to the antenna in each case. An actual picture of the radiation characteristic in space can be obtained by imagining the drawings rotated about the line of the antenna as an axis.

antenna is a quarter wavelength above the ground. As the height is increased, radiation at lower angles is reinforced, although purely horizontal radiation always is cancelled with the horizontal antenna. On frequencies where low-angle radiation is desirable, particularly 14 mc., and higher, a horizontal antenna always should be at least a half wavelength (about 35 feet) above ground, and preferably higher.

The effect of the ground is exactly the same with a vertical antenna an even number of half-waves long; that is, horizontal radiation is cancelled. Thus a vertical antenna should not be a full wave long if very low-angle radiation is wanted. With an antenna an odd number of half-waves long, however, the ground will in general reinforce the low-angle radiation regardless of height. Vertical antennas are ordinarily used only for 14 mc. and higher frequencies because of constructional difficulties at the lower frequencies.

Fig. 1601 shows that as the antenna length is increased the major radiation lobe (each loop or cone of radiation is known as a "lobe") makes a smaller angle with the axis of the wire. Since this applies in all planes, long-wire antennas are lower-angle radiators than short antennas. A horizontal antenna one or two wavelengths long at a height of from one-half to one wavelength above ground will be a quite effective low-angle radiator at 14-mc. The angle which the major radiation lobes make with the antenna wire are shown in Fig. 1602 as a function of the antenna length.

The foregoing discussion should make it plain that the drawings of Fig. 1601 are not pictures of the directivity of a horizontal antenna viewed from above. They will represent approximately the horizontal-plane directional pattern at the lowest possible angle of radiation, but considerable radiation may take place at higher angles in directions which appear to give no radiation at all in the drawings. A half-wave horizontal antenna, for example, will be practically non-directional on frequencies where the angle of radiation is not highly important, as at 3.5 mc. On the other hand, at 14 mc. a half-wave antenna may show more pronounced directional characteristics because only the low angle radiation is effective under ordinary conditions. Such an antenna radiates best at right angles to the wire.

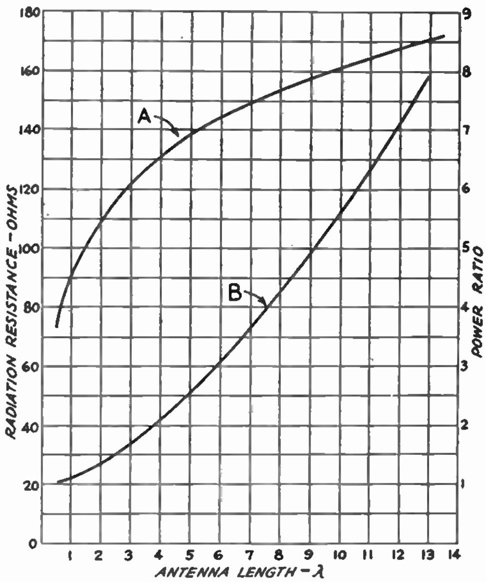


FIG. 1603 — THE IMPORTANT CURVES FOR HARMONICALLY-OPERATED HORIZONTAL ANTENNAS

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.

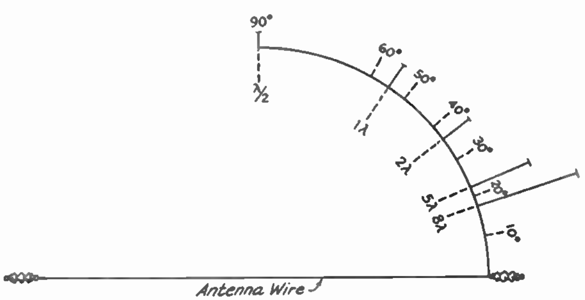


FIG. 1602 — ANGLES OF MAXIMUM RADIATION, MEASURED FROM THE LINE OF THE ANTENNA, FOR ANTENNAS OF DIFFERENT LENGTHS IN TERMS OF THE OPERATING WAVELENGTH

The angles are shown for one quadrant but correspond for the other three. The relative lengths of the extended solid lines indicating the angles of maximum lobes show power ratios compared with the maximum for a half-wave doublet (90°), assuming the same current at a current loop for each case.

Radiation Resistance and Antenna Impedance

● As explained in Chapter Four, an important antenna property is its radiation resistance. This varies with the length of the antenna, its position with respect to surrounding objects, character of the ground and other local conditions. In space, the radiation resistance of a half-wave Hertz antenna is approximately 70 ohms, measured at the center of the antenna. Curve A in Fig. 1603 shows how the radiation resistance varies with the length of the antenna. Because of the higher radiation resistance, the proportion of power radiated to power supplied the antenna is increased as the length of the antenna is increased. Curve B shows the relative power in the major radiation lobe, using a half-wave antenna as the basis of comparison. The power in the major lobe of a four-wave antenna, for instance, will be twice as great as in the major lobe of a half-wave antenna, assuming the same antenna current in both cases. Since the antenna current will decrease as the radiation resistance increases, however, the actual power ratio will not be as favorable, assuming the same *power* input to the antenna. Some gain actually results from the use of a long antenna, however.

The impedance of an antenna varies with the point along the antenna at which it is measured. It is minimum and practically equal to the radiation resistance at a current loop or antinode, and is maximum at a voltage loop, with intermediate values at intermediate points. The impedance of a half-wave antenna varies from approximtely 70 ohms at the center to something in the vicinity of 2000 ohms at the ends.

Methods of Feeding

● Before the antenna can do any radiating it must be supplied with power from the transmitter. This process is called "feeding" or "exciting" the antenna. Antennas may be directly excited or fed through a non-radiating transmission line, the transmitter being placed in any convenient location in the latter case. The transmission-line method has a number of advantages, since it permits placing the antenna in the clear, well away from objects such as trees and buildings which might absorb some of the radiated energy.

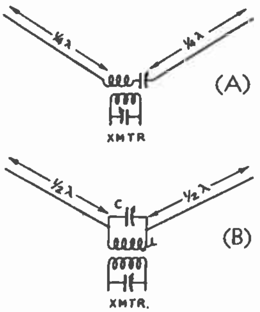


FIG. 1604 — DIRECT EXCITATION OF ANTENNAS, SHOWING CURRENT AND VOLTAGE FEED

When an antenna is directly excited a portion of it must be brought into the station to reach the coupling apparatus at the transmitter. General practice is to feed such an antenna either at one end or at its center. The antenna may be either "current" or "voltage" fed. These labels simply mean that the power is introduced into the antenna either at a point of maximum current — a current loop — or a point of maximum voltage — a voltage loop or current node.

Current and Voltage Feed

● Current and voltage feed are shown in Fig. 1604. The coupling apparatus for current feed (A) consists of a coil and condenser (often two condensers, one on each side of the coil are used) connected in series with the antenna. This type of tuning, known as *series tuning*, is used because the power is introduced at a point of low impedance.

When coupling to a voltage loop, it is necessary to feed the power to the antenna at high r.f. voltage but low current. For this purpose the tuning apparatus is connected as shown in Fig. 1604-B. This is known as *parallel tuning*, and is suitable for introducing power at a high-impedance point. A balanced arrangement, using a half-wave antenna each side of the coupling apparatus, is shown; however, one of the half-wave antennas could be omitted.

With series tuning, the coil usually consists of but comparatively few turns, while the series condenser or condensers should have a capacity of about 250 to 350 μμfd. each. Parallel tuning calls for a high *L-C* ratio for best results; if the antenna is a half-wave or an exact multiple of a half-wave long the circuit *CL* should be proportioned to tune to the transmitting frequency without the antenna connected.

An End-Fed Multi-Band Antenna

● A simple and practical antenna system suitable for operation in five amateur bands is shown in Fig. 1605. One end of the antenna must be brought into the station; the other end should be in the clear and as high as possible. The antenna is voltage-fed — or "end-fed" — on four bands and is operated against ground as a Marconi antenna on the fifth.

The tuning procedure should be as follows: With the antenna disconnected from the circuit *LC*, start the transmitter and tune *LC* to resonance as indicated by a sharp increase in the transmitting-tube plate current. Now loosen the coupling until the plate current gives only a small kick as *LC* is tuned through resonance. Next, connect the antenna and retune *LC* for the plate-current kick; the resonance indication will be broader with the antenna connected, but should still come at the same setting of *C* if the antenna length is correct. Increase the coupling in small steps, simultaneously readjusting *C* and the transmitter tank condenser to resonance each time the coupling is changed, until the transmitter is drawing normal plate current. *Always use the loosest coupling that will give normal transmitter plate current with both the transmitter tank and coupling tank adjusted to resonance.* A neon

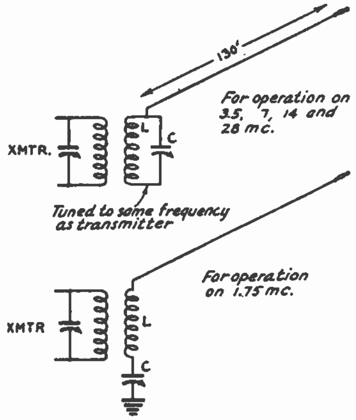


FIG. 1605 — A SIMPLE ANTENNA SYSTEM FOR FIVE AMATEUR BANDS

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.

bulb touched to the end of the antenna will give, by the brightness of its glow, some indication of the r.f. voltage at the coupling point.

In using the antenna arrangement of Fig. 1605 as a grounded antenna, tuning is simply a question of adjusting the size of L and the setting of C to give resonance with the transmitter frequency. An ammeter may be inserted in the antenna at the point where it is connected to the upper end of L and the tuning adjusted for maximum current. The ground lead with this antenna system should preferably be short, otherwise it will make the antenna length a great deal more than a quarter wave and necessitate a change in the tuning system.

This type of antenna also may be coupled to the transmitter through a link line, using a parallel-tuned tank as shown at the antenna end, or through an antenna-coupling filter. These methods are detailed in Chapter Eight.

Transmission-Line Feed

● Radio-frequency transmission lines are of two general types, those on which standing waves similar to the standing waves on the antenna appear (tuned or resonant lines) and those having uniform current distribution along the line (untuned, non-resonant or aperiodic lines).

The impedance of the untuned transmission line must be matched to that of the antenna at the point of connection. Since this can be done accurately for only one frequency, an antenna system incorporating an untuned line is essentially a single-frequency (or perhaps single-band) affair, although with certain systems multi-band operation is possible with some sacrifice of efficiency. The tuned transmission line, on the other hand, is readily adaptable to multi-band operation. With the lengths of line used by most amateurs there is little to choose between the two types from the standpoint of line losses, although when the line is more than a wavelength or two long the untuned line, properly adjusted, usually will have somewhat lower losses. Tuned lines are somewhat simpler to build and adjust than untuned lines.

Tuned Transmission Lines

● A resonant transmission line is simply an antenna that has been folded so that the currents flowing in the two parts are opposite in phase but of the same magnitude, as explained in Chapter Four. The radiation from one wire therefore cancels that from the other.

Although tuned transmission lines may be of almost any length, there are two important practical cases. The first is that of a line one or any odd number of quarter waves in length. The line length is considered to be that of one wire only; that is, a folded half-wave wire is a quarter-wave line, etc. Such a line possesses the property of transforming the impedance of the part of the antenna to which it is connected from a high to a low value and vice versa. In other words, if the output end of the line is connected to a voltage-feed point on the antenna, current feed will be required to the line itself at its input end. If the line is connected to a current-feed point, voltage feed will be required to the line at the input end.

The other type of tuned line is that having a length equal to some even number of quarter waves. With such a line the impedance looking into the line at the input end will be the same as the impedance connected to the output end. Therefore if a half-wave line is connected to a voltage-feed point on the antenna, voltage feed will be required at the input end of the line, etc.

The two wires of the tuned transmission line should both be exactly the same length. They are usually spaced from three to twelve inches apart. The spacing is not critical at most frequencies; since even a foot separation represents but a very small fraction of a wavelength the cancellation is practically complete. It is preferable to make the length of the line an exact multiple of a quarter wavelength, although this is not strictly necessary because the tuning apparatus can serve the double purpose of coupling in the power from the transmitter and of loading the feeders to compensate electrically for differences between a quarter wavelength and the actual length of the wires.

The Zepp

● Probably the most popular type of Hertz antenna with tuned feeders is the Zeppelin or "Zepp" antenna, so-called because of its early use on Zeppelin airships. The Zepp is a Hertz antenna with one wire of the tuned feed line connected to one end of the antenna. The other feed wire is left floating. The antenna is therefore voltage-fed from the transmission line.

The antenna may be any number of half waves long, the length of a half wave being computed by the formula previously given. The feeder is usually an odd multiple of a quarter wavelength long, although other lengths may be used. Series tuning can be used with feeders having a length between one-quarter and three-eighths of a wavelength; for feeders much less than a quarter wave long, or for lengths from approximately three-eighths up to one-half wavelength, parallel tuning will be required. Some lengths are more easily handled than others; recommended lengths for various frequencies and the tuning method required in each case are given under

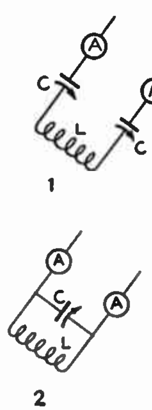


FIG. 1606 — SERIES AND PARALLEL FEEDER TUNING

Series tuning is used when there is a current loop on the feeders at the coupling point; parallel tuning when a voltage loop appears at the coupling point. The feeders are operating properly when the currents indicated by the two ammeters are identical.

Fig. 1607. Fig. 1606 shows larger-scale diagrams of series and parallel feeder tuning, and also shows how r.f. ammeters may be connected in the feeders to indicate resonance. The use of two ammeters is not actually necessary; a single ammeter may be switched from one feeder to the other during the tuning process. Both ammeters should give the same readings; if the readings differ by more than 10% or so when the antenna system is tuned exactly to resonance with the transmitter, the system is not properly balanced. Care should be taken to see that both feeders are the same length and that the leads inside the station from the coupling apparatus to the feeders are symmetrical. The length of the antenna itself also must be correct if the feeder currents are to be balanced.

In the series-tuning arrangement it is not necessary to have two tuning condensers, but they are often used because with two condensers it is possible to shift the voltage node to a desirable point on the coupling coil, *L*, and to compensate for the effect of stray capacities at the tuning apparatus. The current distribution in the feeders at resonance will be the same with either one or two condensers provided distributed and stray capacities in the tuning apparatus are negligible.

The numerical value of the feeder current indicated by the antenna ammeter or ammeters is not the true indication of how well the system is operating. If the meters happen

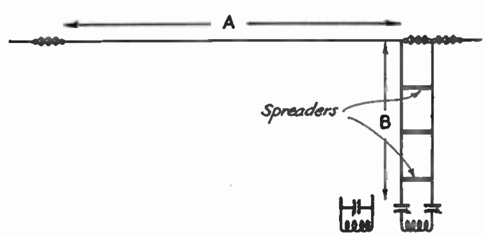


FIG. 1607 — THE ZEPPELIN ANTENNA

The antenna length, A, is given by the formula earlier in the chapter. It should be cut for a half wavelength on the lowest frequency to be used. Feeder lengths, B, and tuning arrangements can be taken from the table below.

Approximate Length of Each Wire, Feet	Tuning Arrangement for Various Bands				
	1750 kc. (160 m.)	3500 kc. (80 m.)	7000 kc. (40 m.)	14000 kc. (20 m.)	28000 kc. (10 m.)
120	Ser.	Par.	Par.	Par.	Ser. or Par.
90	Par.	Ser.	Ser.	Par.	Ser. or Par.
60	Par.	Ser.	Par.	Par.	Ser. or Par.
40	(---)	Par.	Ser.	Par.	Par.
30	(---)	(---)	Ser.	Par.	Ser. or Par.
15	(---)	(---)	Par.	Ser.	Par.
8	(---)	(---)	(---)	Par.	Ser.

Ser. — *Series Tuning.* Par. — *Parallel Tuning.* (---) — *Not Recommended.*

to be connected at or near current nodes (voltage loops) they will indicate very little current. This is particularly likely to happen when parallel tuning is used and the feeders are nearly multiples of ½-wave long for the frequency being used.

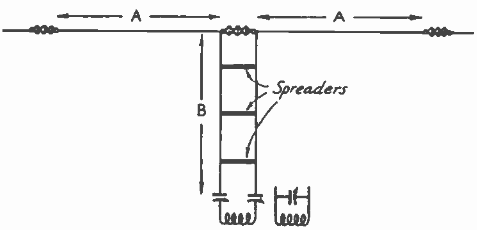


FIG. 1608 — CENTER-FED ANTENNA WITH TUNED FEEDERS

The total antenna length, A plus A, is calculated from the formula given early in this chapter. The antenna should be cut to be a half-wave long on the lowest frequency to be used.

Feeder lengths may be identical with those recommended for the Zepp antenna in Fig. 1607. If the antenna is a half-wave long at the operating frequency, the tuning arrangements should be reversed (parallel tuning where series is specified, etc.). If the antenna is operated on a harmonic, use the tuning specifications exactly as given in Fig. 1607.

A Zepp antenna system suitable for operation in several amateur bands is shown in Fig. 1607.

Center-Fed Antennas

● An antenna also may be fed at the center through a tuned transmission line. When a half-wave antenna is fed at the center there must be a current loop at the end of the transmission line; the antenna is cut in the center, and each half is connected to one of the feeder wires. The center-fed arrangement may be preferred when it is more convenient to feed the antenna at the center than at one end.

An antenna fed at the center by a tuned transmission line may be either current- or voltage-fed. If the antenna is a half wave in length, it will be current-fed; however, voltage-feed will be necessary if the length is a multiple of a half wave. A center-fed antenna with tuned feeders is shown in Fig. 1608.

Tuning

● The tuning of Zepp and center-fed systems is quite similar. When series tuning is used with either of the typical antenna systems shown in Figs. 1607 and 1608, the series condensers should be set at maximum capacity; with parallel tuning, at minimum. After the transmitter has been set on the desired frequency the antenna coupling coil should be coupled to the transmitter tank and the series condensers tuned simultaneously, from maximum capacity down, until the radio-frequency ammeter shows maximum feeder current and the plate milliammeter shows normal plate current. If the meters should show two points of maximum current, the coupling should be loosened. After tuning for maximum current the capacity of the feeder series condensers should be increased until the current drops about 15%, if the transmitter is a self-excited rig. With an oscillator-amplifier set the best tuning adjustment is the one which gives maximum balanced feeder current. The procedure with parallel feeder tuning is similar except that the parallel condenser is tuned from minimum capacity upwards instead of from maximum capacity down. If the feeder current should be very low in value with parallel tuning, the plate input as shown by the plate milliammeter will be a better indication of resonance. Plate current should be the greatest when the feeder circuit is tuned to resonance.

Tuned transmission lines are particularly advantageous for amateur work because all the adjustments can be made inside the station. The dimensions of the antenna system also are less critical than when the antenna is fed by an untuned line. Should the length of the antenna be slightly incorrect for the operating frequency the only result will be a corresponding lack of balance in the feeder currents. While this may cause the feeders to radiate a small portion of the energy supplied to them, nevertheless the whole system can still be tuned to resonance and will operate at good efficiency.

Untuned Transmission Lines

● The tuned transmission lines just described operate with standing waves on them and therefore their length is an important consideration. The untuned transmission line, on the other hand, operates without standing waves and can be made any random length, provided it is properly coupled to the antenna.

Any transmission line has distributed inductance and capacity, just as has the antenna. The inductance and capacity per unit length determine the characteristic or surge impedance of the line; inductance and capacity in turn depend upon the size of the wire used and the spacing between the wires, if the line consists of two parallel wires. The surge impedance will be

$$Z = 276 \log \frac{b}{a}$$

where Z is the surge impedance, b is the wire spacing, and a is the radius of the wire.

It is a characteristic of a transmission line that if it is terminated in an impedance equal to its surge impedance, reflection cannot occur and standing waves will not be present. It is the object, therefore, in adjusting the untuned transmission line to terminate it at the antenna in an impedance equal to its surge impedance. When this is done the line can be any convenient length, radiation will be eliminated, and substantially all the power fed into the line will be delivered to the antenna.

Practically all r.f. transmission lines have fairly low impedance — 600 ohms or less — so that the line usually is terminated near the center of the antenna where the antenna impedance also is low. The termination can be made by inserting a coil at the center of the antenna (in series with a condenser so the loading effect of the coil can be cancelled) and using inductive coupling to the line, which is also provided with a coupling coil. Then by adjusting the coupling and the number of turns in each coil — while power is being supplied by the transmitter to the sending end of the line — for maximum current in the antenna and uniform current along the transmission line, the antenna impedance can be properly matched to that of the line. An untuned line is properly terminated only when the current shows no variations with distance along the line. On very long lines there may be a gradual but uniform decrease in current, but there will be no standing waves.

Terminating a line by the method just described requires that tuning apparatus be inserted in the antenna, which is inconvenient. Simpler methods make use of the fact that the impedance of an antenna varies through a wide range of values along its length, and depend for the impedance match upon connecting the line to the proper point along the antenna or, when this is not practicable, by the use of linear matching devices. The need for tuning apparatus at the antenna is thereby eliminated.

Single-Wire Feed

● The single-wire matched-impedance feed system operates on the same principle as the two-wire line, the return circuit being considered to be through the "mirror" effect of the ground. There will be no standing waves on the feeder

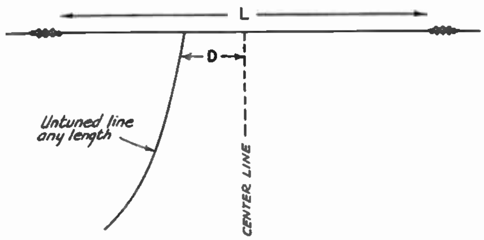


FIG. 1609 — SINGLE-WIRE FEED SYSTEM

The length L and coupling D are determined from the chart, Fig. 1610.

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. 1609, and the distance *D* from the exact center of the antenna to the point at which the feeder is attached. These dimensions can be obtained from Fig. 1610 for an antenna system having a fundamental frequency in any of the amateur bands. Although the dimensions shown in the chart are for the 3500-kc. band, the dimensions for the 7000-kc. band can be obtained by multiplying the frequency by 2 and dividing the lengths by 2; and for the 14,000-kc. band by

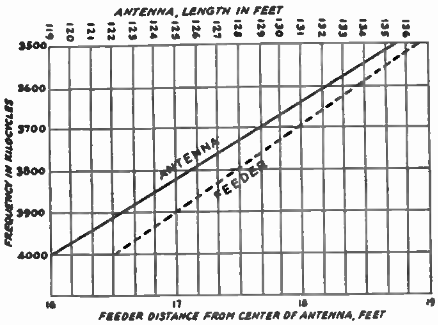


FIG. 1610 — SINGLE-WIRE FEED DATA CHART FOR NO. 14 WIRE FEEDER

multiplying the frequency by 4 and dividing the lengths by 4.

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 ⅓ the length of the antenna. Otherwise the field of the antenna will affect the feeder and cause faulty operation of the system. There should be no sharp bends in the feeder wire at any point.

The feeder may be tapped directly on the transmitter tank coil, the position of the tap being adjusted to make the final stage draw normal plate current.

Twisted-Pair Feeders

● It is evident from the formula for characteristic impedance previously given that the 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. 1611.

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, however. Special twisted line for transmitting purposes, having lower losses than ordinary rubber-covered wire, is available. It is known as "EO-1" cable.

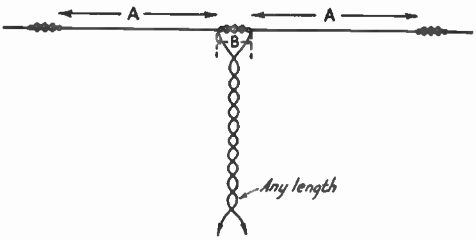


FIG. 1611 — A HALF-WAVE ANTENNA CENTER-FED BY A TWISTED PAIR LINE

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.

The "Doublet" Antenna

● A third type of matching is used in the "doublet" type of antenna shown in Fig. 1612. 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.

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 more critical than those of tuned feeder systems.

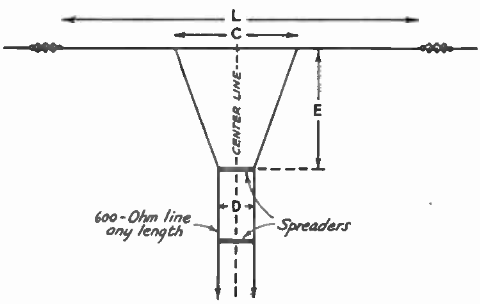


FIG. 1612 — TWO-WIRE MATCHED-IMPEDANCE ANTENNA SYSTEM

The dimensions L, 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.

The length of the antenna is figured as follows:

$$L \text{ (feet)} = \frac{492{,}000}{F} \times K; \text{ or}$$

$$L \text{ (meters)} = \frac{150{,}000}{F} \times K$$

where L is the antenna length in feet or meters for a desired fundamental frequency F, and K is a constant depending on the frequency. For frequencies below 3000 kc. (wavelengths above 100 meters) K is 0.96; for frequencies between 3000 and 28,000 kc., K is 0.95; and for frequencies above 28,000 kc., K is 0.94. F is the frequency in kc.

The length of the antenna section C is computed by the formula:

$$C \text{ (feet)} = \frac{492{,}000}{F} \times K_1; \text{ or}$$

$$C \text{ (meters)} = \frac{150{,}000}{F} \times K_1$$

K_1 is 0.25 for frequencies below 3000 kc., 0.24 for frequencies between 3000 and 28,000 kc., and 0.23 for frequencies above 28,000 kc.

The feeder clearance E is worked out from the equation:

$$E \text{ (feet)} = \frac{147{,}600}{F}; \text{ or}$$

$$E \text{ (meters)} = \frac{45{,}000}{F}$$

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.

The "Q" Antenna

● The impedance of a two-wire line of ordinary impedance (400 to 600 ohms) can be matched to the impedance of the center of a half-wave antenna by the use of a quarter-wave line of special characteristics which acts as a matching transformer. The quarter-wave section must have a 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. 1613. 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.

The curves of Fig. 1614 show the required surge impedance for the matching section when connected at a current loop in antennas of several different lengths, using several values of untuned line impedance. A quarter-wave section matching a 600-ohm line to the center of a half-wave antenna, for example, should have a surge impedance of 212 ohms. Values for lines of other impedances can be found by interpolation. The spacings between conductors of various sizes of tubing and wire for different surge impedances are given in graphical form in Fig. 1615. With half-inch tubing, for example, the spacing should be 1.6 inches for an impedance of 212 ohms.

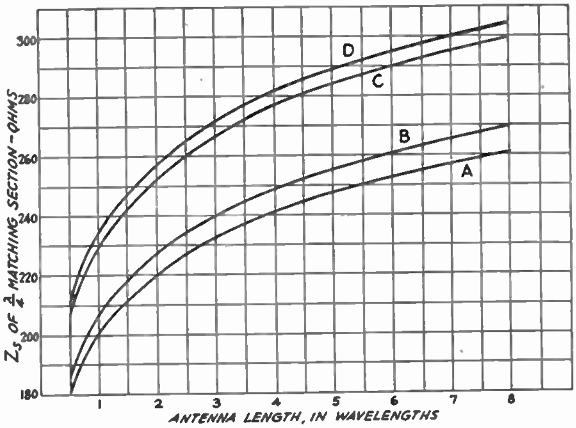


FIG. 1614 — REQUIRED SURGE IMPEDANCE OF QUARTER-WAVE MATCHING SECTIONS FOR RADIATORS OF VARIOUS LENGTHS

Curve A is for a transmission line impedance (Z_L) of 440 ohms, Curve B for 470 ohms, Curve for 580 ohms and Curve D for 600 ohms.

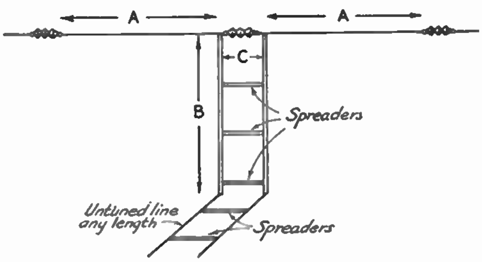


FIG. 1613 — THE "Q" ANTENNA WITH QUARTER-WAVE MATCHING SECTION USING SPACED TUBING

Antenna length, A plus A, can be calculated from the formula given earlier in this chapter. The matching section length, B, in feet, is equal to 246,000/freq. in kc., or 246/freq. in mc. The spacing, C, depends upon the impedance of the untuned line, and can be found from the charts of Figs. 1614 and 1615.

The length, *B*, of the matching section should be equal to a quarter wavelength in space. The length of the antenna can be calculated from the formulas given earlier in this chapter. It should be kept in mind that if the antenna is several half-waves long the matching section must be connected an odd number of quarter waves from one end of the antenna.

Matching by Linear Transformers

● A quarter-wave line of ordinary construction (spaced wire) can be used as a matching transformer in somewhat similar fashion to the matching section in the "Q" type antenna just described. The open-wire quarter wave section cannot satisfy the conditions for impedance match between an antenna and feed line when these are connected to its ends, however. It is therefore necessary to obtain the match by tapping the line at an appropriate point along the matching section, as shown in Fig. 1616. The impedance of a quarter-wave resonant line varies from a low value at one end to a high value at the other, as we have already pointed out, hence a point along the line can be found to match practically any type of transmission line.

Assuming that the antennas in Fig. 1616 have a length of one-half wave, the matching section in the center-fed system will be open-ended at the bottom, while the lower end will be closed in the end-fed system. In each case the length *B* will be a quarter wavelength in space; in the end-fed system this length can be adjusted by moving the shorting link, while in the center-fed system the length must be adjusted by cutting the wires. If the matching section is extended to a half wave in the center-fed system, a shorting link can be used at the lower end for adjustment. The length of the antenna can be found from the formulas previously given, *A* being a quarter wave and *A'* the full half wave.

To adjust these systems it is necessary to move the untuned line taps along the matching section until the current throughout the line is uniform. Standing waves on the line indicate a mismatch between line and antenna. It is important that the antenna length, as well as the matching section length, be correct. If they are not, a satisfactory match is practically impossible of attainment.

The position of the taps will depend upon the impedance of the line as well as the impedance of the antenna at the point of connection to the matching section. In general, the correct position can be found only by experiment.

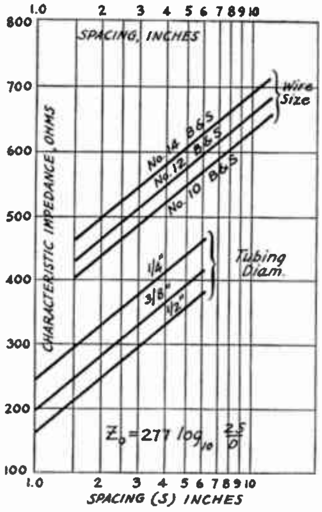


FIG. 1615 — GRAPHICAL TABLE OF CHARACTERISTIC IMPEDANCES OF TYPICAL SPACED-CONDUCTOR TRANSMISSION LINES

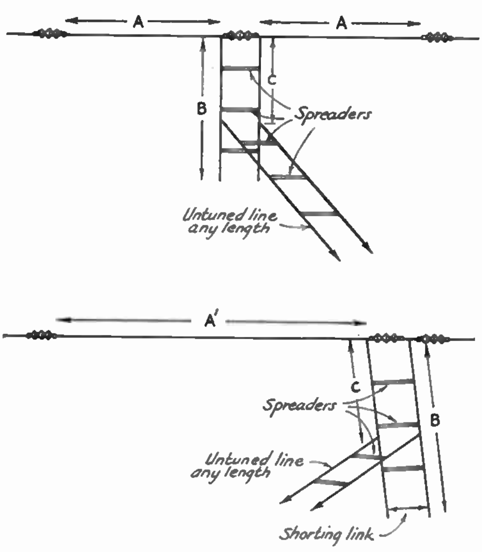


FIG. 1616 — IMPEDANCE-MATCHING ANTENNA SYSTEMS WITH QUARTER-WAVE OPEN WIRE MATCHING TRANSFORMERS

Antenna dimensions, A plus A in upper figure, A' in lower, can be found from the formulas earlier in this chapter. The dimension B, one-quarter wavelength, in feet, is equal to 246,000/freq. in kc., or 246/freq. in mc. The dimension C must be found by experiment, as described in the text.

Corrective Stub Matching

● A method of matching which resembles that just described employs a so-called "corrective stub" line whose length and point of attachment are adjusted to eliminate standing waves on an untuned transmission line connected to the center of an antenna. This system is shown in Fig. 1617. To use the corrective stub it is necessary to measure the current along the line without the stub, noting the positions of current maxima and minima, as shown in Fig. 1618. The table gives the length and position of the corrective stub for various maximum-to-minimum current ratios. An open stub is used near a current maxima and a closed stub near a current minima.

The stub performs much the same function as the matching section, but can be inserted at any convenient point along the transmission line, two positions being possible for every half wavelength of line.

Construction and Adjustment of Open-Wire Lines

● Since the wire spacing is the critical dimension in determining the impedance of an untuned line, it is essential that the wires be kept taut and uniformly spaced throughout the length of the line. This calls for the use of suitable spacers at frequent intervals along the line. The line may be transposed by using transposition insulators available from a number of manufacturers, but for transmitting work a non-transposed line is generally preferable. The line may be run around corners if suitably insulated and rigidly supported, but sharp bends in the wires must be avoided, since they cause a change of impedance.

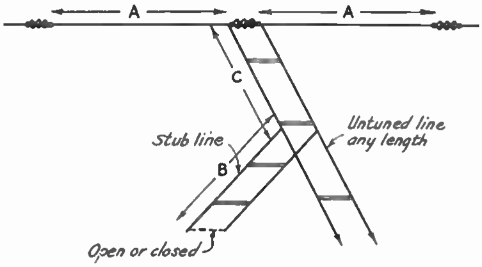


FIG. 1617 — ANTENNA SYSTEM WITH CORRECTIVE STUB FOR IMPEDANCE MATCHING

The formulas given earlier in the chapter give the antenna length, A plus A, each half being a quarter wave. The stub length, B, and point of attachment to the non-resonant line, C, can be found from the data in Fig. 1618.

In any of the matched systems, with the possible exception of the "Q" type when calculations have been carefully made and the line and matching section spacing is adjusted with equal care, the performance of the line should be checked in actual operation to make

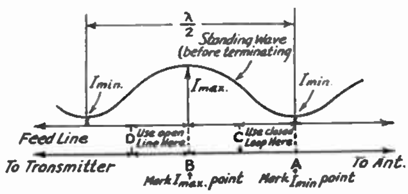


FIG. 1618 — SHOWING THE TWO POINTS, D OR C, AT WHICH THE AUXILIARY OPEN LINE OR CLOSED LOOP MAY BE PLACED, POINT D TAKING THE LINE AND POINT C THE LOOP

Only one or the other is used, depending upon the position selected on the feeder line.

Ratio I_{max}/I_{min}	Distances		Length of Line (For D)	Length of Loop (For C)
	B to D	A to C		
0.9	0.123λ	0.128λ	0.02λ	0.232λ
0.8	0.119λ	0.134λ	0.04λ	0.210λ
0.7	0.114λ	0.139λ	0.06λ	0.191λ
0.6	0.108λ	0.143λ	0.08λ	0.170λ
0.5	0.100λ	0.153λ	0.10λ	0.150λ
0.4	0.090λ	0.162λ	0.122λ	0.130λ
0.3	0.080λ	0.173λ	0.145λ	0.105λ
0.2	0.068λ	0.187λ	0.170λ	0.080λ

Distances and lengths of the line or loop are given in terms of λ or one wavelength. Wavelength, λ, in meters, equals 300,000 divided by frequency in kilocycles. One meter equals 3.28 feet.

certain that standing waves are eliminated. This can be done by measuring the current in the wires, using a device of the type pictured in Fig. 1619. 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 a few percent 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 and may be responsible for radiation which causes interference to nearby receivers and possibly extra losses in house-wiring circuits near which the transmission line must pass.

Coupling the Line to the Transmitter

● Untuned transmission lines may be tapped directly on the output tank coil of the transmitter. Balanced or two-wire lines should be tapped on symmetrically about the ground point on the tank; it is necessary to have a balanced tank for this purpose. The method is shown at *A* in Fig. 1620. 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.

When a single-ended tank must be coupled to a balanced line the method shown in Fig. 1620-B may be used. In this case the coupling tank is first adjusted to resonance with the plate tank, using loose coupling; the taps are then set at trial positions on L_1 and the current in the line measured. The tap positions and coupling between L_1 and L_2 are then adjusted to give maximum line current with normal tube plate current.

An antenna-coupling filter of the type shown in Chapter Eight also may be used to couple the transmitter to the line. The link-coupled antenna tuning-unit also is satisfactory.

Antenna Construction

● For the purpose of this discussion let us divide the antenna system into two parts — the conductors and the insulators. If the system is to operate most effectively the conductors must be of low resistance. On the other

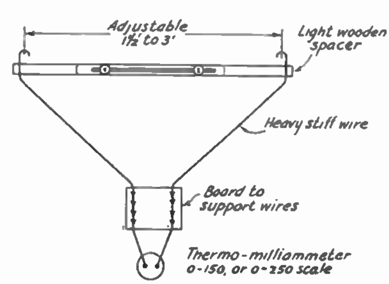


FIG. 1619 — LINE-CURRENT MEASURING DEVICE FOR ADJUSTMENT OF UNTUNED TRANSMISSION LINES

hand the insulators must be of the highest possible resistance. For short antennas and feeders an entirely satisfactory conductor is No. 14 gauge hard-drawn enamelled copper wire. For long antennas No. 12 gauge is preferable. 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 thoroughly soldered. It should always be possible to make the Hertz antenna portion in one piece.

If the feeder system is of the tuned type the currents in it will be of the same order as those in the antenna and the same care in avoiding joints is necessary. In the untuned feeder system, however, the currents are relatively low and this consideration is therefore not as important. In these cases smaller wire can be used if necessary.

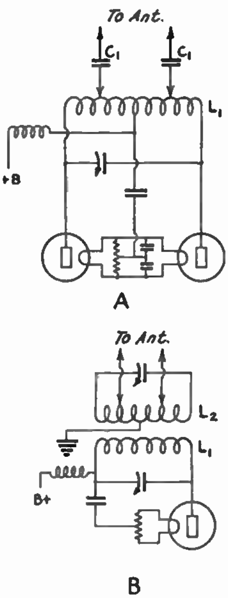


FIG. 1620 — METHODS OF COUPLING THE TWO-WIRE UNTUNED TRANSMISSION LINE TO THE TRANSMITTER

A is for coupling a push-pull or balanced tank circuit. The condensers marked C_1 are blocking condensers of about .002 μμfd. to keep the d.c. plate supply voltage from being applied to the feeders. The inductively-coupled arrangement at B is for use with single-ended oscillators or amplifiers. It can also be used with push-pull, thus making unnecessary the blocking condensers C_1.

In building a two-wire feeder the wires may be separated by wooden dowels which have been boiled in paraffin. In this way the feeder is given a tendency to swing in windy weather as a unit. When heavy glass or porcelain spacers are used the tendency is for each wire to vibrate with respect to the other, so causing changes in the capacity between the wires and consequent changes in the emitted frequency. 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.

A good insulation to use throughout the antenna system is Pyrex electrical-resistant glass. Glazed porcelain also is very good. 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. A 12″ Pyrex insulator is quite satisfactory for amateur transmitters of any power. For the low-powered transmitters one of the smaller sizes, or two in series, would be satisfactory.

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.

In most locations a variety of possible arrangements will present themselves. It will be well for the amateur to try the antenna in different positions or to try different types of antennas. Time expended in such experiment undoubtedly will be well worth while.

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. Likewise, it is advantageous to have the receiving antenna well out in the clear, away from power wiring which radiates the noises resulting from the use of electrical household appliances, and to bring the signal in to the receiver over a radio-frequency transmission line. A non-radiating transmission line is inefficient at intercepting signals, hence it can pass through locations where noise is great without picking up much interference. The transmission-line fed antennas used for transmitting will make excellent receiving antennas; a switch can be fitted in the feeders inside the station so that the an-

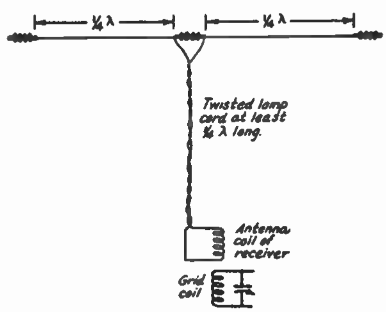


FIG. 1621 — DOUBLET RECEIVING ANTENNA

tenna can be connected to either the transmitter or receiver.

If a separate receiving antenna is preferred, a doublet antenna of the type shown in Fig. 1621 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.

Dummy Antennas

● The absolute value of current in an antenna or feeder system is practically meaningless so far as indicating actual power is concerned, because the resistance of the antenna or feeder at the point where the current is measured is rarely known. 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 interference 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. 1622. 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 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 ($W = I^2 R$). 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

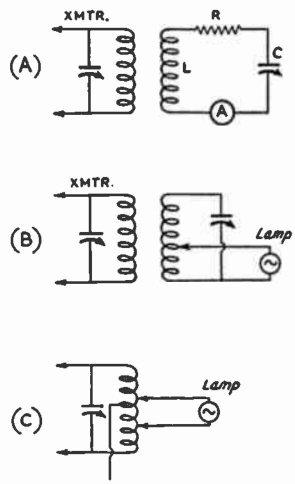


FIG. 1622—DUMMY ANTENNA CIRCUITS

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.

Practical Directive Systems

● As has already been indicated, directive arrays may be used to great advantage when particularly effective transmission or reception is desired in some one or two directions. Indeed, it is sometimes practical to arrange the directive system on a rotating framework, so allowing transmission or reception with maximum effectiveness in any desired direction.

It is unfortunate that all directive systems require much greater space than simple antennas. Because of this, it is rarely possible for the amateur to erect a satisfactory array for frequencies lower than 14 mc. Even on that frequency, more than the average yard space is usually required for the erection of the system and, at that, the optimum performance of the array cannot be expected unless the space is well clear of trees and buildings.

Another factor which complicates the erection of a satisfactory array for amateur work is the necessity for precise cut-and-try adjustment of the antennas, reflectors (if any) and the feeder system. While it is possible to compute the dimensions of the simple antenna with a fair order of accuracy, such computations are rarely adequate in the more complex arrays because of unpredictable "proximity" effects peculiar to any one set-up and location.

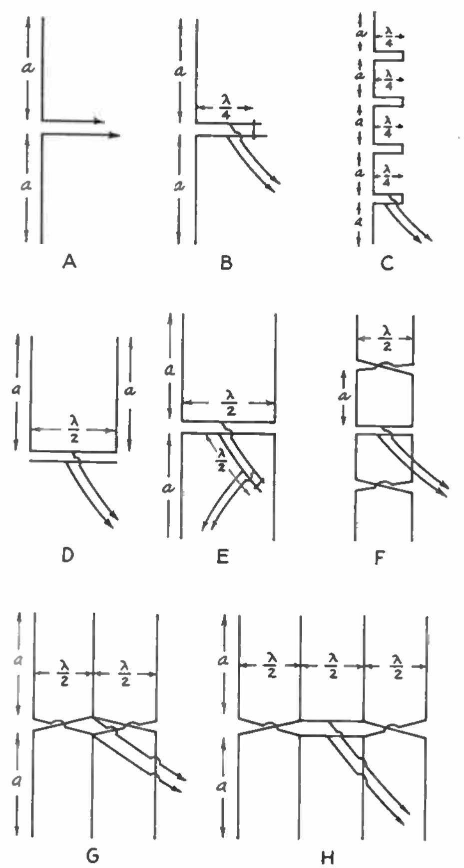


FIG. 1623 — A VARIETY OF DIRECTIVE ARRAYS INVOLVING THE USE OF PHASED ANTENNAS

Most of the types illustrated are suited particularly for the ultra-high frequencies. Types "A" and "D" are small enough to fit the average available space on 14 mc. The more complex arrays are usually too extensive except on 56 mc. and higher. Tuned feeders are shown on some types — matching sections and untuned lines on others. Obviously, the feed systems are interchangeable. See text for details of tuned feeders.

Phased Antennas

● By combining a number of half-wave antennas in various space relationships and exciting them in the proper phase, it is possible to concentrate the radiation in one or more desired directions. One of the simplest types of array involving this principle consists of two

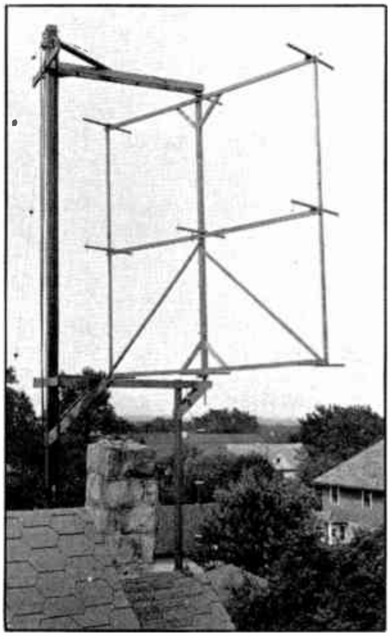


FIG. 1624 — THE 112-MC. ARRAY AT W2CUZ: AN EXCELLENT EXAMPLE OF CONSTRUCTION TO ALLOW ROTATION OF THE SYSTEM

The electrical arrangement of the antennas is that shown at "G" of Fig. 1623. Reflectors are mounted one quarter wave behind each of the antennas.

half-wave antennas stacked one above the other and excited in phase. The result is a system which radiates equally well in all directions in a horizontal plane but which tends to concentrate the radiation at some particular angle in the vertical plane. At the high frequencies, where it is possible to support the lower half-wave section well clear of the ground, the main "lobe" of radiation is usually at a low angle — a condition considered to be very favorable under the circumstances.

The same type of array can be carried further on the ultra-high frequency bands by using as many as five or six half-wave antennas one above the other and all operating in phase. With such a system, the directivity at a low angle to the horizon is very marked and a considerable gain in the range of the station is made possible. One simple method of maintaining the correct phase relationship in the antennas is that shown in Fig. 1623 at "C". A quarter-wave section is inserted at the junctions between each pair of antennas. These sections, in the actual array, may be mounted on small wooden cross-pieces on the mast itself. An alternative method is to include a coil-condenser tuned circuit in place of the quarter-wave sections. These tuned circuits may be built up with a small coil and midget variable condenser mounted on the metal lid of a small glass jar. The circuits may be tuned by the absorption method to the transmitter frequency and then connected into the antenna system.

Horizontal Directivity

● When half-wave antennas are mounted side by side and excited correctly, the radiation is concentrated in two directions in a horizontal plane. The simplest form of "broadside" antenna is that shown at "D" of Fig. 1623. The two antennas are a half wave apart and are excited in phase. Radiation is then concentrated in the directions at right angles to the plane of the antenna wires. The scheme can be carried further by providing four or more similarly phased antennas.

Array of Arrays

● On the ultra-high frequencies in particular, it is very desirable to use a combination of the vertical or "stacked" array and the broadside array, so obtaining directivity in both horizontal and vertical planes. The system shown at "E" in Fig. 1623 consists of a "broadsided" pair of array elements each consisting of two "stacked" half-wave antennas. Two variations of the same idea are shown at "F" and "H". In the former case, a number of two-element broadside sections are stacked vertically to give slight directivity in a horizontal plane but considerable vertical directivity. In the latter case, the horizontal directivity is accentuated. Both arrangements are particularly suited for ultra-high frequency working where the small length of the antenna elements permits eight or more of them to be used.

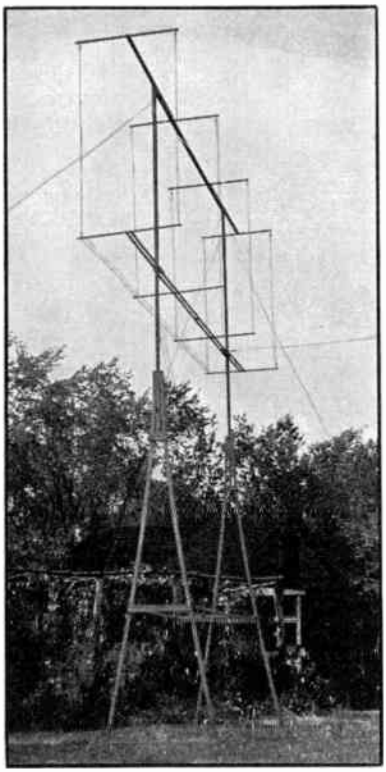


FIG. 1625 — A TYPICAL RIGID MOUNTING FOR THE ULTRA-HIGH FREQUENCY DIRECTIVE ARRAY

The array shown is similar to that of "H" in Fig. 1623 except that only the upper four antennas are used. Reflectors are mounted behind each antenna wire. Some such rigid mounting is very desirable for u.h.f. work. This particular array is used at W1HRX.

Feeding the Array

● The simplest method of feeding any of these arrays in practice is with a tuned feeder connected at some appropriate point. The simple rule to remember, in deciding on the point of attachment, is that an odd number of quarter waves will be required in the main feeder when it connects to the ends of antenna elements (as at "A" and "G" in Fig. 1623); and that an even number of quarter waves will be required when the feeders are connected in the center of one antenna element or in the center of any half-wave secondary feeder (as at "D" or "H". The same considerations apply to a tuned matching section which may be used in conjunction with an untuned line. At "B" the matching section is one quarter wave. At "E" it will need to be two quarter waves.

The array shown at "H" is relatively simple to feed since the impedance presented by the system is approximately 600 ohms. A 600-ohm line may merely be used in place of the tuned line to get reasonably good performance. The impedance of arrays of this particular type may be computed by dividing the end impedance of a half-wave antenna (about 2300 ohms) by the number of pairs of half-wave antennas employed.

Using Reflectors

● When a wire of appropriate length is placed an appropriate distance behind any simple antenna, the wire will function as a reflector and increase the intensity of the radiation forward from the antenna. Usually such a reflector wire may be slightly longer than the half-wave antenna with which it is used and spaced one quarter wave behind the antenna.

Should the antenna and reflector be well in the clear, it is usually safe to make the reflector about 2 per cent longer than the antenna. Trees and buildings in the vicinity of the system are likely to demand considerable departures from this figure and in one very effective installation of this type (described by H. E. Smith in *QST*, May, 1935) the reflector wire, as the result of careful measurement, had to be made *shorter* than the antenna.

Such reflector wires may be used in conjunction with arrays of antennas to provide unidirectional transmission and added power gain. The reflector elements are strung together as a replica of the antenna array (but without any interconnecting feeders) and then mounted one quarter wave behind the antenna assembly. Unidirectional arrays of this type are widely used on the ultra-high frequencies where the small size of the array permits it to be mounted on a simple structure capable of rotation.

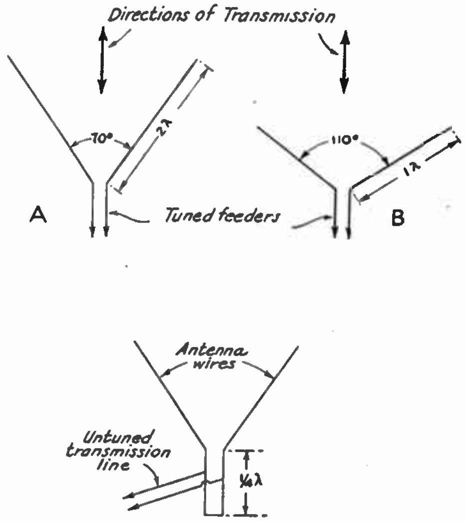


FIG. 1626 — ILLUSTRATING THE MODEL D OR "V" TYPE LONG-WIRE ARRAY

The array consists primarily of two long antennas some multiple of a wavelength long and arranged in "V" form. The angle between the wires depends on their length. Angles for antennas longer than those shown are: 3 wavelengths — 60 degrees; 4 waves — 52 degrees; 5 waves — 45 degrees; 6 waves — 40 degrees; 7 waves — 38 degrees; 8 waves — 35 degrees. These figures are approximate only and in practice will be influenced by any trees or buildings near the wires. The system may be fed with a tuned line an odd number of quarter waves long, or with a quarter-wave matching section and untuned line. This array is horizontally polarized and is therefore unsuited for u.h.f. communication with stations using vertical antennas. (See text.)

Using Directors

● Still greater improvement in the directivity of this type of array may be had by using director wires in front of the antenna elements. Practice indicates that these wires should be mounted approximately three-eighths of a wavelength in front of the antenna elements and that the wires should be approximately 87 percent of a half-wave long. Here again, the optimum dimension and spacing can be determined in individual locations only by a careful cut and try procedure.

Long-Wire Arrays

● As has already been explained, the long-wire antennas have definite directivity characteristics. Two long-wire antennas may be combined to give pronounced directivity in one or two directions only. This type of array has the advantage of requiring a simple supporting structure but even on the ultra-high frequencies a large tract of land is required if a high order of directivity is to be had.

In the "V" type, the system consists of two wires separated by an angle determined by the number of wavelengths on each wire. Since the antennas are being excited at a voltage loop, an ordinary tuned line an odd number of quarter-waves long may be used as the feeder. Alternatively, a tuned quarter-wave section may be provided to enable an untuned line to be "matched in."

The "Rhombic" type of antenna array contains four antenna elements arranged in

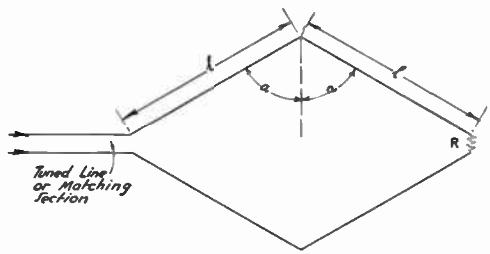


FIG. 1627 — THE GENERAL ARRANGEMENT OF THE "DIAMOND" OR "RHOMBIC" DIRECTIVE ARRAY

The angle "a" between the antenna elements and the transverse axis of the system depends on the length of the antenna elements. The following approximate figures should be observed:

"l" in wavelengths	*"a" in degrees*
1	*30*
2	*50*
3	*57*
4	*62*
5	*65*
6	*67*
7	*68*
8	*69*

The system is bi-directional without the resistor R. With the resistor in place and correctly adjusted, the array is unidirectional — transmitting in the direction away from the feeder end toward R. Like the "V", this array, in its conventional form, is horizontally polarized.

"diamond" form — the angles between the wires again being related to the length of the antenna elements. This type of array may either be operated with the far end open — in which case it is bi-directive — or with a non-inductive resistor of about 800 ohms across the far end. In this case, the system is non-resonant and unidirectional. It may be operated with little variation in performance over a 2 to 1 range of frequencies.

Both of these long-wire arrays become highly effective when their length is of the order of three to eight wavelengths but in this case a relatively enormous space is required even for 14 mc. operation. On the 56-mc. band, the dimensions become more nearly reasonable but unfortunately the arrays radiate horizontally polarized waves and are therefore unsuited for use in communication with stations using vertical antennas. Since almost all amateur u.h.f. stations today use vertical antennas, the long wire arrays have found little use. This particular point will be given further consideration later.

Antenna Systems for the Ultra-High Frequencies

● The problem of designing an antenna for the ultra-high frequencies is in no respect different to that faced on the lower frequencies. Antenna lengths are determined in the same fashion, tuned feeders remain some multiple of a quarter wave and matching systems are treated in the same manner. The u.h.f. antennas are, of course, much smaller than their low frequency counterparts and it is therefore more readily possible to observe their performance with a neon bulb or galvanometer. Their small size also permits the erection of arrays of antennas even in space which would be considered restricted for lower frequency working.

Obviously, an intelligent approach to the antenna problem requires a knowledge of fundamental principles. To the ultra-high frequency worker we would suggest thorough study of this entire chapter in addition to latter portions, in particular, of Chapter Four.

The Simple Systems

● For some experimental work and portable u.h.f. operation it is often desirable to use the simplest possible form of antenna. In such cases, a half-wave element with tuned feeders connected at the bottom is one very satisfactory arrangement. Alternatively some of the special 75-ohm feeder or even common twisted pair may be connected in the center of the half-wave element. With the superregenerative receiver it is particularly important that the antenna and feeder be tuned or, in the case of the untuned feeder, that the coupling to the grid coil of the receiver be very carefully adjusted. Untuned receiving antennas of the type commonly used on the lower frequencies are disappointing on the ultra-high frequencies.

The same type of simple antenna with any of the feed systems described earlier in this chapter may be used for transmitting. However, the advantages to be had by using even a simple array are such that the day of plain antennas is rapidly passing.

Construction of Arrays

● Any of the arrays shown in Fig. 1623 are thoroughly suited for ultra-high frequency operation. Systems such as those shown at "A" and "B" can be erected simply by hauling them into position on the pole available. Arrays of the type shown at "D" to "H" can usually be suspended from a rope between two supports. The most satisfactory structures, though, are rigid types either rotatable (shown in Fig. 1624) or fixed (Fig. 1625). On 56 mc., a rotatable array giving appreciable gain is a large affair, difficult and expensive to build. On 112 mc. the structure becomes much simpler. The example of an array of six half-wave antennas and six reflectors shown in Fig. 1624 is an excellent model to follow.

Vertical vs. Horizontal Antennas

● It has become general practice in amateur u.h.f. work to use vertical antennas exclusively. This is probably the result of early experimental work, which showed the vertical antenna to outperform the horizontal antenna in transmission over short direct paths. The trend of today, however, 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 merely 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.

Long Wire Antennas for the Ultra-Ultra Highs

● Undoubtedly the most effective and certainly the simplest arrays of all are the "V" and "Diamond" or "Rhombic". In their conventional form, these both transmit horizontally polarized waves and have therefore been considered in amateur circles to be unsuited for u.h.f. work. It seems certain, however, that the next year or two will see them in wide use—particularly for the 112- and 224-mc. bands. The dimensions of these systems are, in terms of wavelengths, exactly the same as when operated on the lower frequencies.

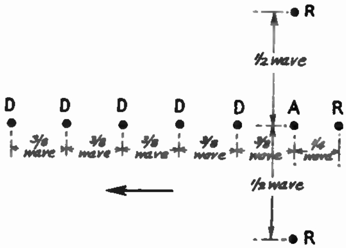


FIG. 1628 — SHOWING THE ARRANGEMENT OF THE ANTENNA, REFLECTOR AND DIRECTOR ELEMENTS IN A "YAGI" DIRECTIVE SYSTEM

This type of system has been used effectively on the ultra-high frequencies and is particularly suited for operation above 112 mc. The various elements may be made of copper rod or hard-drawn tubing mounted on a wooden framework. The approximate length of the elements may be determined from the relationships given in the text — remembering that one meter equals 3.28 feet.

The Yagi Antenna

● For the 112- and 224-mc. bands, another simple antenna is that shown in Fig. 1628. It consists of a half-wave antenna, fed in any conventional fashion, with reflectors behind it and, in the advanced form, with a row of directors in front of it. The system is capable of being turned readily from the vertical to horizontal positions. Usual practice is to make the antenna 95 percent of a half wave long, the reflectors and directors being 97 and 87 percent of a half wave respectively.

The Gain of Arrays

● It is common practice to express the gain of an array as the gain over a single element of the array. While this gain may be computed for the ideal theoretical case or measured in the actual installation, it is extremely difficult to estimate the probable performance of an amateur antenna built, as it usually is, in anything but the ideal location. Because the actual performances obtained in typical cases have provided such contradictory results, we hesitate to attempt to treat this complex and extensive phase of the subject. The interested reader will find a wealth of information on the subject in Terman's *Radio Engineering* and other standard texts.

CHAPTER SEVENTEEN

Instruments and Measurements

MONITORS — FREQUENCY METERS — VOLTMETERS AND MILLIAMMETERS — OHMMETERS — TEST OSCILLATORS — V. T. VOLTMETERS — CATHODE-RAY 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. These range from ordinary meters for the measurement of d.c. voltage and current to frequency-meter monitors for aurally checking the frequency and quality of the transmitted signal and cathode-ray oscilloscopes for the visual inspection of the signal. In addition, various instruments such as ohmmeters, oscillators and vacuum-tube voltmeters are of great utility for tracing down sources of trouble in receivers and transmitters and for many types of measurements in experimental work. While the amateur station can be operated successfully with nothing more than a means for checking transmitter plate current 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.

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 example shown in Fig. 1701 illustrates the simplicity of a typical monitor.

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.

Almost any sort of metal can or box can be used as a shield for the monitor. The can shown in Fig. 1701 is an ordinary six-inch cracker tin given a coat of black lacquer. The circuit diagram, given in Fig. 1702, uses a Type 30 tube in a simple oscillating circuit.

All parts except the "A" and "B" batteries

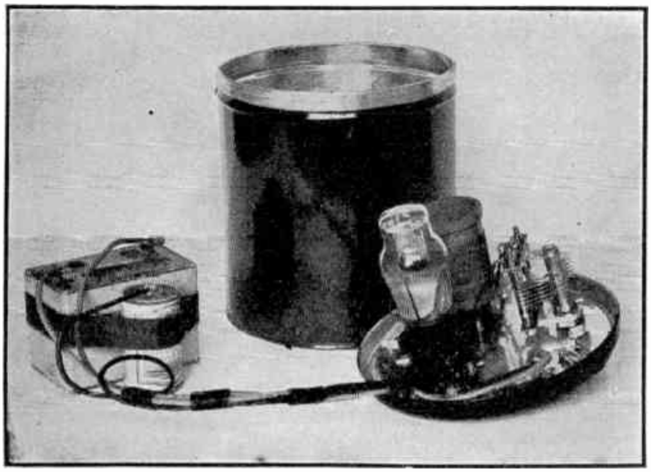


FIG. 1701 — AN INEXPENSIVE MONITOR BUILT IN A CRACKER TIN

The simple construction shown above is typical. The monitor, despite its simplicity and low cost, is an extremely useful piece of station equipment.

are mounted on the under side of the lid. The "A" battery is a single 1.5-volt dry cell of the type used in tubular flashlights, the "B" bat-

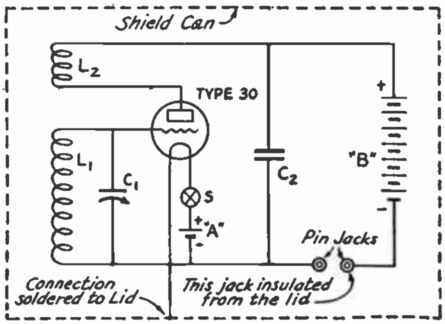


FIG. 1702 — WIRING DIAGRAM OF THE MONITOR

The circuit components have the following values:
C_1 — 50-μμfd. (.00005 μfd.) midget variable condenser.
C_2 — .002-μfd. fixed condenser.
S — Single-pole toggle switch.

Band	*L_1*	*L_2*
1750 kc.	*70*	*20*
3500 kc.	*35*	*10*
7000 kc.	*15*	*6*
14,000 kc.	*5*	*4*

The coil forms are 1½ inches in diameter. All coils are wound with No. 30 d.s.c. wire.

Other materials required include two 4-prong tube sockets, a Type 30 Tube, a pair of 'phone-tip jacks, a small-size 22½-volt "B" battery (Eveready No. 763 or equivalent), and a single-cell 1.5-volt flash-light battery. Two or even three of these cells can be connected in parallel for longer life.

The coils L_1 and L_2 are wound on the same plug-in coil form (4 prong) and are wound in the same direction, L_1 at the upper end of the form. The upper terminal of L_1 connects to the grid of the tube, the lower terminal to the filament of the tube; the terminal of L_2 nearest L_1 goes to the positive side of the "B" battery and the remaining terminal to the plate of the tube. The arrangement of the pins on the form may be anything convenient.

tery a small-size 22½-volt block. These two batteries are taped together and connected to the monitor proper with rubber-covered leads, also taped together to keep them from vibrating after the monitor has been assembled. Wadded paper may be packed around the batteries when they are placed in the bottom of the container so that they will not move when the monitor is carried around.

It is a worthwhile plan to fit a small double-pole double-throw switch so that the 'phones can be shifted from the receiver to the monitor. In this way it is possible to monitor all transmissions simply by flipping the switch. This not only makes for much snappier and more readable sending but also provides a continuous check on the signal. Should anything go wrong with the transmitter the trouble is immediately apparent.

Checking the Transmitter Frequency

● In the absence of more elaborate frequency-measuring equipment, a monitor is useful in the highly-important operation of setting the frequency of a self-excited transmitter within an amateur band. To do this it is necessary to calibrate the receiver dial settings in terms of frequency, or at least to know to a fair approximation where the limits of the band lie on the dial. 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. The receiver also may be checked against A.R.R.L. Standard Frequency Transmissions, schedules for which appear regularly in *QST*.

After the band limits have been determined a suitable working spot should be picked within the band and the receiver left running at that setting. The monitor then should be put into operation. If an extra pair of 'phones is not available a bent piece of bare No. 14 wire may be plugged into the 'phone tip jacks of the monitor so that its plate circuit will be closed. Tune the monitor condenser slowly across the band, stopping when the signal from it is heard in the receiver. The monitor will now be set exactly on the frequency to which the transmitter is to be tuned. If no signal is heard, check the monitor to make sure it is oscillating, move it closer to the receiver, or open the lid so that the shielding will not be so great. Make certain that the right coil is in the monitor.

With the monitor setting determined, transfer the headset from the receiver to the monitor, start up the transmitter, and tune carefully until a signal from the transmitter is heard in the monitor. Set the transmitter frequency to "zero beat" — the silent space between the two beat notes — and the transmitter frequency will be exactly on the spot picked out. The frequency upon which the transmitter is set should be well inside the limits of the band so there will be no possibility of off-frequency operation.

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. 1703. 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. Although this type of frequency meter is not well adapted to very accurate measurement of frequency, it is useful in a variety of ways.

To make the absorption meter most useful, a series of coils should be provided so that it will cover a continuous frequency range from about 1500 kc. up to the highest frequency likely to be needed — perhaps 20,000 kc. A rather large condenser should be used; a variable with 350 μμfd. maximum capacity is about right. Coils to cover the range with a condenser of this size may be made as shown in the table below. The frequency ranges are approximate only. The specifications are for coils wound on a two-inch form with No. 20 d.c.c. wire, no spacing betweeen turns.

Range	*Turns*
1500–5000 kc.	*25*
3000–10,000 kc.	*10*
6000–20,000 kc.	*5*

Calibration of the absorption frequency meter calls for a receiver of the regenerative type to which the coil in the meter can be

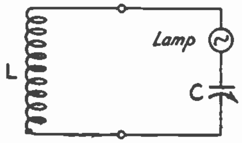


FIG. 1703 — ABSORPTION FREQUENCY METER CIRCUIT

The variable condenser, C, should have a maximum capacity of about 350 μμfd. The meter should be arranged so that the coils are readily interchangeable. The lamp acts as a resonance indicator when the absorption meter is used with a transmitter; its use is not essential, although it is a convenience. Coil specifications are given in the text.

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 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 resonance 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.

Heterodyne Frequency Meters

● We have outlined the simple procedure necessary to determine definitely whether the transmitter frequency is within the limits of the band and roughly in what part of the band it is located. Many amateurs, however, will be interested in knowing how to measure frequency to within a few kilocycles. The heterodyne frequency meter is most suitable for this work.

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.

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 excellent. 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.

The Electron-Coupled Frequency Meter

● One of the most stable oscillator circuits, and therefore most suitable for the frequency meter, is the electron-coupled circuit. The os-

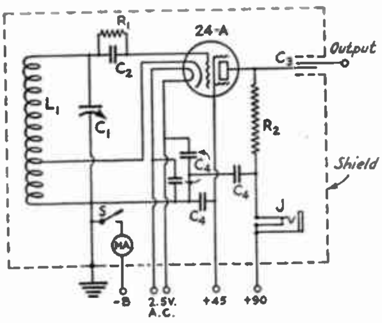


FIG. 1704 — CIRCUIT OF THE ELECTRON-COUPLED FREQUENCY METER

This circuit is for use with indirectly heated tubes such as the 24-A and 36. If pentode-type tubes are used the suppressor should be connected to ground, not to cathode.

C_1 — Band-spread condenser, minimum capacity 53 μμfd., maximum capacity, 81 μμfd., approximately. (Such as General Radio Type 556 or National Type 40–75.)
C_2 — 250-μμfd. mica condenser.
C_3 — Approximately 10 μμfd. See text for details.
C_4 — .01-μfd. mica by-pass condenser.
R_1 — 100,000-ohm grid leak.
R_2 — 50,000-ohm 1-watt resistor, pigtail type, non-inductive.
J — Close-circuit 'phone jack.
S — On-off switch, s.p.s.t.
L_1 — Approximately 90 turns of No. 30 d.s.c. wire close-wound on a 1-inch bakelite tube, tapped at the 30th turn from the grounded end. A few more or less turns may be needed to spread the 1750-kc. band over the dial scale to the best advantage.

cillation 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.

Circuit diagrams for electron-coupled frequency meters are given in Figs. 1704 and 1705. The former is for use with tubes having indirectly-heated cathodes; the latter for filament-type tubes. With directly-heated tubes it is necessary to provide an extra winding, L_2, in series with one leg of the filament so that both filament terminals will be at the same r.f. potential.

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.

It is desirable to design the frequency meter so that the oscillator operates in the 1715–2000-kc. band, with a "spread" such that almost the entire dial scale is used to cover the band. While the specifications for the oscillator

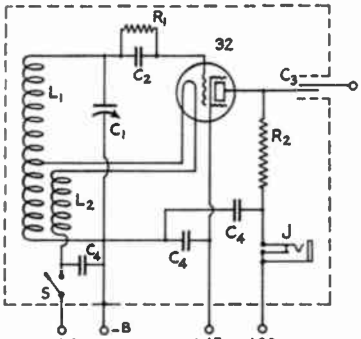


FIG. 1705 — ELECTRON-COUPLED FREQUENCY METER CIRCUIT FOR USE WITH DIRECTLY-HEATED TUBES SUCH AS THE 32

The circuit is essentially the same as that of Fig. 1704 except that both sides of the filament must be fed through coils to prevent grounding the filament. L_1 has the same specifications as in Fig. 1704. L_2 has the same number of turns as the tapped portion of L_1. It may be wound over the corresponding part of L_1 or directly on the coil form between the turns of the tapped portion of L_1. The other components have the same values as in Fig. 1704. In this circuit the filament switch as well as the output binding post and 'phone jack must be insulated from the shield.

FIG. 1706 — A TWO-TUBE FREQUENCY-METER MONITOR

Among the essentials in frequency-meter design are mechanical construction of high stability and the use of a dial having a vernier scale.

inductance under Fig. 1704 will be found to work out closely, it may be necessary to add or subtract a few turns to get the band-spread

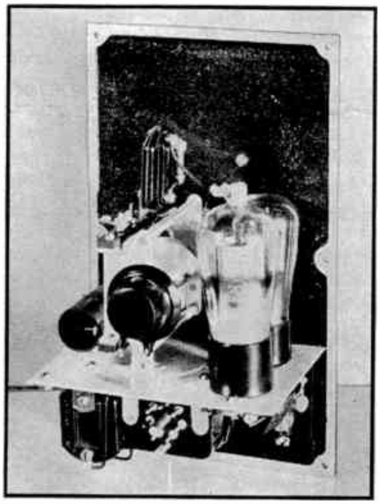


FIG. 1707 — AN INTERIOR VIEW OF THE TWO-TUBE E. C. FREQUENCY-METER-MONITOR

just right. For the higher-frequency bands harmonics of the oscillator are used. Thus the second harmonic will cover the 3500–4000-kc. band, the fourth the 7000–7300-kc. band over part of the scale, and so on to the highest frequencies used by amateurs. Strong harmonics can be taken from the frequency meter even on the 56,000-kc. band.

The output coupling condenser, C_3, in Figs. 1704 and 1705 should have very small capacity — about 10 to 15 micromicrofarads. A midget variable condenser will do — both sides must be insulated from the shield — or a small trimmer condenser can be used. Alternatively, a suitable condenser can be made from two pieces of metal strip measuring approximately one-half by one inch, arranged to face each other with a space of about ⅛ inch between their surfaces.

The signal from the frequency meter can be fed into the receiver by connecting a wire from the output post on the meter to the antenna post on the receiver. If the signal should be too loud, the wire from the output post can be disconnected from the receiver but left in the vicinity of the receiving lead-in.

The frequency-meter can be used as a monitor by plugging a pair of headphones in the jack, *J*, in the screen circuit.

When the frequency meter is first turned on some little time is required for the tube to reach its final operating temperature; during this period the frequency of oscillation will drift slightly. Although the drift will not amount to more than two or three kilocycles on the 3500-kc. band and proportionate amounts on the other bands, it is desirable to allow the frequency meter to "warm up" for about a half hour before calibrating, or before making measurements in which the utmost accuracy is desired. The on-off switch in Fig. 1704 is a useful adjunct to the meter because the "B" supply can be cut off independently of the filament supply, permitting the operator to keep the frequency meter up to temperature without wasting "B" current when no measurements are being made.

With careful construction, a good readable dial, and an accurate calibration made as described in a later section, measurements made with the electron-coupled frequency meter can be depended upon to be accurate to within 1 part in 1000, or one-tenth of 1%, an accuracy more than sufficient for amateur work.

A Combined Frequency Meter-Monitor

● Although an electron-coupled frequency meter constructed according to Figs. 1704 or

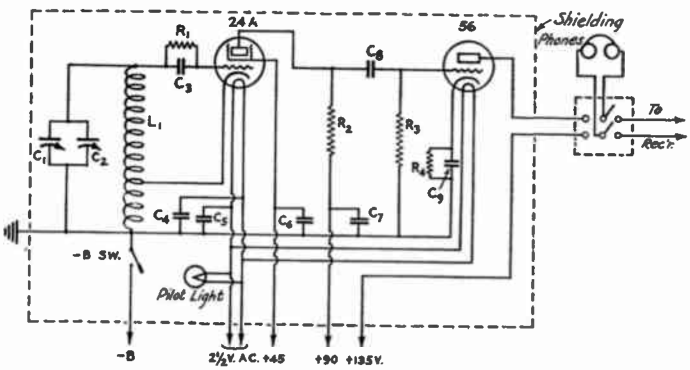


FIG. 1708 — CIRCUIT OF THE TWO-TUBE FREQUENCY-METER-MONITOR

C_1 — 3-plate Cardwell Midway Type 401-B, maximum capacity 26 μμfd., minimum capacity 7 μμfd.
C_2 — 5-plate Cardwell Midway Type 402-B, maximum capacity 50 μμfd., minimum 8 μμfd.
C_3 — .0001-μfd. fixed condenser.
C_4, C_5, C_6, C_7 — .01-μfd. fixed by-pass condensers.
C_8 — 40-μμfd. fixed coupling condenser.
C_9 — .25-μfd. fixed condenser.
R_1 — 100,000-ohm ½-watt size.
R_2 — 100,000-ohm 1-watt size.
R_3 — 1-megohm 1-watt size.
R_4 — 900,000-ohm 1-watt size.
L_1 — 79 turns No. 30 d.s.c. wire on a 1-inch diameter tube. Cathode tap should be at 23rd turn from "ground" end. The heater and "B" supplies may be from the receiver power pack.

1705 can be used as a monitor as explained in the previous section, the monitoring function will be performed more satisfactorily if a separate detector tube is added to the unit. Installation of the extra tube will give a stronger signal for monitoring purposes.

A combined frequency meter-monitor of this type is illustrated in Figs. 1706–1708. The circuit diagram of the oscillator is similar to that of Fig. 1704 up to the "output" terminals, where condenser C_8 replaces C_3. The oscillator output is fed into the grid circuit of a Type 56 tube connected as a plate detector. This tube operates both as an amplifier of the radio-frequency output of the oscillator and as a detector when the oscillator output or one of its harmonics is made to beat with the signal from the transmitter.

The construction of the unit is illustrated in the two photographs. The case is a sturdy aluminum box measuring 10 by 6 by 5 inches. An aluminum shelf bolted to the panel holds all the parts. There are two tuning condensers, C_1 and C_2, C_2 being used as an adjustable fixed section to set the minimum capacity in the circuit to spread the 1750-kc. band over most of the dial scale. It is left alone when once properly set. The grid condenser, C_3, and grid leak, R_1, are mounted by a small bracket on the upper stator-plate terminal of C_2 to make a short, direct connection to the grid of the 24-A oscillator tube. To the left of C_1 and C_2, near the shelf, is the oscillator coil, L_1. Bypass condensers and resistors are mounted underneath the shelf, together with a cable socket for the heater and plate-supply connections.

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 1750-kc. band with a little overlap at each end. This can be done by checking against a receiver covering the 1715–2000 or 3500–4000 kc. bands, picking up the frequency-meter signal on the receiver.

After the coverage has been checked, the current issue of *QST* should be consulted for information as to the next transmission of standard frequencies for calibration purposes. These transmissions are given once or twice each week by the stations comprising the A.R.R.L. Standard Frequency System, located in different geographical sections of the United States. Each of the stations is equipped with a frequency standard which is accurate to better than one part in 10,000 or .01%. These individual standards have been calibrated directly against the national frequency standard located in the laboratory of the Bureau of Standards at Washington, and the calibration signals transmitted for amateurs are therefore based on the national frequency standard. The transmissions consist of signals which mark accurately the limits of the 3500- 7000-, and 14,000-kc. bands with intermediate points at 100 kc. intervals.

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.

Listening 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 to the transmitter frequency.

A satisfactory type of 'phone monitor, using a Type 55 tube as a diode detector and audio amplifier, is shown in Fig. 1709. The circuit *LC* is tuned to the transmitter frequency; any constants which satisfy this requirement can be used. A headset can be connected to the output posts in series with C_4 and ground.

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 check-

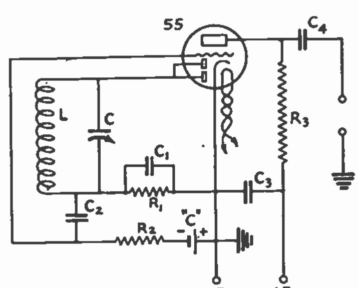


FIG. 1709 — SIMPLE 'PHONE MONITOR USING A TYPE 55 TUBE

C_1 — 250 μμfd.
C_2 — .01 μfd.
C_3 — .002 μfd.
C_4 — 1 μfd.
R_1 — .5 megohm.
R_2 — 2 megohms.
R_3 — .1 megohm.

ing the effect of transmitter adjustments on hum and other carrier noises.

The 'phone monitor usually must be used with a headset, since a loud-speaker will actuate the microphone and cause the audio amplifier to break into a howl.

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.

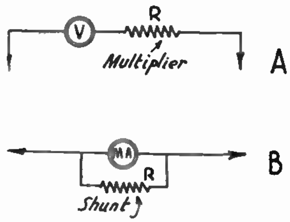


FIG. 1710 — HOW VOLTMETER MULTIPLIERS (A) AND MILLIAMMETER SHUNTS (B) ARE CONNECTED

The ways in which multipliers and shunts are connected to voltmeters and milliammeters are shown in Fig. 1710. 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 voltmeter 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. 1710-B, can be found from the formula:

$$R = \frac{R_m}{n-1}$$

where the letters have the same significance as before.

Multi-Range Voltmeters and Milliammeters

● 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.

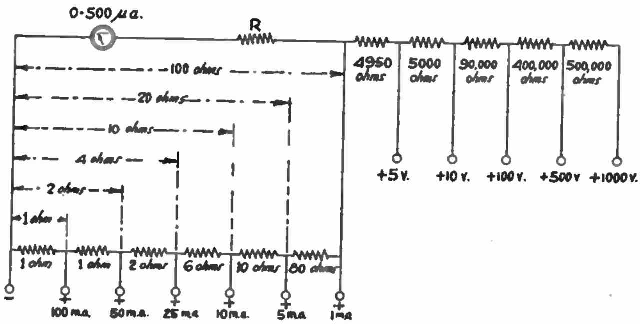


FIG. 1711 — A MULTI-RANGE VOLTMETER-MILLIAMMETER USING A 0-500 MICROAMMETER

The value of resistor R is discussed in the text. From the "Aerovox Research Worker."

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. A better method, however, is shown in Fig. 1711. Resistors of the proper value are connected in series with the meter and the external circuit tapped across appropriate connections for the various ranges. Inaccuracies due to switch contact resistance are avoided. The values given are for use with a 0–500 microammeter. The resistance marked R should be $100 - R_m$ ohms, where R_m is again the resistance of the meter.

Ohmmeters

● It is often necessary to check the value of a resistor or to find the value of an unknown resistor, particularly in receiver servicing. For this purpose the 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, then insertion of the external resistance will cause the reading to decrease in proportion to the amount of resistance inserted. The scale can therefore be calibrated in ohms.

A simple combination ohmmeter and d.c. voltmeter suitable for general receiver testing is diagrammed in Fig. 1712. As an ohmmeter it consists of the 0–1 d.c. milliammeter, 3-volt battery, fuse and 2800-ohm resistor in series. The ends of the leads are tapped across the circuit whose resistance is to be checked. It can be used for fairly accurate measurement of resistances between the values given in the calibration table, which calibration can be plotted on graph paper.

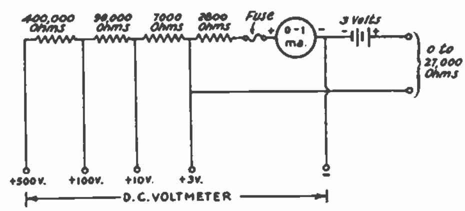


FIG. 1712 — A COMBINATION OHMMETER AND D.C. VOLTMETER SUITABLE FOR RECEIVER TESTING

Two flash-light cells in series serve as the battery. The resistors preferably should be "precision" type. A 1/100-amp. low-voltage type Littelfuse should be connected as shown. If it is omitted, the 2800-ohm resistor should be replaced by one of 3000 ohms. Alternatively, a 3000-ohm variable resistor, adjusted to give full scale deflection with a 3-volt battery, may be used. The approximate ohmmeter calibration is as follows:

Meter Scale (Ma.)	*Ohms*	*Meter Scale (Ma.)*	*Ohms*
1.0	*0*	*.375*	*5000*
.96	*100*	*.30*	*7000*
.85	*500*	*.25*	*9000*
.75	*1000*	*.20*	*12,000*
.60	*2000*	*.15*	*17,000*
.50	*3000*	*.10*	*27,000*

As a four-range d.c. voltmeter it has a resistance of 1000 ohms per volt, with full-scale reading (1 ma.) on each range corresponding to the maximum voltage specified for that range, lesser voltages on each range being in direct proportion to the scale reading (80% maximum voltage at 0.8 ma., 50% at 0.5 ma., etc.).

An ohmmeter 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 made.

Test Oscillators

● For lining up superhet receivers and checking receiver frequency ranges, a low-power oscillator, giving a wide continuous frequency range, is extremely useful. Such a "test oscillator" preferably should have a means for varying the strength of the signal; it is also helpful at times if the signal is modulated, especially when the receiver must be lined up by ear in the absence of indicating instruments.

The diagram of a test oscillator which will operate directly from the 110-volt line, either a.c. or d.c., and having a continuous frequency range from 12,000 to 545 kc., is given in Fig. 1713. A Type 32 tube is used as an electron-coupled oscillator; its filament is lighted from the 101-volt line through a series resistor. Since a.c. is used on the plate, the oscillator tone is "raw a.c." If a d.c. note is desired, the filament of the 32 can be lighted by a dry cell or two and "B" batteries used to supply screen and plate potentials.

The filament is maintained above ground for r.f. by a 1- or 2-millihenry r.f. choke coil and by the 1900-ohm filament-drop resistor. The choke must be capable of handling 60 milliamperes. The most satisfactory type of choke for this and the other two units is the universal-wound type.

Fig. 1714 shows the construction of the coil. The four main windings are wound on 1-inch tubing 3½ inches long, each winding separated ¼-inch from the next. The tickler winding is in three sections. Between the two smallest tuning windings there is a tickler winding of 3 turns, 5 more between the second and third sections, and 7 between the third and fourth, all ticklers being connected in series. The main coil windings also are series-connected. The band selector switch picks out the proper inductance by adding up the various sections, and likewise cuts in the proper amount of tickler for each band.

A three-section switch is necessary, the third section being used to short the two larger sections of the secondary winding when the oscillator is on its two higher-frequency ranges. This avoids "dead spots." The switch should be one of the type used in "all-wave" sets.

The unit should be mounted in an all-metal container.

Care must be taken in wiring to get all the radio frequency leads from the coil to the switch and to the variable condenser as short

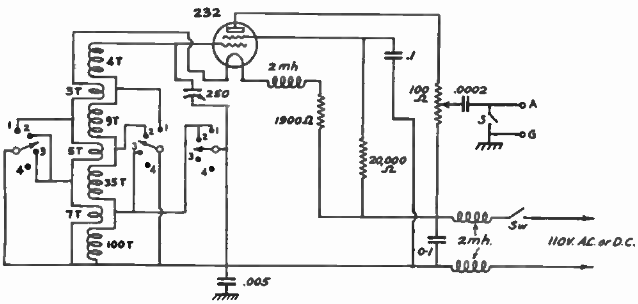


FIG. 1713 — A WIDE RANGE TEST OSCILLATOR CIRCUIT

This oscillator, by R. F. Shea, is useful for lining up and checking receivers. The following parts are needed:

1 Metal case and panel (panel 5 by 10 inches, case 6 inches deep).
1 Type 32 tube.
1 4-prong socket.
1 250-μμfd. variable condenser.
2 0.1-μfd. tubular condensers.
1 200-μμfd. mica condenser.
1 0.005-μfd. mica condenser.
1 1900-ohm 5-watt resistor.
1 100-ohm potentiometer with line switch.
1 20,000-ohm ½-watt carbon resistor.
1 3-section 4-position short-wave switch.
3 1- or 2-mh. chokes.
1 Line cord and plug.
2 Binding posts.
1 Vernier 4-inch dial.
1 Coil assembly (See text and diagram).
1 On-off switch for low output.

as possible. All parts, including the tuning condenser, should be insulated from the metal panel and case, to prevent accidental shocks to the operator.

The frequency ranges on the four taps are approximately as follows: 25,000 to 12,000 kc., 11,500 to 4000 kc., 4300 to 1400 kc., and 1500 to 545 kc. The amplitude of the signal fed to the receiver antenna and ground terminals is regulated by the potentiometer in the plate circuit of the oscillator. With the switch *S* closed the signal voltage will be very low.

I.F. Oscillators

● The same type of oscillator can be used for generation of intermediate frequencies for lining up i.f. amplifiers in superhets. Another 100-turn grid coil and 7 turn tickler coil, with an additional switch position, would extend the frequency range to approximately 350 kc., thus covering all intermediate frequencies used in amateur-type superhets.

Alternatively, a separate oscillator of the electron-coupled type can be built, using the regular circuit but with the plate potentiometer shown in Fig. 1713 for output signal regulation. The tuned circuit to cover a range of 350 to 600 kc. could consist of a 150-μμfd. condenser and a coil having 250 turns of No. 30 enamelled wire on a two-inch diameter form. The cathode tap should be about 25 turns from the ground end.

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 capabilities of the vacuum tubes are determined by the peak voltages and currents which must be handled.

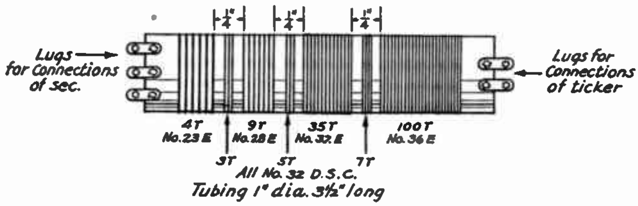


FIG. 1714 — DETAILS OF COIL CONSTRUCTION FOR THE TEST OSCILLATOR OF FIG. 1713

The single-tube vacuum-tube voltmeter is restricted in sensitivity, since accurate measurements cannot be made of low voltages because the plate current change is small. However, a second tube connected as a d.c. amplifier can be added to the voltmeter to increase its sensitivity. A wide-range voltmeter of this type is shown diagrammatically in Fig. 1715.

The input tube T_1 is biased to plate current cut-off. Tube T_2 is connected to the output of T_1 to act as a d.c. amplifier. The Type 80 tube provides the d.c. plate voltage for tube T_1.

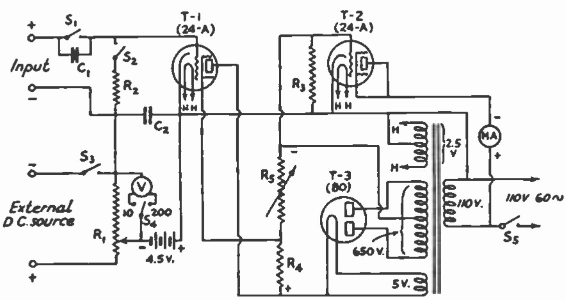


FIG. 1715 — A VACUUM TUBE VOLTMETER WITH D.C. AMPLIFIER

Described by D. C. Duncan in October, 1935, QST.
C_1 — 0.001-μfd. mica.
C_2 — 0.001-μfd. mica.
R_1 — 10,000-ohm 6-watt wire-wound.
R_2 — 1.0-megohm 1-watt.
R_3 — 8000-ohm 1-watt.
R_4 — 15,000-ohm 10-watt wire-wound.
R_5 — 2000-ohm 2-watt wire-wound.

A series condenser, C_1, with shorting switch, is provided in the input circuit to isolate d.c. voltages when desired, as when measuring audio amplifier voltages or the hum or ripple voltage across a rectifier output. A shunt resistance R_2 is provided to give the grid a d.c. return when C_1 is used, or when the external circuit will not furnish a d.c. path.

The potentiometer, R_1, provides the means for adjusting an external d.c. source to give the negative potential necessary to balance the voltage being measured, the value being indicated by the two-range d.c. voltmeter. Switch S_3 can be the type associated with the potentiometer R_1, and operated by the same knob.

A small 4½-volt "C" battery is wired into the input. The purpose of this battery is to bias tube T_1 to plate current cut-off. Vernier adjustment of the plate current cut-off is accomplished by variation of the screen-grid voltage, using control R_5.

R_3 forms part of the output circuit of tube T_1; it also forms the input to tube T_2. With T_1 operating near cut-off, the d.c. voltage drop across R_3 is small. In contrast to the single-tube voltmeter, T_2 will be operating at *maximum* plate current, which will be indicated by the milliammeter in the plate circuit of this tube. A very small increase in the plate current of T_1, due to a small voltage applied to the input, will cause a relatively large increase in voltage drop across R_3. This in turn will cause a sharp reduction in the deflection of the milliammeter in the plate circuit of T_2. By adjustment of R_1, the milliammeter pointer can be brought back to its original reading, or "false zero."

The plate supply voltage for T_2 is r.a.c. taken directly off the primary of the power transformer. The milliammeter in this circuit should have high mechanical damping, so that the pulsating current will not cause the needle to vibrate badly and thereby make reading difficult.

To place the instrument in operation, connect the 110-volt 60-cycle supply and close switches S_2 and S_5. When the tubes have warmed up, the milliammeter should give nearly full-scale deflection. Turn R_5 to its position of zero resistance. T_1 will now be operating below cut-off. Gradually increase the resistance of R_5 until the milliammeter reading begins to drop off sharply. This represents the point where plate current begins to flow in T_1. Increase the resistance of R_5 until a reduction of 0.2 milliamperes is obtained; this adjustment, which is slightly above cut-off, gives good sensitivity.

After adjustment of R_5, note the exact scale reading of the milliammeter. This is the "false zero." Close S_3, and using the appropriate d.c. voltmeter scale, adjust R_1 to give a higher counter-voltage than the expected peak value of the unknown voltage to be measured. This will protect tube T_1 from abuse caused by making its grid excessively positive by a large input voltage. Now connect the unknown voltage to the input. If this voltage is d.c. or has a d.c. component, connect the positive side toward the grid. Next vary R_1 until the milliammeter returns to the "false zero" reading. The reading of the d.c. voltmeter will now be equal to the peak value of the unknown voltage.

The input wire to the grid of tube T_1 should be short and direct, to keep the capacity of the input circuit low. At high frequencies, appreciable input capacity is undesirable.

The vacuum-tube voltmeter is especially useful in checking both the r.f. and audio circuits of amateur transmitters, and can be used for checking directly positive-peak modulation. In this application an r.f. pick-up, with coupling to the transmitter's output circuit, would be connected to the "Input" terminals. Voltage measurements are taken of the carrier alone and of the carrier with steady modulation; the modulation percentage is then

$$\left(\frac{E_m}{E_o} - 1\right) \times 100$$

where E_m is the modulated peak voltage and E_o the unmodulated carrier voltage.

The instrument also can be used to measure the actual peak audio voltages (and, possibly, r.f. voltages) applied to the grids of the various tubes in audio amplifier circuits, thus providing positive checking for overload conditions that may be causes of distortion.

Used as a device to indicate resonance, as in lining up an i.f. amplifier in a superheterodyne receiver, resonance will be indicated by the point of greatest dip in the milliammeter reading. If the voltage applied to the input is more than about 2 volts, it will be necessary to add some d.c. counter-voltage with R_1, in order to keep the milliammeter deflection within the sensitive range.

The Cathode-Ray Tube

● The cathode-ray tube is rapidly assuming an important place in amateur measurements. 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.

A drawing of a typical cathode-ray tube, the type 906, is shown in Fig. 1716.

The tube contains eight useful electrodes, heater-cathode, control electrode, anode No. 1, anode No. 2, and two pairs of deflection plates. The assembly of the cathode, grid, anode No. 1 and anode No. 2 is known as the *electron gun.* The electrons furnished by the cathode are controlled, accelerated, and focused by the other gun electrodes into a tiny beam, the cathode ray. This beam of electrons strikes the viewing screen, which is coated with a substance that fluoresces to produce a brilliant green glow at the impact point of the electron beam. The cathode ray thus produces a luminous spot on the front of the screen.

In order to keep the electron beam focused to a small spot-size on the screen, it is necessary to maintain a constant ratio of anode No. 2 to anode No. 1 voltage. The sharpness of focus is usually adjusted by varying the anode No. 1 voltage. The input power to the screen (the product of anode No. 2 voltage and the beam current) controls screen illumination. Anode No. 2 current is controlled by means of the negative bias on the control electrode.

To obtain a useful pattern or wave-form, it is necessary to move the spot horizontally back and forth across the screen at some convenient frequency and with some suitable motion with respect to time. This produces a horizontal line of narrow width (equal to the diameter of the spot) in the middle of the screen. The horizontal motion or "sweep" is obtained by applying a suitable a.c. voltage across the deflection plates D_1 and D_2, which, in operation, are placed vertically. For studies of wave-form, a linear time base is generally required; that is, a sweep-circuit wave-form which moves the spot at a constant velocity. Such a wave-form is produced by utilizing a Type 885 gaseous-discharge tube operating as a relaxation oscillator whose frequency can be controlled within limits by a.c. voltage applied to its grid.

In some applications a linear time base is not required and the 60-cycle line voltage is sometimes suitable for the horizontal sweep. A peak voltage of about 150 volts at the deflection plates will usually be adequate.

The voltage to be viewed is applied across deflection plates D_3 and D_4, which are placed horizontally. Thus, the spot is moved not only back and forth, but also up and down. Such movement produces a tracing of the desired wave-form of the voltage under inspection.

Although a cathode-ray tube requires relatively high voltage, its space current requirements are very small. Therefore, the power supply can be quite simple. No filter choke and almost no bleeder current are necessary. A half-wave rectifier using a Type 81 with a 2- to 4-μfd. filter condenser is adequate. The deflection plates are returned to the positive 1000-volt lead, which usually is grounded for convenience in circuit arrangement. The heater and cathode circuits are consequently at a high negative potential with respect to ground, therefore, these leads and the negative high-voltage lead should be adequately insulated.

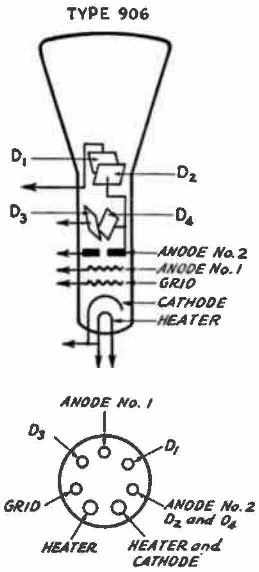


FIG. 1716 — ARRANGEMENT OF THE ELECTRODES AND BASE CONNECTIONS OF THE TYPE 906 CATHODE-RAY TUBE

A Cathode-Ray Oscilloscope

● The circuit diagram of a simple cathode-ray oscilloscope is given in Fig. 1717. 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 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. condensers (C_1), connected in series across the line with the midpoint grounded to the cabinet, will usually be effective. In some cases, however, it may be necessary to increase the size to 0.1 μfd. The condensers must be mounted inside the cabinet where they will not be in the field from the transmitter.

One of the main items of expense in the construction of an oscilloscope is a sweep circuit having a linear time base. For amateur use, however, such a sweep circuit is generally unnecessary; in fact, a clearer and more readily interpreted indication of the performance of the r.f. portion of a 'phone transmitter is obtainable with the a.c. horizontal sweep voltage obtained directly from the modulator. Using this system, the pattern appearing on the screen will be in the form of a trapezoid or triangle, depending upon the percentage of modulation. In this oscilloscope the horizontal sweep voltage can be obtained either from an audio-frequency source or from the 60-cycle line.

Besides the voltage controls indicated in

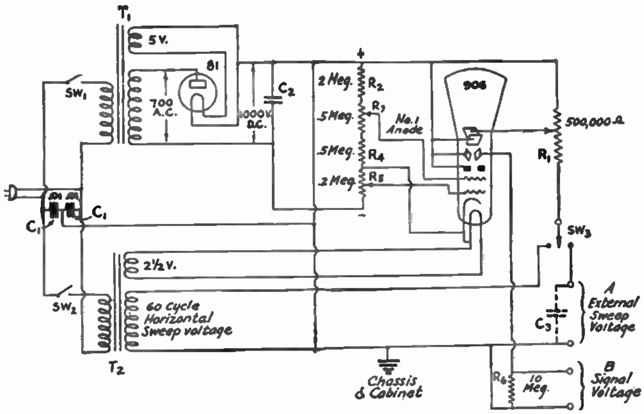


FIG. 1717 — A PRACTICAL OSCILLOSCOPE CIRCUIT

C_1 — 0.01- to 0.1-μfd. r.f. filter condensers.
C_2 — 1-μfd. 1000-volt (working) filter condenser.
C_3 — Small r.f. by-pass, if necessary.
R_1 — 500,000-ohm potentiometer (sweep-voltage control).
R_2 — 2-meg. 1-watt fixed divider resistor.
R_3 — 500,000-ohm potentiometer ("Brightness" control).
R_4 — 500,000-ohm 1-watt fixed divider resistor.
R_5 — 200,000-ohm potentiometer ("Focusing" control).
R_6 — 10-meg. 1-watt fixed stabilizing resistor.
T_1 — Power transformer to deliver voltages indicated.
T_2 — Heater supply and sweep-voltage transformer. Primary-to-sweep-voltage ratio approximately 1-to-1.
SW_1 and SW_2 — Line switches, s.p.s.t. toggles.
SW_3 — Sweep-circuit switch, s.p.d.t. rotary.

Fig. 1717, 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 earth's magnetic field has some effect on the electron beam and may cause the lines to be tilted. This can be overcome by proper orientation of the tube. The whole instrument should be enclosed in a metal box, preferably steel or iron, to shield it from stray fields. Without shielding it is difficult to bring the electron beam to a sharp focus.

Methods of using the oscilloscope for modulation measurements are described in Chapter Eleven.

The ratings and characteristics of the Type 906 cathode-ray tube are as follows:

Heater voltage (a.c. or d.c.)	2.5 Volts
Heater current	2.1 Amperes
Direct interelectrode capacitances	
Grid to all other electrodes	10 (max.) μμfd.
Deflecting plate D_1 to deflecting plate D_2 (Top Set)	4 (max.) μμfd.
Deflecting plate D_3 to deflecting plate D_4 (Bottom Set)	3 (max.) μμfd.
Base	Medium 7-pin

AVERAGE CHARACTERISTICS

High voltage electrode (Anode No. 2) voltage	1000 (max.) volts
Focusing electrode (Anode No. 1) voltage	300 (max.) volts
Grid voltage **	Never positive
Grid voltage for current cut-off	−40 (approx.) volts
Fluorescent-screen input power per sq. cm. (average)	10 (max.) milliwatts

Typical operation				
Heater voltage			2.5	volts
High-voltage electrode (Anode No. 2)	600	800	1000	volts
Focusing electrode (Anode No. 1) (approx.)	120	160	200	volts
Grid voltage	*	*	*	volts
Deflection sensitivity (Plates D_1 and D_2)	0.55	0.41	0.33	mm/volt d.c.
Deflection sensitivity (Plates D_3 and D_4)	0.58	0.44	0.35	mm/volt d.c.

*Adjusted to give suitable luminous spot.
**With approximately 200 volts (to focus) on anode No. 1.

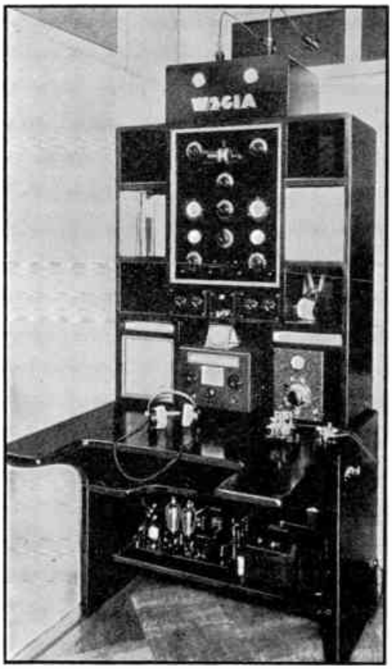
CHAPTER EIGHTEEN

Assembling the Amateur Station

LOCATION OF STATION — OPERATING POSITION — STATION LAYOUT — BREAK-IN AND REMOTE CONTROL — ANTENNA INSTALLATION — MASTS

In the preceding chapters we have seen how all the component parts of an amateur station may be designed and built, and we have come to know that a complete station consists of a receiver, a transmitter with power supply, a monitor or frequency meter or both, and suitable antennas for transmission and reception. Many amateurs, on completion of the necessary units for their station, are so anxious to put the outfit into operation that they merely toss the apparatus on a table, connect it up in some haphazard fashion and begin operating. Mediocre results attend this setup and the installation is never given a chance to perform at maximum efficiency. This procedure frequently results in danger to the operator and his family from exposed wiring. It invariably leads to unreliable and unsatisfactory operation of the equipment. One does not need a powerful transmitter or an elaborate receiver to have a fine amateur station.

It should be recognized from the start that in the final analysis the ultimate pleasure in an amateur station can be derived only when the greatest efficiency is being realized from each piece of gear. This, plus individual neatness and originality, gives that pride of ownership, whether the station be the most elaborate or the simplest.



DESK SPACE IN A CORNER IS AMPLE FOR A COMPLETE STATION

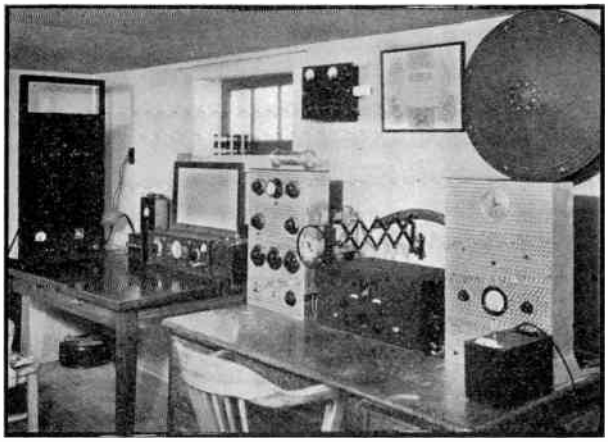
With excellent planning and thought W2GIA puts everything in its proper partition and at handy reach. This is one of a number of ideas for apartment living quarters. See January, '35 **QST.**

Finding a Location

● The first problem encountered in building a station is usually the selection of a suitable space in the house. Some fortunate amateurs are able to provide a special "shack" away from the house. Others are able to monopolize an entire room for their station. Many amateurs, however, are obliged to content themselves with a corner of the basement, their bedroom or the attic. Some fellows, living in apartments, have even been restricted to the space under the kitchen stove. Still others, for the sake of convenience and comfort, have built their transmitter and receiver into a small cabinet located in the living room, the heavier power supply apparatus being arranged in the basement.

Some amateurs put their rigs in roll top desks, others use bookcases. Apartment dwellers resort to gear under daybeds or shelves in closets. We recently heard of the amateur who concealed his rig in a modern "hope" chest!

Further schemes for the amateur limited in space are made available by remote control methods — some typical examples of which are given later in this chapter. With remote control, the transmitter and its power supply may be located in the attic, in the basement, or in a specially built "dog-house" in the back yard. The receiver and control switches may then be located in a small cabinet in the living room or on a small table in any other room available.



THE BASEMENT STATION CAN BE ATTRACTIVE AND HAVE ITS ADVANTAGES

Plenty of room with each piece of apparatus in its place. W9DRD was described in June 1934 QST.

There is certainly room for an amateur station in any house or apartment.

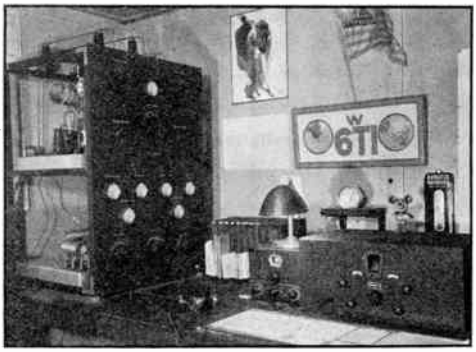
The Operating Position

● In picking the operating position it should be realized from the start that it will be here that long vigils will be kept. Schedules will be kept without regard to outside atmosphere or weather. Pick your operating spot with care, even sacrificing space for comfort. One can always cook up remote control ideas if a single space for receiver and transmitter is not available.

Convenient operation of a station calls for ample space around the receiver and key. There must be room for the log book, call book, message blanks and miscellaneous papers. For this reason, it is almost universal practice to use a table or desk as the operating position. On the operating table there should be no superfluous gear or material.

The items which are handled most frequently are the receiver, power switches, key, frequency meter and monitor. It is well, therefore, to group all of these on the table or desk selected. Perhaps the most popular practice is to place the receiver towards the left of the table. The monitor is then located alongside the receiver on the right (where it is near enough to give a good signal in the receiver) and the key is screwed to the table slightly to the right of this and far enough back to give a good support for the operator's arm. If one does not wish to scratch the table top by screwing a key to it, a worn edition of the *Handbook* will give enough weight. It is also thick enough to carry screws without marring the table top.

Down through the years *QST* has continually sought to simplify operating methods and switching. In days gone past the amateur station that most nearly resembled a panel in a power house was the one that caught the eye. However, this practice has gradually been superseded by the more practical and obvious methods of handling transmissions. It is quite common practice to turn on the filaments of transmitting and rectifier tubes upon entering the operating room and not turn them off until leaving. This insures tubes, especially mercury-vapor rectifier tubes, against breakdown if plate voltage is applied before the filaments are up to temperature. This leaves only one other operation to put the transmitter on the air — application of plate voltage. All plate transformers can be applied by one switch in the primaries. Then, upon closing the key the station is on the air. Break-in operation should be the aim of all operators. It will come in handy many times and save long calls and wasted time — especially important to the DX or traffic man.



W6TI IS A TABLE-TOP STATION

By use of a small transmitter rack mounted on top of one end of a table this station can mount all equipment above the floor and still keep the apparatus from flowing over. See October, '35 QST.

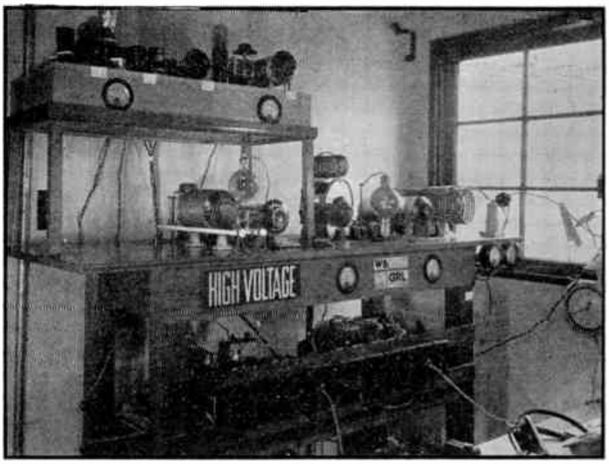
For the 'phone man break-in operation may take the form of "push to talk." Many methods of accomplishing this have been shown from time to time in *QST* and *Hints and Kinks.* Perhaps the easiest method is by having a switch in the crystal oscillator circuit. When the switch is open the crystal will not be oscillating and the amplifiers will have no excitation. The instant the switch is closed the crystal will oscillate and amplifiers will pick up. Advance has been made in the art of crystal grinding and oscillator tubes and circuits so that it is even possible and quite practical to key the crystal oscillator.

Two switches should also be fitted on the table — one for the primary of the filament transformer and one in the supply circuit to the plate supply apparatus. These switches can be mounted under the front edge of the table in a position convenient for right-hand operation. With low-power transmitters, the filament and plate power are often supplied by one transformer; in such a case only one powerline switch will be necessary.

It is usually inadvisable to mount the transmitter or power supply on the operating table. In the case of the self-controlled transmitter, indeed, it is extremely bad practice. All such transmitters are susceptible to vibration and to the effects of "body capacity." Consequently, they cannot be expected to deliver an output of constant frequency when subject to the vibration of keying and the movements of the operator. It is very much better, even in the case of a crystal-controlled set, to mount the transmitter itself on a shelf supported from the wall, on a separate table, or in a special frame.

In crystal-controlled 'phone transmitters frequency modulation has even been traced to transformer vibration. Generally, crystal control is insurance against any frequency modulation, provided the circuits are working properly. In any case, the transmitter should be conveniently placed with respect to the feeder or antenna leads.

Separation of transmitter and receiver is also helpful in keeping unwanted r.f. from transmitter leads out of the receiver circuit. Often the receiver is used as a monitor in which case a separation at least across the room keeps the receiver from "blocking" when listening to the transmitted signal. A shielded receiver and single-pole single-throw switch in the receiver antenna lead right at the receiver will in most cases be ample insurance that the receiver can also be used as the monitor. It is always helpful to those learning to send to be able to listen to their own sending. Should the transmitter become unstable the monitor will show up this condition the moment it occurs. The ideal method is to have a separate monitor-frequency meter.

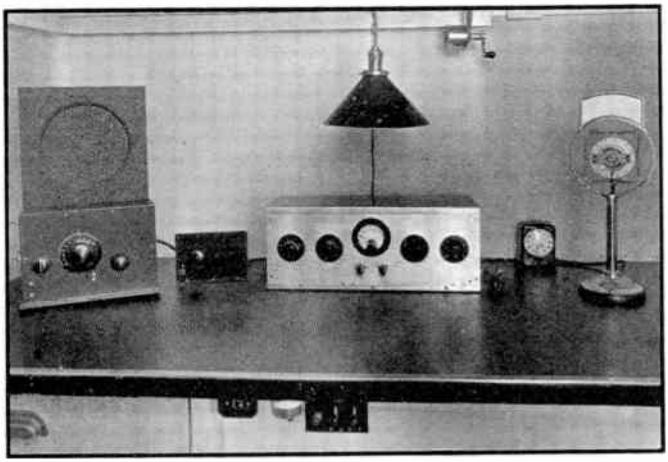


A VERY PRACTICAL BREADBOARD LAYOUT FOR THE HIGH-POWER STATION

With plenty of room and no crowding W6GRL has a convenient arrangement for a breadboard station. The exciter and low-power stages are on a shelf above the table and the final high power stages are on the table-top level. Power supplies are on a shelf underneath. The gear is all readily accessible at all times.

Some operators have a double-throw double-pole switch with the headphones across the switch arms. While sending the switch is changed to the position that will throw the headphones in the plate circuit of the monitor and when receiving the switch position is reversed, with the headphones going in the plate circuit of the receiver. Another method which will save switching is to procure a push-pull audio transformer. One secondary is wired in series with the plate circuit of the monitor and the other secondary is wired in series with the output of the receiver audio. The headphones are across the primary of the transformer. The monitor is set on the frequency of the transmitted signal. Regardless of where the receiver is tuned the transmitted signal will be heard when the key is pressed, unless the transmitter has "hopped" frequency. Thought and perusal of other chapters of the *Handbook* will bring other ideas to light.

The power supply equipment of even a low powered transmitter requires careful placement because of the danger involved. It should not be on the operating table nor should it be under the table in a position where the operator's feet could come in contact with it. Often it is placed on a shelf under the transmitter table or frame. Alternatively, it could be in a large and well ventilated box under the operating table and off to one side.



THE OPERATING POSITION OF AN ULTRA-HIGH-FREQUENCY STATION

W2CUZ only has the bare essentials at his station which is operating only on 56 mc. and above. This station is arranged to remotely-control another local station should communication be desired on the lower frequencies. See July, '34 QST.

The transmitter should be placed in the shack with regard to the operating position and the antenna feeders. The feeders should go directly to the transmitter in as short and straight a manner as is practicable. Often, the antenna series condensers and meters are set on insulators and screwed to the window frame right where the feeders enter the shack.

When radiotelephony is contemplated a great deal of care must be exercised in the manner of placing the audio gear with respect to the radio-frequency apparatus.

Line transformers should be used in coupling audio circuits if there is more than 10 feet between respective amplifiers or transformers. Thus a low-impedance line well used which is much less susceptible to r.f. and the losses are negligible even up to several hundred feet. Great care should be used in the selection of transformers and connections to insure against improper impedance matching. An improper impedance match can result in a very great loss in power and fidelity.

This is important in keeping r.f. out of audio circuits. All leads running from r.f. portion of transmitter to audio should be in metal conduit and grounded. The radiotelephone layout that has the r.f. portion on one side of the room and the audio on another will be the easiest to keep r.f. out of audio system. Audio equipment should be kept away from radiating feeders, as well. In transmitters with some form of grid modulation it is altogether practical to have the audio gear compact in a shielded box on the operating table with only the gain control on the panel. For transmitters that require more audio power the preamplifier may be on the operating table, with low-impedance line to S.A. and modulator.

It is futile, of course, to attempt to outline every possible arrangement of the components of the station. It is better that the amateur should make a study of the stations he visits (and of those illustrated in this chapter and in *QST*) with the idea of improving on them or at least adapting them to his particular needs.

A Simple Remote Control System

● Amateurs are turning in greater numbers to break-in operation and, though to a lesser extent, to remote controlling of transmitters. Both of these systems have been considered standard equipment on commercial installations for several years past. The remote controlling system described in Fig. 1801 has been used at several shore stations in the mobile service and where the receiver is at even a short distance from the transmitter permits perfect break-in operation with the use of a small separate antenna. This same system has been used with amateur rigs where the transmitter has been as much as 7 miles from operating position. In commercial installations the distances have been even greater — limited only by the sensitivity of the relays used. Keying speeds of approximately 250 words per minute have been used with perfect success.

The system's advantages, as may be readily seen, are its great simplicity and its making use of but a single line to perform several duties at the transmitter. The principle of operation is that of having the relays adjusted to operate at different *minimum* values. A careful study of the diagram will make this clear. No values have been shown for the various components. These will all be largely determined by, first the relays, and then the length (resistance) of the line.

The relays used should preferably be of the high resistance-low current "vacuum tube output" type but may, where the length of the line is not very great, be of the ordinary 2- to 12-volt types. Relay 1 is the start-stop control and Relay 2 is the keying control. Relay 1 must be adjusted to close on a current less than that necessary for Relay 2. For example, using relays adjusted to close at 5 and 10 milliamperes respectively, when switch *Sw* is closed resistances R_1 and R_2 will regulate the current flow through the line to 5 mils, which will cause Ry_1 to close and start the transmitter. However, since Ry_2 is adjusted to operate on a minimum of 10 mils it will remain open. When the key is closed, short circuiting R_2 and permitting an increase in current, Ry_1 will stay closed and Ry_2 will close and will follow the make and break of the key circuit.

It should be added that the batteries used may both be at one end of the line. If at both ends it should be remembered that they are still in series and the voltage on the line is the sum of the two. If the line is very long its ohmic resistance must be considered. This, along with the characteristics of the relays, will determine the voltage needed.

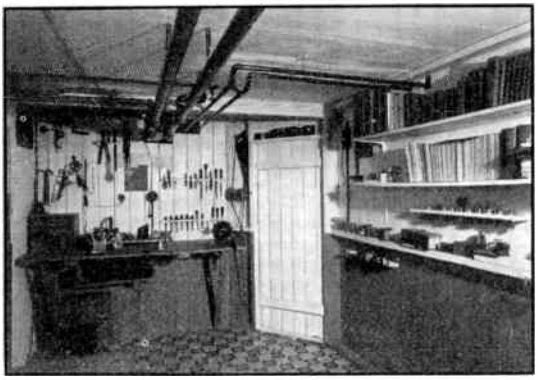
Remote Control, Push-to-Talk for 'Phone or C.W.

● A remote-control system which offers the feature of protection for the final stage in case of excitation failure, and in addition provides a push-to-talk arrangement in which the receiver is automatically cut off during transmitting periods, is shown in Fig. 1802. The filaments of the transmitter tubes are thrown on when the receiver power supply is turned on by means of the relay Ry_4, which is an automobile generator cutout rewound to operate on about 10 ma. Thus the current drawn by the receiver power-pack bleeder is enough to operate this relay, which closes the primary of the filament transformer, T_3.

Under ordinary circumstances the control system uses two push-buttons, one to start and one to stop. Under these conditions the switch, *Sw*, remains closed. Current to operate the relays is taken from the receiver power supply, the relays being wound to operate on 22 volts at about 10 ma. The system operates as follows: When the "start" button is closed the relays Ry_1 and Qy_3 are energized. Ry_3 has two sets of contacts, one a make and the other a break set. The break set cuts the negative "B" lead to the receiver, and the make set locks the relay in the closed position. Relay Ry_1 has two sets of contacts that make when closed; one set is used to lock the relay and the other set to close the primary of the plate-supply transformer for the oscillator, doubler and buffer. As the plate current comes up to normal in the buffer stage it closes relay Ry_2, which is wound to operate in series with the buffer supply, and which in turn closes the primary circuit of the transformer which supplies plate voltage to the final amplifier and modulator. The final only comes on when getting excitation because of the operation of this relay.

The "stop" button shoots the voltage supply to the relays, thus opening them, cutting the transmitter and closing the "B" minus to the receiver.

The switch *Sw* is in the locking circuit of the relays, and if left open the circuit may be used for "push-to-talk," since the relays will not hold themselves closed. When the start button is held down it puts on the transmitter and cuts out the receiver. When the button is let up the reverse takes place. This is similar to the airways system.



A SEPARATE ROOM IN THE CELLAR FOR THE AMATEUR WORKSHOP

This room in W9FQU's cellar is apart from the radio room. All tools are in their place and this room can be used as an amateur's library and workshop, thus not cluttering up the radio shack with unnecessary materials.

The excitation-failure protection can be made even more accident-proof if the relay Ry_2 is made to operate from the final amplifier grid current. This would take care of accidental detuning of the buffer plate circuit, which might cause the tube to draw plate current without delivering excitation power to the final stage.

The microphone and preamplifier would be at the operating position and the output fed into a low-impedance line by means of a tube to line transformer to the transmitter where a line to grid transformer would again match the audio circuit to be controlled.

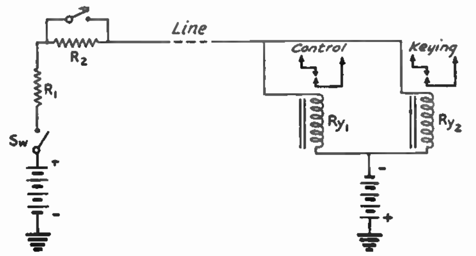


FIG. 1801 — A ONE-WIRE REMOTE CONTROL SYSTEM USING RELAYS OPERATING AT DIFFERENT CURRENT VALUES

The battery voltages and resistor values will depend upon the characteristics of the relays used.

A variety of variations of the above can readily be figured out for the individual location. Tubes are very often used for time delay relays. A circuit showing this application appears in Fig. 1803. Briefly, its operation is as follows. The battery B_1 is of sufficient value to bias the tube so that the plate current is zero, with the key open. The battery B_2 is of the same value as B_1 so that when R_2 is zero the bias on the tube is zero, thereby increasing the current in the plate circuit. The battery B_3 has a voltage of about 90 volts to give a current flow of 40 mils when the resistance of the relay is 180 ohms and the bias zero. The relay used was a 122AM Western Electric, which would close with a current of 28 mils and open when the current dropped to 14 mils.

Best operation will be had when R_1 is varied in steps of 1 megohm from 1 to 8, R_2 is 500,000 ohms and C_1 varies between .25 and 6 μfd.

When R_1 is 5 megohms and R_2 100,000 ohms, it takes longer for the relay to open than it does to close using any value of capacity within the limit stated. When R_2 is increased to 500,000 ohms, it takes longer to close the relay than it does to open it, of course varying again depending upon the capacity used.

There are a great many variations of the application of this circuit and, of course, other tubes might be used in place of the 45. If one should experiment with this circuit he will find a great many uses to which it can be put in the operation of a transmitter or receiver.

The maximum time delay on closing is 16½ seconds when R_1 is 5 megohms, R_2 50,000 ohms and C_1 6 μfd. The opening time for this same arrangement is 7½ seconds. The greatest difference obtained in the other direction is 9 seconds to open with 1½ seconds to close, when R_1 is 5 megohms, R_2 100,000 ohms, and C_1 6 μfd. The two times are practically the same, about 8 seconds, when R_1 is 8 megohms, R_2 500,000 ohms and C_1 4 μfd.

Underwriters' Rules

● Before actually starting on the installation and wiring of the complete station, the amateur should certainly make a study of the Underwriters' requirements.

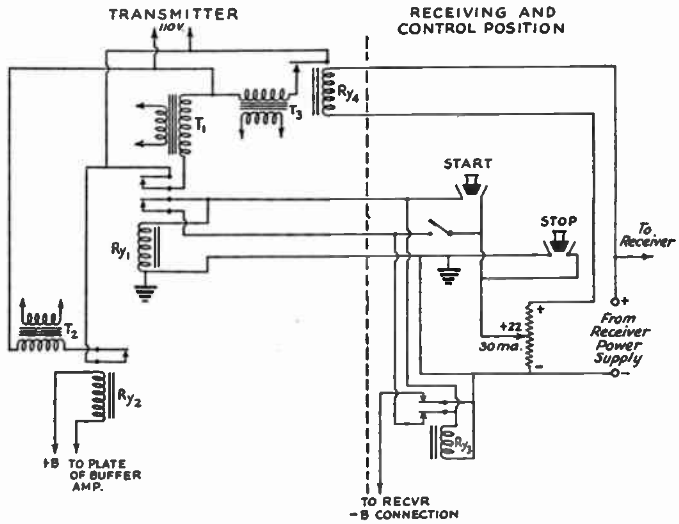


FIG. 1802 — REMOTE-CONTROL SYSTEM INCORPORATING "PUSH-TO-TALK" WITH AUTOMATIC RECEIVER CUT-OUT AND EXCITATION-FAILURE PROTECTION

The specific rules covering radio equipment are given in Article 37 of the National Electric Code, under the heading of "Radio Equipment." Some states have adopted this code or a more strict version of it. Certain cities have adopted it, too, and they enforce their regulations through municipal inspectors. Before making an installation it is well to find out if the apparatus and wiring are subject to a state and city inspection as well as to inspection by insurance interests.

"Approved" refers to devices designed for the purpose used in accordance with recognized practice. The device must be acceptable to the inspection department having jurisdiction (there may be a city or state inspector in addition to the insurance rating or inspection bureau). When there is no inspector for the city or state, insurance interests inspect through their rating organizations, one of which covers each part of the United States. Your local insurance agent can advise you in whose territory you are located so you can get in touch with the proper authority.

A conference with the inspection department *before* making an installation or change will save inconvenience and expense later. Your own interests and those of fellow citizens will be best protected from an insurance and fire-hazard standpoint by having such a conference.

The wiring must follow the requirements observed in your particular community. In some instances a separate power line must be run directly to the watt-hour meter. A few feet of "BX" from the nearest outlet to a "Square-D" switch box, properly fused at the switch, will usually be satisfactory. The installation of high-voltage apparatus and wiring must be done in approved fashion. High-tension cable, supported on porcelain pillar insulators, keeping the high voltage away from all woodwork and neighboring conductors, is a safe type of construction.

A receiving antenna can be connected to ground before it gets to the set through either the in-door or out-door type of lightning arrester. Several approved types are sold by local dealers with complete instructions for installation. These arresters usually are simply spark-gaps sealed in a vacuum to lower the voltage break-down. The ground can be made by scraping a water pipe or ground rod clean and bright with a file. A 10-cent ground-clamp will make a good connection to the pipe. A yearly inspection will insure a good ground. An approved lightning arrester operating at a potential of 500 volts or less is required for each lead-in conductor of a receiving station. There are no requirements for indoor antennas, however.

In the transmitting station section of the Regulations it specifies that transmitting antennas carrying over 400 volts or 100 watts in the station must use No. 7 wire if soft drawn copper, or No. 10 wire if hard-drawn copper. All splices and joints in the antenna must be soldered.

The lead-in wires must be brought into the station through approved lead-in bushings. A good but cheap way to bring in the antenna lead is to drill a hole in the center of a large window pane. A brass machine screw with rubber gaskets will go through this and make an excellent lead-in. The lead-in insulator must have a 3-inch clearance beyond the wall of the structure. Antenna leads must never come within 5 inches of supply wires. A wooden board at the top or bottom of a window will make a good support for lead-in bushings under most circumstances.

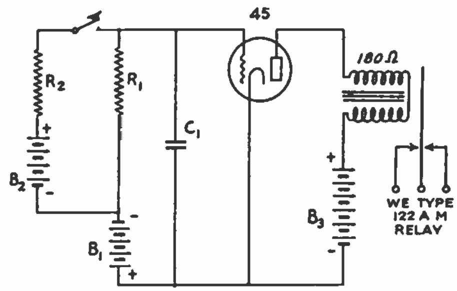


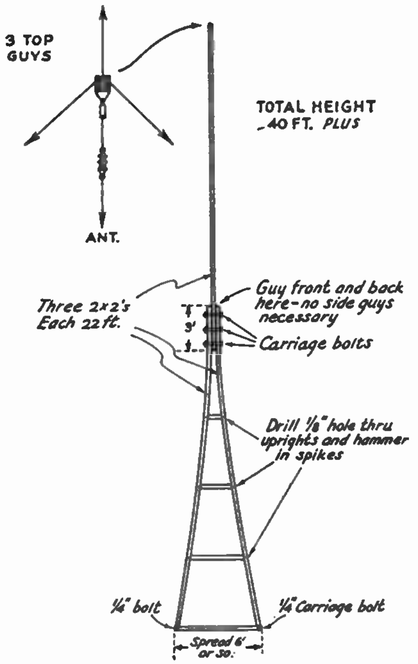
FIG. 1803 — TIME-DELAY CIRCUIT USING A TYPE 45 TUBE

The time constant in the grid circuit regulates the time of opening and closing of the relay. Circuit constants are discussed in the text.

Everyone who owns an amateur station or who plans to have one should send ten cents (not in stamps) 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.

The Antenna

● In addition to the problems of installing the apparatus inside the house, the amateur must also concern himself with the problems of the outdoor equipment — the antenna and its support. In this connection it is very difficult to offer suggestions because of the widely different requirements in different locations. It is certain that any amateur having the patience and application necessary for the completion of the transmitter, receiver and accessories is not to be stumped by the selection and provision of suitable supports for the antenna. In some cases the lack of yard space presents a *real* problem. Usually the owner of the adjoining property will consent to the antenna being extended into his domain. Failing that, about the only alternative is to restrict one's activity to one of the higher frequency bands on which a sufficiently short antenna can be used.



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

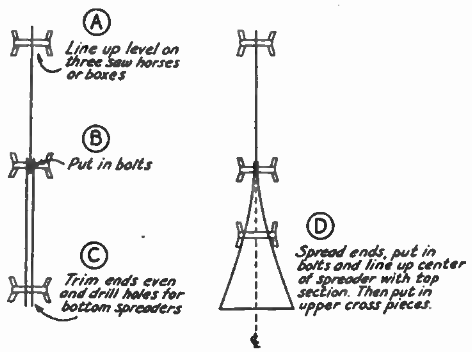
Now that more efficient twisted pair cable is on the market it is possible to erect a transmitting antenna on an apartment and drape the feeder around the outside of the apartment without the worries that accompany the installation of an open-wire type feeder. Radiation from the twisted pair conductor or concentric cable line is also at a minimum if terminated properly at the station end.

Transmitting antenna feeders must be grounded by means of lightning switches unless a special type of feeder is used, such as a concentric cable line with the outer conductor grounded. In this case, when using shunt plate feed the antenna is grounded at all times through the feeder and plate tank.

Underwriters' Rules specify that a flexible lead from ground which grounds both feeders with clips may be used in lieu of lightning switches. In any case, the feeders must be grounded whenever the station is not in use.

The lightning switch to pass Underwriters' Regs must have the following specifications: The switch should be of the single-pole double-throw type having a minimum break distance of 4 inches and a blade of at least 0.0625 square inch cross-section. The switch should be in the most direct line between lead-in and ground but can be located either outside or inside the station. Live parts of the switch must clear the wall (or other conductors) by 3 inches. The switch must be connected to the ground wire whenever the station is not in operation.

Antennas for receiving and low-power transmitting stations should be supported and insulated similarly to public service communication lines, while for medium- and high-power stations the requirements for constructing supply lines for transmitting electrical energy in like situations must be met. Antennas should not cross over or under supply lines or telephone and telegraph wires nor should they run above and parallel to them in such a way that a falling antenna might come in contact with a live wire. Antennas should not cross railroad tracks or public thoroughfares. They should not be attached to poles owned and maintained by local public utilities for supporting power lines or communication cables or wires. In most cases local ordinances forbid such construction as a menace to the public welfare. When antennas are put up in such hazardous locations special precautions should be taken to have ample strength in the



ILLUSTRATING THE METHOD OF ASSEMBLY

antenna wire and its supports, as well as ample clearances. Antennas should not be supported on chimneys. When a tree is used there should be some provision for keeping the antenna from snapping when the tree sways in the wind.

Any size of wire can be used for a receiving antenna. Probably No. 14 B. & S. (American Wire Gauge) hard-drawn copper wire, enameled to prevent corrosion, will have the best balance of electrical conductivity and mechanical strength for that purpose. Transmitting antenna wires for medium or high power amateur stations should have a strength not less than that of No. 10 hard-drawn copper wire and should be insulated with insulators having a minimum creepage distance of 10 inches.

For the amateur interested in directional antennas the mast already detailed will prove highly appropriate. A reasonable height can be obtained with a minimum of expense, space and labor.

Building a Mast

● It is very rarely that an effective antenna can be erected without putting up some form of mast. And in many cases the mast must be erected and guyed in a restricted space. With the idea of providing some suggestions for the prospective mast-builder, we will present the description of a typical mast. The example selected is a 40-foot mast of simple construction and low cost. The only lumber used is 2-by-2 straight-grained pine (which many lumber yards know as hemlock) or even fir stock. The uprights can be each as long as 22 feet (for a mast slightly over 40 feet high) and the cross pieces are cut to fit. Four pieces of 2-by-2 22 feet long will provide enough and to spare. The only other materials required are 5¼-inch carriage bolts 5½ inches long, a few spikes, about 300 feet of No. 12 galvanized iron wire for the guys or stays, enough No. 500 ("egg") glazed porcelain strain insulators to break up the guys into sections and the usual pulley and halyard rope. If the strain insulators are put in every 5 feet approximately 30 of them will be enough.

After selecting and purchasing the lumber — which should be straight-grained and knot-free — three sawhorses or boxes should be set up and the mast assembled in the manner indicated in the diagrams. At this stage it is a good plan to give the mast two coats of "outside white" house paint.

After the second coat of paint is dry, attach the guys and rig the pulley for the antenna halyard. The pulley anchorage should be at the point where the top stays are attached so that the back stay will assume the greater part of the load tension. It is better to use wire wrapping around the stick, with a small through-bolt to prevent sliding down, than to use eye bolts. The latter weaken the mast.

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

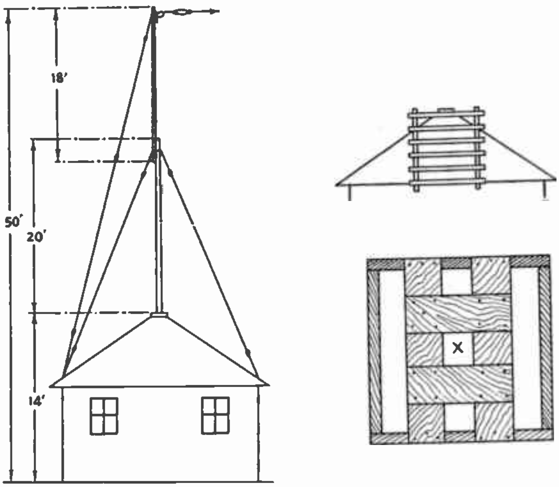


FIG. 1804 — ANTENNA MAST ON TOP OF A TWO-CAR GARAGE

Details of the mast socket and the placing of the "cattle-walk" for erecting the mast are shown.

— 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.

Once the base has been placed on its spot and made level right-and-left, the front and back guys from the mid-section are anchored so that the mast stands vertical fore-and-aft. The last step is to anchor the top guys so that the upper section lines up vertical. This can be done quite accurately by sighting up from the bottom, while a helper tightens and loosens guys as commanded.

A Garage-Top Mast

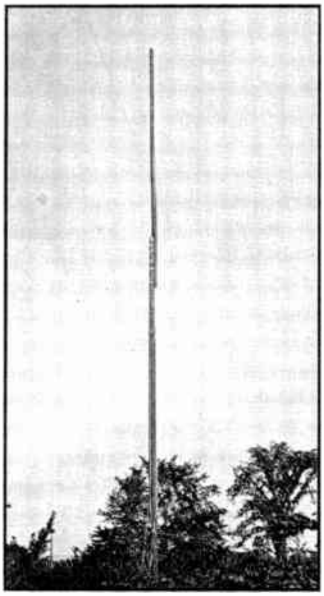
● In some cases a garage may be used to support a simple mast. The usual two-car garage is 20 feet square. Because of the slope of the roof, the actual effect of guys placed on the diagonals is as if they were but 8 feet from the base of the mast.

The mast in Fig. 1804 was made by bolting an 18 foot 2½ by 2¼ on a 20-foot 3 by 4. The overlap was 2 feet. Four guys run from the splice to the four corners of the garage. Two back-guys work against the pull of the antenna, but are not at all necessary to support the mast itself.

Short pieces of guy wire go through the corners of the roof to the scantlings inside and terminate in turnbuckles immediately outside, to which the guys are made fast. A shallow "nest" surmounts the peak of the pyramid and acts as a footing for the mast; it holds itself in place without fastening.

The mast, with guys attached, is stood up against one side of the garage. A "cattle-walk" is then temporarily laid down on one slope of the garage and lashed in place. A ladder is leaned against the side of the garage alongside the mast, its upper end reaching to the "cattle-walk." With four fellows to hold the lower guys (the upper back-stays dangling loose), two fellows on the roof can readily lift the mast vertically hand over hand, it being rested on the rungs of the ladder while fresh grips were taken. With the foot of the mast lifted to the edge of the roof, it was then a simple matter to walk it, a foot at a time, up the "cattle-walk" and place it in its step, the guys meanwhile supporting it.

The antenna halyard runs through the garage roof at the base of the mast, thence over two pulleys which lead it to one wall where an old grate-bar does duty as a counterweight. Where the halyard goes through the roof it runs through a one-foot length of rubber hose to prevent chafing. Without a counterweight an antenna is always too tight or too slack. When a halyard shrinks after a rain, great strain is placed upon rope and fittings and the antenna wire elongates in a fashion that eventually pulls a Hertz antenna clear out of the band. With a weight just sufficient to keep the antenna taut, even No. 14 soft-drawn copper wire will not stretch. One of its greatest benefits, however, is that it also keeps the feeders drawn up snug. In the absence of an old grate-bar of exactly the right weight, try a bucket of sand, using just enough weight to pull things up tight.



SPLICED TELEPHONE POLES MAKE AN IDEAL MAST FOR EXPERIMENTAL ANTENNAS

Telephone Pole Mast

● Telephone poles either in one piece or spliced are becoming more popular because they do not need to be guyed if properly installed and vertical and horizontal arrays may be supported from this type of mast as well as rotatable directive arrays. This type of mast is relatively expensive but the first expense should be the last. One interested in such a structure should contact the foreman of a pole setting crew or a person in the distribution department of either a telephone or light company. Friendly advice should be taken and in the end will help financially.

The photograph shows a two-section telephone pole which rises 88 feet above the ground. A 40′ pine pole was spliced on a 65′ cedar pole with an overlap at the splice of 7′. At the splice three through bolts and four clamps are used. No steps were put on the pole as there are four heavy pulleys on through bolts at the top carrying half-inch rope. Galvanized bolts and pulleys were used in all cases. Should trouble develop, a boatswain's chair can be rigged and raised with a man aboard, using a life belt around the pole. The pole is set ten feet in the ground and three yards of cement fill the hole, 3½ feet in diameter, giving a weight of 6 tons at the base. While the concrete was setting the four halyards at the top were used as guys. This particular pole cost $170 with the labor of pole splicing and hole digging not considered. The "mast raising" was done with the aid of a 50′ crane which happened to be in the vicinity.

CHAPTER NINETEEN

Operating a Station

THE enjoyment of our hobby comes from the operation of our station once we have finished its construction. Upon the *station* and its *operation* depend the traffic reports, DX, and communication records that are made. We have taken every bit of care that was possible in constructing our transmitter, our receiver, frequency measuring and monitoring equipment and in erecting a suitable antenna system. Unless we make ourselves familiar with uniform standard operating procedure, unless we use good judgment and care in operating our stations, we shall fall far short of realizing the utmost in results achieved. More than this, we may make ourselves notorious unless we do the right thing, because we may interfere with other stations or delay their work.

After some listening-in experience you will hear both kinds of operators and realize the contrast that exists between the operation of the good men and that of "lids" and "punks" who have never taken the trouble to familiarize themselves with good practice. Occasionally you will pick up an amateur whose operating is so clean-cut, so devoid of useless efforts, so snappy and systematic, that your respect is gained. It is a pleasure to listen and work with him. On the other hand 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.

For most efficient operation, the transmitter should be adjusted for satisfactory, stable, operation *on one frequency* in the amateur band. Use of quartz crystal control helps to insure close adherence to one frequency and gets results when once a dependable arrangement has been installed. With self-controlled sets known condenser settings to approximate certain frequencies will make it possible to change location in the band slightly to get around interference if necessary. But when such a change is made take no chances; always check frequency with care for there is *no* good excuse for off-band operation. Calibrations of the station frequency standard should be checked at least once a month by A.R.R.L. standard frequency transmissions to guard against variations, and daily comparison with dependable stations assigned channels adjacent to our bands is desirable. 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.

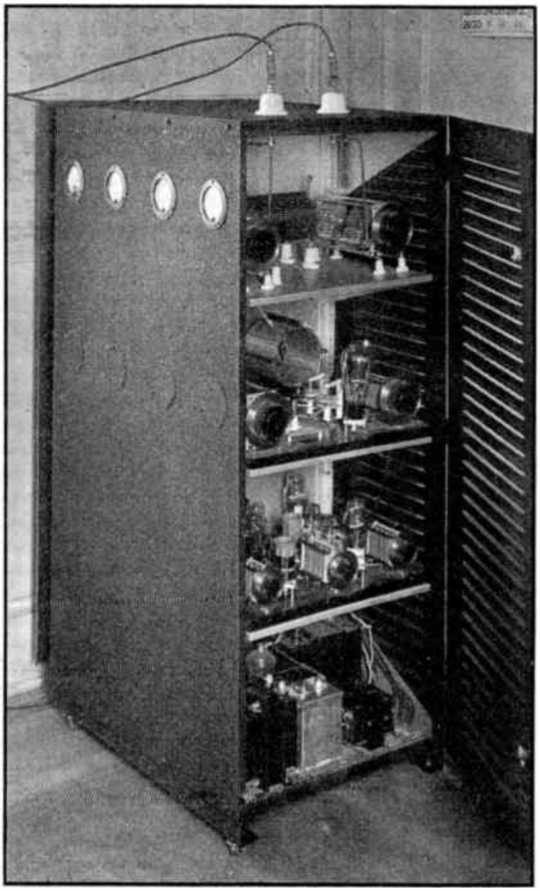
The operator and his methods have much to do with limiting the range of the station. The operator must have a good "fist." He must have patience and judgment. Some of these qualities in operating will make more station records than many kilowatts of power. Engineering or applied common sense are as essential to the radio operator as to the experimenter. Do not make several changes in the set hoping for better results. Make one change at a time until the basic trouble or the best adjustment is found. The quality of operating ability is just as essential and important in radiotelephone operating work.

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."

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.

The good operator sends signals which are not of the "ten words per minute" variety, but they are slow enough so that there is no mistaking what he says. 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 the "inquiry signal." 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.

The adjustment of 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.



W1INF, STATION OF THE A.R.R.L. HEADQUARTERS' OPERATORS' CLUB

This completely self-contained transmitter is located at the West Hartford office of the League where club member-operators may drop in conveniently for noon-hour and after-hours operation. The four transmitter sections shown are, respectively (bottom to top), power supply, exciter (2A5 (2)2A5's (2)801's circuit as described in Chap. 9, two 800's constituting the driven stage, and the antenna coupling unit. On the other side of the equipment housing is located an additional power supply, the modulator (also two 800's), the speech amplifier, and a unit containing relays, and other protective equipment.

A control desk across the room from this transmitter holds the metal-tube single signal receiver whose features are described in full, in Chap. 7. Staff members who operate follow a voluntary operating schedule at INF during the active season, operation alternate weeks being on 20-meter or 75-meter bands. Crystal-switching is provided with crystals for either voice or keyed operation.

Communication

● After all, communication has as its object the exchange of thought between two minds. Sometimes those minds are near each other and it is possible for the individuals concerned to converse at length and exchange their thoughts freely. At other times, and this when radio communication is involved, the individuals are miles apart and the thoughts to be transmitted 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 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 have become necessary to insure a ready understanding of what is going on in the minds of each operator. "Q" signals and abbreviations of various sorts have been devised and are in general use to-day just because of the time element involved, to enable every operator to exchange intelligible thoughts with as little waste effort as possible. 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.

Accuracy is of first importance. Then *speed* in transmission and handling of radiograms must be considered. Very often, transmission at moderate speeds moves traffic more quickly 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.

Procedure

● Official Relay Stations and Official Phone Stations conform in their operating procedure to definite high standards which are mentioned on the appointment certificate. Some specific rules and regulations have been made to raise the standard of amateur operating. 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.

1. The calling station shall make the call by transmitting not more than three times the call signal of the station called and the word DE, followed by its own call signal sent not more than three times, thus: VE9AL VE9AL VE9AL DE W1MK W1MK W1MK. In amateur practice this procedure may be expanded somewhat as may be necessary to establish communication. 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 (this repeated not more than five times) 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.

Stations desiring communication, without, however, knowing the calls of the operating stations within range, may use the signal of inquiry CQ, in place of the call signal of the station called in the calling formula. The A.R.R.L. method of using the general inquiry call (CQ) is 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 expected 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. Stations desiring communication with amateur stations in a particular country shall include the official prefix letters designating that country after each CQ. The city, state, point of the compass, etc., is mentioned and the thrice-repeated station call. International prefixes (page 353) may be used to identify a particular country. Examples follow. A United States station looking for any Canadian amateur calls: CQ VE CQ VE CQ VE DE W1MK W1MK W1MK 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 W6CIS W6CIS W6CIS K. A station with messages for points in Massachusetts calls: CQ MASS CQ MASS CQ MASS DE W3QP W3QP W3QP 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. W1BIG DE W1MK GE OM GA K (meaning, "Good evening, old man, I am ready to take your message, go ahead").

3. Ending signals and sign off: The proper use of AR, K and VA ending signals is as follows: 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." VA (or SK) shall be used by each station only when signing off, this followed by your own call sent once for identification purposes. 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:

(AR) G2OD DE W1AQD AR (showing that W1AQD 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 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.) W9APY DE W3ZF NR 23 R K. (Evidently W9APY is sending messages to W3ZF. The contact is good. The message was all received correctly. W3ZF tells W9APY to "go ahead" with more.)

(VA) R NM NW CUL VY 73 AR VA W7NT. (W7NT 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 W7NT 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 in which the call signal of the transmitting station shall appear 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 ending 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. 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.

Above all, 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.

In acknowledging messages or conversation: Never send a single acknowledgment until the transmission has been successfully 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. The string of acknowledgments leads one to believe that the message has been correctly received and that it can be duly filed away. By the time this much is clear it is discovered that most of the message did not get through at all, but must be repeated. The part after the string of R's may be lost due to fading or interference. It may be assumed the message *was* correctly received. (The message then filed never arrives at its destination.) Be clear and understandable. Use R *only* when *all* is received correctly.

Here is the proper procedure to follow when a message has been sent and an acknowledgment is requested. When all the message has been received correctly a short call followed by "NR 155 R K" or simply "155 K" is sufficient. 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. ?BM ..... 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 unless otherwise instructed by the receiving operator. When reception is very poor, a QSZ can be requested to help make better copy. When conditions are even moderately fair, a QSZ is unnecessary. Few things are as aggravating as perfect transmission with every word coming twice. Develop self-confidence by not asking others to "QSZ" unless conditions are rather impossible. Do not fall into the bad habit of sending double without a request from fellows you work.

Do not accept or start incomplete messages. Omission of the fundamental parts of a message may keep a message from getting through to its destination. Official Relay Station appointments are subject to cancellation for failure to make messages complete enough.

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. Several contests have grown greatly from year to year, being modified only slightly in character from time to time in accordance with suggestions and expressions from amateurs. Probably the most well known of all are the annual Sweepstakes, and the DX contests, which are open to every ham and carry an appeal to nearly all groups.

Within the A.R.R.L. field organization (in which there are appointments open to every amateur, specified lines of work in ham radio for those with the qualifications) there are monthly and quarterly activities that play an important part in making ours a real radio fraternity. The first Saturday night of each month is the time 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 first Saturday night in each month is known to the gang generally as RM NITE because this get together started as a gathering of Route Managers only, the number of RMs exceeding somewhat the number of other officials. The basic appointments of Official Relay Station and Official Phone Station include several times as many individual operators as there are A.R.R.L. officials of course. Special activities are scheduled quarterly for the ORS-OPS appointees, these having something of the character of an operators' competition to test stations and develop operating ability. At the same time, every appointee gets a chance to chat as formally or informally as he likes with his Section Manager, Phone Activities Manager, Route Manager, or perhaps with A.R.R.L. Headquarters men or League Directors all of whom have come to look forward to these get togethers. The qualifications of both O.R.S. and O.P.S. are such that these groups are at all times made up of only the keenest and most active operators. The quarterly QSO Parties held on a Saturday-Sunday in late January, April, July and October assist in testing out stations, developing equipment, and maintaining fraternalism at the same time all participating operators keep themselves in readiness for either routine or emergency operating with the true A.R.R.L. spirit of preparedness.

It may be interesting to review briefly the general activities of a typical "full" season, for what sort of a program is 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. Many new stations can be worked. This contest is announced in coöperation with the Wireless Institute of Australia, and as with all activities, rules are given in the current issue of *QST*, distributed on this continent just before the activity opens. 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 to the most proficient, follow the running off of this event.

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. This is usually held in October or early November.

One of the very biggest events of the year is the annual Sweepstakes Contest, or National A.R.R.L. QSO Party which has potentialities of operating fun and new QSOs for everybody, the operation extending to all bands. Each November (it falls the last nine days in November in 1935) the rules for this are announced, again with A.R.R.L. certificate awards in each W and VE Section in the League's Field Organization. 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 69 A.R.R.L. Sections.

In December for the last two or three years a Copying Bee has been arranged. The League offers a silver loving cup 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.

In February several successful 'Phone-C.W. QSO Parties have been held, the idea being to make possible more contacts between operators using these different modes of transmission. It is fun, and requires operating skill to hook up. Voice operated stations have found that telegraphing hams "line up" for contacts so they can be worked very rapidly indeed, once the technique is mastered.

Every year, in March, comes the annual A.R.R.L. International Relay Competition, or DX Contest, 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.

Last, but by no means least on the League's operating program, is the annual A.R.R.L. Field Day which ordinarily is 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 and individual groups always have a good time, learn much about the requirements for knock-about conditions afield, and achieve success in testing equipment carefully built or quickly thrown together to suit the needs of the occasion.

Operating Notes

● A sensitive receiver is often more important than the power input in working foreigners. There is not much difference in results with the different powers used, though a 250-watter will probably give 10% better signal strength at the distant point than a Type '52, 800 or 10's, 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 your call.

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.

The signal "V" is sometimes sent for two to five minutes for the purpose of 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 "2R30 PM." A long dash for "zero" and the Morse C (. . .) for "clear" are in common use. An operator who misses directions for a repeat will send "4," meaning, "Please start me, where?" These latter abbreviations, like others in our present-day practice, are hybrids, originating in wire practices and Morse usages.

Improper calling is a hindrance to the rapid dispatch of traffic. Long calls after communication has been established are unnecessary and inexcusable. Some stations are slow to reply to a call. However, the day of the station with dozens of switches to throw is past. Controls for both receivers and transmitters are simpler, fewer in number, and more effective. The up-to-date amateur station uses a "break-in" system of operation and just one switch controlling the power supply to the transmitter.

Poor sending takes the joy out of operating. There are stations whose operators are not able to send better and those who can send better but do not. The latter class believe that their "swing" is pretty. Some use a key with which they are not familiar.

Beginners deserve help and sympathetic understanding. Practice will develop them into good operators. 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* at anything. When not sure of part of a message they ask for a repeat. The "lid" operator can be told very quickly when he makes a mistake. He does not use a definite "error" signal and go on with his message but he usually betrays himself by sending a long string of dots and nervously increasing his rate of sending. The good operator sends "?" after his mistakes and starts sending again with the last word sent correctly. Unusual words are sent twice; "?" is sent and then the word repeated for verification.

The law concerning superfluous signals should be noted carefully by every amateur. Some operators hold the key down for long periods of time when testing or thinking of something to send. Whenever this is done during operating hours, someone is bothered. Unnecessary interference prevents someone from getting in contact with (QSO) someone else, and if messages are being handled the copy is ruined. If you must test, disconnect the antenna system and use an equivalent "dummy" antenna (made of lumped resistance, capacity and inductance). Always send your call frequently when operating with the antenna. Pick a time for adjusting the station apparatus when few stations will be bothered.

Using a Break-In System

● A break-in system of operation makes it possible for us to interrupt the other fellow if we miss a word or do not understand him. With a telephone we stop talking as soon as the distant party speaks and interrupts us. In a telegraph office the operator who misses a word opens his key so that the sending is interrupted and cannot go on until the receiving operator has had his say and again closed the circuit. In a radio system using break-in the receiving operator presses the key and makes some long dashes for the transmitting operator to hear. As soon as he gets the signal he stops transmitting and listens to what the receiving operator says, before resuming sending.

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. Appreciation of the many advantages should make the use of break-in wide-spread for *both* voice and code work.

Useless calling and unnecessary transmission during periods of heavy QRM can be prevented through intelligent use of break-in. Long calls, for example, are inexcusable, inconsiderate and unnecessary. Every transmitter can be so arranged that by lifting the key (and connecting 'phones to the receiver if these are cut off during transmission) the operator can ascertain if the station called is replying. Brief calls with frequent short pauses to listen for replies constitute intelligent operating, devoid of useless effort. During c.w. transmissions insert a "BK" and pause briefly at intervals. This makes it possible for the other operator to stop you, or get fills, if necessary. If not, transmission may be resumed. If you find that the station you are calling has, in the meantime, connected with another amateur instead of answering your call you will have at least saved yourself some wasted effort. QRM will also be lessened thereby. If the operators understand that break-in is being used, a "bk" and "g.a." will be of greatest value to interrupt transmission and direct when it shall be resumed. Where voice is being used similarly, conversations resemble wire telephone communication, and flow smoothly from subject to subject, and the "click" noted when the carrier is cut off momentarily can be as effective as the word "break" (so this can be eliminated) when two operators experienced in this mode of operating use this improved system of operation.

The faster the change from transmitting to receiving can be engineered the better. A Morse-wire type key with a switch on the side, in series with either the filament center-tap (cathode) of the oscillator stage, or in the negative high voltage supply can be used for *voice* break-in. (There must be enough fixed bias on amplifier stages to keep the plate current low when r.f. excitation is nil, and h.v. on, of course.) If there is audio feed-back from speaker to microphone, head-phones should solve the problem, or if desired a relay can be used to short the microphone transformer. 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. When two stations are using break-in, they can interrupt each other at any time when something goes wrong or a letter is dropped, and traffic can be handled in half the usual time. There is a real "kick" from working a break-in arrangement.

Keeping a Log

● Every operator of an amateur station must keep a log of the operating work that is done; it should cover, as well, the tests of an experimental nature that are carried out with the transmitter or receiver.

The well-kept log is invaluable in checking up reports of any nature concerning amateur station operation. It contains positive evidence of every transmission. It is a permanent record of the achievements of the station. The Federal Communications Commission obliges every amateur station to maintain an accurate log of the time of *each* transmission, the station called, the input power to the last stage of the transmitter, the frequency band used, the time of *ending* each QSO and the operator's personal "sine" for each session of operating. So, in addition to other excellent reasons for log-keeping, the regulations make a complete record of transmitting activity compulsory.

Amateurs always have kept logs because of the ready-reference value in proving records and because of the pleasant recollections and associations that come from reviewing the history of friendly radio contacts and from displaying the record of the accomplishments of the station to interested visitors and friends.

A loose-leaf notebook can be used. The sheets can be renewed each month and those used can be taken out and filed away with the cards and station records. A stenographer's ordinary notebook costing from ten to thirty cents and about 4½" by 8½", takes little space on the operating table and also makes a good log book. If simplicity and low cost are the only considerations, such a modified notebook-log is recommended.

A dozen pages may be ruled in advance with vertical lines. In the first column the date and times are noted. In the second column the calls of stations worked, heard, and called are put down. A circle, parentheses, or a line drawn under the call can indicate whether a station was worked, heard and called, or simply heard. A special designating sign or abbreviations before or after the call letters can show this information. Provision must be made for entering the power, the time of ending QSOs, and the frequency band used. *W*, *H*, and *C* can be used for "worked," "heard" and "called."

Most amateurs find it more convenient to get an inexpensive ready-made log, instead of going to the trouble to rule the home brewed variety. In keeping a log, power and frequency can be written across the page, or in the page heading, new entries being made only when these are changed. The dial settings of receiver or frequency meter may be entered in logging stations so that we can come back to these same stations without difficulty when desired.

Figure 1 shows the official A.R.R.L. log. The first entry for each watch is that for the date and time. Greenwich Civil Time is the logical reference standard but local standard time is easiest to use to avoid confusion and so this is used by most amateurs; *PST*, *MST*, *CST*, *EST*, *GCT*, etc., is entered in the heading of the first column in the A.R.R.L. log and then the date which corresponds to that kind of time is put in the first space below the heading, and time entries on the first vacant line below that, those to be entered progressively until a change in date.

CW and *F* (or *P*) can be used in the heading to distinguish between your use of c.w. telegraphy and radiophone operation; or *A1*, *A2*, or *A3* standing for c.w. telegraphy, c.w. telegraphy modulated at audible frequencies, and radiotelephony (speech), respectively.

Log users will quickly adopt certain convenient practices which simplify the keeping of a log such as use of an X for one's own call signal, to save time in making the entries. When several stations answer a CQ, each should be listed in the third column following your own call signal in the second column. Any unusual data requiring explanation, such as an interrupted or incomplete contact due to power line failure, local interference, etc., should go in the "remarks" column. Also a detailed record of messages exchanged should be entered. This last column should show the "sine" of a new operator taking the key, remarks, message notations, changes from previously recorded (heading) information, etc. Special provision is made in the A.R.R.L. log, for recording signal reports, and the time of ending each QSO as required by the F.C.C. Entries in this column at once show which stations were "worked" without special indications of C, W, or H being necessary.

Left-hand pages in the log may be left blank to use for extensive remarks on emergencies or expeditions, for diagrams, records of tuning adjustments and ranges, or changes in equipment.

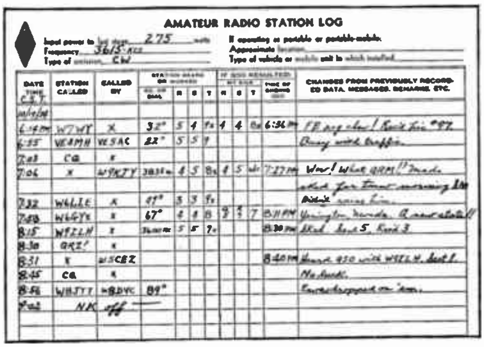


FIG. 1

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.

A log is of great value in a number of additional ways through use of these left-hand pages. A comparison of the operating results obtained with different apparatus in use at different times is valuable. The "DX" or traffic-handling value of the various frequencies over varying distances may be readily found from the log. The effect of weather or time of day may be also quickly found. Every change made in either the transmitter or antenna system should be noted down in the log so that results may be compared for dates before and after the date when a change was made. No matter how trivial the change, put it down in the log. Remember that only one change at a time should be made if the changed results are to be attributed to one definite cause.

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 — SAIL
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	

'Phone Procedure

● Amateur radiophone stations should use the international radiotelephone procedure which is part of the supplementary regulations to the International Radiotelegraph Convention.

For spelling call signals, service abbreviations and words, such lists as just given should be used.

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 of 'phone procedure in accordance with the International Radiotelegraph Convention:

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."

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, test, 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.

Amateur Status

● It is most important that individually and as an organization we be most careful to preserve our standing as amateurs by doing nothing to harm that most precious possession, our amateur status.

No brief can be held for the amateur who accepts direct or indirect compensation for handling specific messages. This is in direct violation of the terms of the amateur station license and the regulations of the Federal Radio Commission.

It is the purpose of these paragraphs to warn amateurs to avoid being "used" by commercial interests in unethical ways. An amateur asked our advice recently on accepting a whole set of fine station equipment from a business house — the only string being that he should consistently try to handle some traffic with a certain foreign point. 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 a "net control station" in return for the things it could gain by making amateurs violate their amateur status!

There are plenty of legitimate activities in which amateurs may participate. The League approves amateur coöperation with worthy enterprises, sponsors tests to show the utility of short-wave communication, encourages worth-while service to expeditions in getting their messages from the far parts of the earth. Be assured that there is nothing wrong in accepting trophies and prizes of any sort for legitimate amateur competition in communication contests. Watch carefully and refuse to enter into any agreement or alliances through which you accept anything in the nature of a consideration for services rendered in connection with your amateur radio station. There is no question of the good intentions of the amateurs involved in the several cases cited. Very great damage can be done unless there is strict observance of both the spirit and letter of the regulations involving amateur status. Avoid sugar-coated promises and opportunities which might be construed as direct or indirect compensation and a violation of amateur status. Seek competent advice before you jump at chances to get something for nothing. Preserve your most valued possession, your status as an amateur.

Our right to handle friendly communications of worth-while character and to engage in valuable work of all kinds in emergencies and with expeditions remains unquestioned. A "consideration" of any nature whatsoever absolutely establishes the "commercial" nature of any traffic.

Emergency Work — QRR

● Amateurs have always given an excellent account of themselves in many emergencies of local and national character. In every instance, the amateurs who have considered the possibilities of an emergency arising *before* the trouble actually came to pass were the ones who must be credited with doing the most important work. They were ready, prepared for the crisis when it came.

Considerations of an emergency power supply are of first importance in many cases where radio is destined to play a part. If local electric service mains are crippled one may have recourse to B batteries, dynamotors driven from storage batteries, and the like. By consulting with other amateurs and putting all the available facilities together in the most favorable location a station can be made operative in short order. An order from some competent authority will make supplies of batteries or temporary service from a public utilities company available for emergency stations. It is sometimes as easy to move the amateur station to a power supply as to collect a power supply together and bring it to the amateur station. This is especially true if the transmitter and receiver are built as independent units. In some emergencies B batteries have been provided from local electrical supply stores.

During emergencies it is often possible to send press addressed to U.P., A.P., N.A., A.N., etc. between the transmissions of relief priority traffic. Invariably such messages are correctly delivered to local member-newspapers in such associations, the public kept informed, and amateur radio credited. Such broadcasts should be sent at regular intervals if possible. They have sometimes been overlooked in the rush.

BEFORE EMERGENCIES

Be ready, with really portable sets, and emergency power supply.
Overhaul and test periodically.
Give local officials and agencies your address; explain the availability of amateur radio facilities through your station in emergencies.

IN EMERGENCY

CHECK station operating facilities; offer your services to all who may be able to use them; inform A.R.R.L. an emergency exists, if possible.
QRR is the official A.R.R.L. "land SOS," a distress call for emergency use *only* . . . for use *only* by station asking assistance.
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. Don't clutter the air with useless CQs. 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 first 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 33 major disasters since 1919 has won glowing public tribute. Maintain this record.

Be ready for the emergency call, QRR, when it comes. Jump into the breach with your station if feasible or stand by and avoid interference to those handling emergency traffic if this seems to be the right thing to do. "Standing by" is sometimes the harder but wise course if the important communications are being handled satisfactorily by others and your traffic is "public correspondence" for individuals.

Make note of the address of railroads, of Red Cross headquarters, of local military units, police departments, representatives of press associations and the like, if possible putting your station on record with such organizations and other competent authorities so that you will be called upon to assist when emergency communication is necessary. When storms approach or disaster threatens it is best to keep in touch with the situation by radio and again to offer service to these agencies well in advance of the actual emergency. Emergency work reaps big returns in public esteem and personal satisfaction.

After emergency communications are completed, report in detail direct to A.R.R.L. just what part you and fellow amateurs played in the situation. On such reports *QST* articles are written. *From analysis of all reports an Award Committee of A.R.R.L. Headquarters officials, base their recommendations for awards granted for notable "public service" work.* Certificates are given individual amateur operators from time to time in recognition of meritorious work contributing substantially to the service record of the amateur through noteworthy achievement in *emergencies*, and regular work with *expeditions*. Report your work!

Stations outside an "emergency zone" in communication with relief stations in that zone are requested to inform A.R.R.L. Headquarters of this situation by telegram to facilitate traffic movement and for the information of the press.

A.R.R.L.'s Emergency Corps — Join Now

● At least one amateur station in every community should be equipped with auxiliary station equipment for use in emergency. For real preparedness such equipment should be designed to operate from power supplies other than the regular a.c. or d.c. lines. Although it is true that much of the most valuable emergency work is done using equipment operating directly from a.c. or d.c. mains, it must be remembered that the "stricken area" itself *is usually without current from the power company.* This means a wait until lines are repaired. "Waits" are inexcusable in emergencies. Communication should be established at the earliest possible moment. To guard against delays the "emergency set-up" must operate from auxiliary power, and the operator must at all times know where he can secure the auxiliary power (if he does not have emergency power himself, arrangements can usually be made with local hardware dealers, radio stores, etc., for the loan of batteries when the need arises).


This Certifies that ____________________
is a member of the
AMERICAN RADIO RELAY LEAGUE
EMERGENCY CORPS
FOR PUBLIC SERVICE
QRR
This operator is prepared to furnish communication to his community in the event of failure of regular communication facilities due to storms, floods and similar disasters.
____________________ Comms. Mgr. A.R.R.L.

MEMBERSHIP CARD, A.R.R.L. EMERGENCY CORPS

The "A.R.R.L. Emergency Corps" is made up of those amateurs who have available at their stations transmitting and receiving equipment suitable for use in an emergency, and capable of operating from power auxiliary to regular a.c. or d.c. mains. An important part of A.R.R.L.'s operating organization, all amateurs are invited to enlist at once in this "Corps." The only requirement is the possession of enough emergency equipment to make a complete station, capable of being set up in a short time.

How to join the "A.R.R.L. Emergency Corps": Every member of the Corps is required to "register" at headquarters on the emergency equipment available at his station. Appointment to the Corps will remain in effect only during the time when such equipment is on hand and in operating condition. *To join* simply send a post card to the Communications Department, A.R.R.L., West Hartford, listing what emergency equipment you have (transmitter, receiver, frequency band(s) it works on, auxiliary power — whether on hand or whether arrangements have been made to secure power quickly if emergency arises). If your application proves OK, you will be issued a *membership card,* and your availability will be registered on a headquarters record. Our annual A.R.R.L. Field Days stress emergency preparation and stimulate development and trial of successful portables also.

Every member of the "A.R.R.L. Emergency Corps" will be expected to make known his availability for emergency communication to local Red Cross officials, railroads, military units, police departments, representatives of press associations and the like. All Corps stations should be on record with such organizations and other competent authorities so that they will be called upon to assist when emergency communication is necessary. The front of the membership card in the Emergency Corps is shown elsewhere in these columns; on the reverse is a summary of communication principles to be followed in emergencies and an introduction to local agencies that you may have occasion to assist.

The goal of the "A.R.R.L. Emergency Corps" is: AN AMATEUR RADIO EMERGENCY STATION IN EVERY COMMUNITY!! Will *you* help us achieve that aim? Amateur Radio as an emergency communication system is invaluable. Every red-blooded ham should want to do his part! Send your application to the Emergency Corps as soon as possible. We need you! And your community needs you!! Clubs working in the interest of amateur radio and their communities have a real opportunity in this field too, and we shall be glad to enroll club stations in the A.E.C.!

The QSA- and R-Systems

● The Madrid Convention (Appendix 10, General Regulations) gives a scale of definitions which indication, given after the appropriate Q signal, shows progressive signal strength. QSA means, "The strength of your signals is . . ." Some of the definitions, however, appear to confuse audibility or signal strength with readability, which may be impaired even when signals are strong, by atmospherics, interference, a noisy receiver, etc.

QSA1 — Hardly perceptible, unreadable
QSA2 — Weak, readable now and then
QSA3 — Fairly good, readable but with difficulty
QSA4 — Good, readable
QSA5 — Very good, perfectly readable

Since, due to the wording, the internationally-formulated definitions of signal strength by the QSA system have been used by amateurs as a "readability" scale, amateurs have supplemented this by use of the following table of definitions, constituting the R system of indicating audibility, or signal strength without regard to other sounds in the 'phones or room.

R1 — Faint signals, just audible
R2 — Weak signals, barely audible
R3 — Weak signals, copiable (in absence of any difficulty)
R4 — Fair signals, readable
R5 — Moderately strong signals
R6 — Strong signals
R7 — Good strong signals (such as copiable through interference)
R8 — Very strong signals; can be heard several feet from phones
R9 — Extremely strong signals

The QSA and R systems are usually used together, when used. The R-S-T system reports, next to be explained, are given as a three-numeral block, so the definitions cannot be confused with QSA-R designations.

The R-S-T System of Signal Reports

● For many years amateurs have been concerned with the problem of exchanging concise yet complete reports. From the simple use of QSA-QRK-QRZ in the early days to indicate three possible degrees of loudness, the requirements have become more exacting, involving the use of numbers to indicate not only gradations of signal strength, but to show other qualities of signals such as readability and tone. Just as the QSA-definitions tend to confuse strength and readability, the earlier tone scales included mention of key clicks, back wave, modulation frequency, etc., making the scales incapable of ready memorization, and improperly adding things besides tone which were associated with the complex signals we hear. The demand for greater accuracy, for fuller reports, and maximum brevity in transmission, led to the consideration in 1934 of the R-S-T system which eliminated some of these earlier defects.

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.)

The system proved popular, at once supplanting other systems that had been in use on the major communication band used by amateurs in North America for domestic purposes. Some time after the presentation had received such acclaim and adoption, the author of the system, responsive to amateur opinion, recommended a 9-point strength scale in place of the 5-point scale which was first suggested. W2BSR's second proposal was likewise favorably received. The completeness and timesaving characteristics are appreciated wherever the R-S-T system is used. The Handbook would not be complete without including this up-to-date reporting system, the present standard recommended for your use.

The R-S-T system is an abbreviated method of indicating the main characteristics of a received signal, the Readability, Signal Strength, and Tone. The method of using the R-S-T system is extremely simple. 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?

Such a signal report as "RST 387X" (abbreviated to 387X now it is understood that reports follow the R-S-T system) 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. Various report combinations are based on the tables given on the previous page.

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 in his neighborhood and when there are simple remedies to be applied. 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.R.C. representatives find it necessary to investigate facts in an interference case.

Actually most interference is traceable to faulty electrical equipment, inadequate shielding or poor design of receivers, and less than one per cent. of the interference reported is traceable to amateur sources.

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. Where "proximity" is part of the problem special measures should be considered to isolate circuits and equipment by installation of suitable "traps," to aid selectivity, or by chokes and condensers to prevent "coupling" through common supply line wires. Each individual must accept responsibility for his equipment. Coöperation is the only policy that will help either party — a full measure of coöperation and understanding must be brought about in every interference case.

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.

The club interference committees investigate reports of *amateur* interference, put the interested parties in touch with each other and suggest ways of reducing or getting rid of the interference. When quiet hours are necessary, they are recommended.

Call Books

● The "Radio Amateur Call Book Magazine," listing amateur and many high-frequency commercial stations of the entire world, may be obtained from A.R.R.L. Headquarters, 38 La Salle Road, West Hartford, Conn., single copies, $1.25 (foreign $1.35). This call book now appears in March, June, September and December, with new calls added up to the date of issue. Yearly subscription, $4.00 (foreign $4.35). This publication is the most up to date of all such books, since it is issued and revised quarterly. An up-to-date call book is a practical necessity and convenience in just about every ham station.

A complete list of Canadian amateur station calls can be obtained for 25 cents from the Department of Marine and Fisheries, Ottawa, Canada.

Operating Hints

● Listen carefully for several minutes before you use the transmitter to get an idea of what stations are working. This will help in placing messages where they belong.

Use abbreviations in operating conversations. This saves time and cuts down unnecessary interference.

Report your messages to the local traffic official every month on time, otherwise you cannot expect your report to reach *QST*. Reports sent to Headquarters are routed back to the local officials who make up the monthly report.

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.

W1AUF DE W1BMS P, meaning paid, personal, or private message (adopted from commercial procedure) is much quicker than *HR MSG* added to a call. *NIL* is shorter than *QRU CU NEXT SKED.* Instead of using the completely spelled out preamble *HR MSG FM AUGUSTA MAINE W1BIG NR 156 OCTOBER 13 CK 14 TO*, etc., transmission can be saved by using *AUGUSTA ME W1BIG 156 OCT 13 14 TO*, etc. One more thing that conserves operating time is the cultivation of the operating practice of writing down "156 W1UE 615P 11/13/36" 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.

All messages should be handled in standard A.R.R.L. form.

Be courteous over the air. Offer suggestions for improving the other fellow's note or operating methods. Expect and ask for similar suggestions without expecting any praise. Constructive things can be said without being disagreeable or setting one's self up as a paragon. *Be truthful but tactful.*

A-1 Operator Club

● The object of this club is to promote and encourage a high calibre of operating in the amateur bands. To become a member, one must be nominated by at least two operators who already "belong." In choosing operators for the "A-1 Operator Club" the following points are considered by members: (1) General keying. Well formed characters and good spacing will be considered before "speed." Similarly, good voice operating technique, clearness, brevity, coöperation with other operators, careful choice of words, etc., may be used as criteria in nominating 'phone operators. (Special extra credit may be given for use of standard word-lists in identifying calls and unusual expressions.) (2) Procedure. Use of correct procedure is a natural qualification. This applies to both general operating and message handling. (Procedure as recommended in this *Handbook* is a good standard.) Long CQs, unnecessary testing, long calls without signing, too much repetition when not requested, and all other such poor practice, are grounds for disqualification. (3) Copying ability. This to be judged by proficiency in copying through QRM, QRN and other difficulties, and accuracy of copy, as well as by ability to copy at fast speeds. (4) Judgment and courtesy. The "CUL 73" type operator can never make the grade. An operator should be courteous and willing to consider the other fellow's viewpoint. He should QRS or QSZ, without "crabbing" when requested. He should embrace every opportunity to assist beginners, and to help them along through some of the more trying experiences of operating. He should never knowingly QRM another station, but should coöperate as much as possible with stations working on his frequency. He should not decry "lid" operating but should assist the newer operators and offer friendly, courteous advice as to how they might improve their operation. The matter of "good notes," "sharp" signals, lack of frequency "wabbulation," good quality ('phone), use of sound technical arrangement and proper adjustment, while not directly points of *operating* ability, are certainly concerned directly *with courtesy and judgment* and as such these things must be weighed under (4).

A-1 operators, in considering candidates for nomination to the "club" carefully consider each of the four qualifications, each counting a possible 25 points (of 100 total). No operator nominated should have a rating of less than 15 on any qualification, and the total must be *80 or over*, to warrant a recommendation for a particular operator.

Regarding *disqualification*. After an operator has been nominated if exception shall be taken, or complaint made of faults in his operating work, copy of such complaint shall be sent to him in order that he may profit from constructive suggestions, or explain the circumstances. In the event of a sufficient number of objections to a nomination or lacking a satisfactory explanation, the call may be added to a "disqualified" list or record at Headquarters.

The A-1 Operator club should include in its ranks *every* good amateur operator who follows standard practice after he gets on the air, and after gaining experience contacts hams who are already members. *Aim to become a fine operator, and also an "A-1" operator.*

CHAPTER TWENTY

Message Handling

MESSAGE handling as a form of amateur activity has never required any boosting — for just as the ultimate aim of amateur radio on all frequency bands is *communication*, so is the relaying of word by radiogram a "natural" when one has something to say to a party beyond immediate reach. Not all hams perhaps appreciate the utility that results from using amateur message service in our ham correspondence. However, no ham, not even a new member of the brotherhood, but feels the satisfaction of having really accomplished something tangible in exchanging a message (recorded communication) with another amateur. Of course not all beginners develop the advanced operating technique of the finished message handler, but it is within the reach of all who will try. The knack of handling a key is explained elsewhere. In this chapter we shall discuss basic points to follow in message handling activities.

In spite of occasional complaints of delay or non-delivery of ham messages, amateur traffic handling is effective and highly developed, *if one knows how to use it.* Don't expect that you can get on the air with the message you have written and give it to the first station that comes along and expect miracles to happen. You fellows who get your fun principally from DX, rag chewing, and building equipment should appreciate that you must place the occasional message *you* start and wish to have reach its destination, not in the hands of others like yourselves, but in the hands of one of the many operators who specializes in keeping schedules and handling messages, one who gets his fun mainly out of this branch of our hobby, who knows the best current routes and is in a position to use them. Reference to the "station activities" of the latest *QST* to identify the calls gleaned from listening as those of men actually handling and reporting traffic regularly will enable anyone to start a message on its way intelligently by giving it to a station that will properly and reliably direct it on its way with minimum delay.

Station owners may originate traffic *of any kind* going to any part of the United States, Hawaii, Porto Rico, Alaska, or the Philippines. Messages with amateurs in Canada, Chile, and Peru may be handled under certain restrictions. Important traffic in emergencies or messages from expeditions for delivery in Canada must be put on a land wire by the U. S. amateur station handling. International regulations prohibit the handling of third party messages to the majority of foreign countries. Messages relating to experiments and personal remarks of such unimportance that recourse to the public telegraph service would be out of the question may be handled freely with the amateurs of any country, but third party messages only under special arrangements between U. S. A. and other governments, and only to the extent agreed upon by the contracting governments.

Messages may be accepted from friends or acquaintances for sending by amateur radio. Such messages should be put in as complete form as possible before transmitting them. *Incomplete messages should not be accepted.* As messages are often relayed through several stations before arriving at their destination, *no abbreviations should be used in the text* as mistakes are bound to happen when the text is shortened in this manner. To people not acquainted with radio abbreviations, messages written in shortened form are meaningless. Delivering stations must be careful to see that messages are written out fully.

In handling messages we are doing something really worth while. We want to start only good worth-while messages from our stations. Our efforts should be directed to making the quality of our message service high. The number of messages we handle is of secondary importance. The *kind of messages* we originate or start from our stations and the *speed* with which the messages pass through our station and the *reliability or accuracy* with which the messages are handled are the things of paramount importance.

Message Form

● Each message originated and handled should contain the following component parts in the order given:

(a) City of origin

(b) Station of origin
(c) Number
(d) Date
(e) Check (optional)
(f) Address
(g) Text
(h) Signature

(a) The "city of origin" refers to the name of the city from which the message was started. If a message is filed at League Headquarters by someone in Hartford, Conn., the preamble reads *Hr msg fm Hartford Conn W1MK Nr 457 April 9*, etc.

If a message is sent to your radio station by mail the preamble reads a little differently to show where the message came from and from what city and station it originated as well. If a message was filed at A.R.R.L. Headquarters and if it came by mail from Wiscasset, Maine, the preamble would run like this to avoid confusion: *Hr msg fm Wiscasset Maine via Hartford Conn W1MK Nr 457 April 9*, CK 26, etc.

(b) The "station of origin" refers to the call of the station at which the message was filed and this should always be included so that a "service" message may be sent back to the originating station if something interferes with the prompt handling or delivery of a message. In the example of preambles just given W1MK is the station of origin, that call being the one assigned the League Headquarters Station.

(c) Every message transmitted should bear a "number." Beginning on the first day of each calendar year, each transmitting station establishes a new series of numbers, beginning at Nr. 1. Keep a sheet with a consecutive list of numbers handy; file all messages without numbers; and when you send the messages, assign numbers to them from the "number sheet," scratching off the numbers on that list as you do so, making a notation on the number sheet of the station to which the message was sent and the date. Such a system is convenient for reference to the number of messages originated each month.

(d) Every message shall bear a "date" and this date is transmitted by each station handling the message. The date is the "day filed" at the originating station unless otherwise specified by the sender.

(e) Every word and numeral in the text of a message counts in the check.

(f) The "address" refers to the name, street and number, city, state, and telephone number of the party to whom the message is being sent. A *very complete address* should always be given to *insure* delivery. When accepting messages this point should be stressed. In transmitting the message the address is followed by a double dash or break sign (—...—) and it always precedes the text.

(g) The "text" consists of the words in the body of the message. No abbreviations should ever be substituted for the words in the text of the message. The text follows the address and is set off from the signature by another break (—...—).

(h) The "signature" is usually the name of the person sending the message. When no signature is given it is customary to include the words "no sig" at the end of the message to avoid confusion and misunderstanding. When there *is* a signature, it follows the break; *the abbreviation "sig" is not transmitted.*

The presence of unnecessary capital letters, periods, commas or other marks of punctuation may alter the meaning of a text. For this reason commercial communication companies use a shiftless typewriter (capitals only). The texts of messages are typed in block letters (all capitals) *devoid of punctuation*, underlining and paragraphing, *except where expressed in words.* In all communication work, accuracy is of first importance.

Numbering Messages

● Use of a "number sheet" or consecutive list of numbers enables any operator to tell quickly just what number is "next." Such a record may be kept in the log, or with the message file, or posted on the wall of the station. Numbers may be crossed off as the messages are filed for origination. Another method of use consists of filing messages in complete form *except for the number.* Then the list of numbers is consulted and numbers assigned as each message is sent. As the operator you work acknowledges (QSLs) each message cross off the number used and note the call of the station and the date opposite this number.

A "number sheet" is quite essential to help in keeping records straight, and to avoid possible duplication of numbers on messages. It is of assistance in checking the count of originated messages in a given month. With each amateur station log book A.R.R.L. provides C.D. Form 3, a *number sheet of originated messages* — or you can start a consecutive list of numbers in January of each year on a blank sheet, adding numbers as needed.

The original number supplied each message by the operator at the originating station is transmitted by each station handling the message. No new numbers are given the message by intermediate stations. If a message is filed at W1MK on April 9 and when sent is given the number "nr 458," this same call, date and number are used by all stations handling this message. The number and date become a part of the city-and-station-of-origin identification used for the purpose of tracing. Only at stations where a message originates or is filed can a number be assigned to a message. Intermediate relaying stations neither change numbers nor supply new ones to messages.

Checking Traffic — The Land Line Check

● The League's check is the land line or "text-only" count, consisting of the count of only the words in the body or text of the message. It is quicker and easier to count in this fashion than to use the cable count words in address text and signature check which is followed in marine operating work, this simplification being the reason for its adoption. When in the case of a few exceptions to the basic rule in land line checking certain words in address, signature or preamble are counted, they are known as extra words, and all such are so designated in the check right after the total number of words.

COUNTING WORDS IN MESSAGES

The check includes: (1) all words, figures and letters in the body, and (2) the following extra words:

(a) Signatures except the first, when there are more than one (a title with signature does not count extra? but an *address* following a signature does).

(b) Words "report delivery," or "rush" in the check.

(c) Alternative names and/or street addresses, and such extras as "personal" or "attention" - - - - - - - -."

Examples: "Mother, Father, James and Henry" is a family signature, no names counted extra. "John Brown, Second Lieutenant" or "Richard Johnson, Secretary Albany Auto Club" are each one signature with no words counted as extra. An official title or connection is part of one signature, not extra. "Technical Department, Lamb, *Grammer and Mix*" as a signature would count three extra words, those italicized after the first name counting as extras. The check of a message with ten word text and three such extras in the signature would be "CK 13 3 extra."

Dictionary words in most languages count as one word irrespective of length of the word. Figures, decimal points, fraction bars, etc. count as one word *each*. It is recommended 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, bar 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
Adcool (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:

HR MSG FM HARTFORD CONN W1MK NR 766 NOV 17 CK 18
E F ENGLISH
282 BALLARD PLACE
WINONA LAKE TEXAS
SUGGEST YOU UTILIZE ARRL TRUNK LINE K THROUGH W5NW TO HANDLE PROPOSED TRAFFIC 73
HANDY ARRL

The use of a check on amateur messages is optional. 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 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. Furthermore, what sort of a communication service is it that concerns itself with what is said in a message, so long as the remarks are not obscene so the transmission is contrary to law? 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 material considerations become involved in the communications. 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."

The radio portion of the Madrid treaty is in full effect as between the United States and the following foreign countries: Australia and territories, Austria, Belgium and Belgian Congo and Ruandi Urundi, Bulgaria, China, Colombia, Czechoslovakia, Denmark, Egypt, Estonia, Ethiopia, Finland, Germany, British India, Italy and its colonies and islands, Japan (and Chosen, Taiwan, Karafuto, Kwantung, and islands under mandate), Morocco except Spanish zone, the Netherlands plus Netherlands Indies, Surinam and Curacao, New Zealand, Persia, Poland, Spain and its territory of Gulf of Guinea, Switzerland, Syria & Lebanon, Vatican City State, Yugoslavia.

The treaty relation also exists with Canada, but the handling of certain types of traffic is permitted by special arrangement with Canada, Chile, and Peru. With all other countries 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.

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. August 1934 *QST* (pages 52–53) gives an interesting résumé of the amateur regulations of many foreign countries. Any country ratifying the Madrid (1932) Convention can make its domestic arrangement 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) regulation in conducting international amateur work. Article 8:

> **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 licensees of amateur stations to transmit international communications emanating from third parties. The above provisions may be modified by special arrangements between the interested countries.**

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 bands 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 of Article 8 prohibits *international* handling of third party traffic, except where two governments have a special arrangement for such exchange (we have such agreement with Canada and are negotiating similar agreements with other countries). 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.

As always, the major opportunity for outstanding message-handling work exists right at home. There are chances to render a real service to local communities everywhere that an amateur puts up a station and gets on the air, and especially in time of emergencies. Excellent work in traffic handling is so very common that it takes almost exceptional emergency and expedition work, or work with unusual characteristics, to "rate" special mention. Many expeditions and exploring parties go to the far parts of the earth — and now they always take high-frequency equipment along for contact work.

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. Similar special agreements have been concluded by the U. S. A. with Chile and Peru, and are under consideration by other countries.

Originating Traffic

● Every message has to start from some place and unless some of us solicit some good traffic from friends and acquaintances there will be no messages to relay. Of course the simplest 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. A number of the amateur fraternity have distributed pads of message blanks to local stores and business houses to assist in getting good traffic to originate regularly. A neatly typed card is 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.*

The time of collecting messages and the list of schedules kept may also be posted for the benefit of those interested. Wide-awake amateurs have distributed message blanks to the nearest tourist camps during the summer seasons of recent years and lots of good traffic has been collected through a system of message-collection boxes placed in public buildings and hospitals. A sign prominently displayed outside the radio station has in some instances proved a good source of obtaining worth-while messages. Messages from broadcast listeners to the stations where programs originate have helped in the search of the traffic-minded amateur to be of service to the public at the same time he enjoys his hobby.

Messages that are not complete in every respect *should not be accepted* for relaying. The city of origin, station of origin, number, date, address, text, and signature constitute a complete message. All these parts are necessary to make a message of value to the recipient, to make it possible to deliver the message and to route and answer back to the sender. A very *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 RADIOGRAMS, 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. Also, it is desirable to word messages as telegrams would be worded instead of writing letters. 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" since there are not active amateurs in all countries, and more important, since the majority of countries outside the U. S. A. and Canada prohibit the handling of third party traffic altogether, by a restriction written into the station licenses of foreign amateur stations.

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. Have the latest copies of *QST* at hand and study the traffic summaries at the end of sectional activity reports. Nearly all these stations are reliable Official Relay Stations interested in traffic handling. The list of calls will help you to identify or distinguish reliable, consistent operators to whom to entrust valuable messages.

Operators must route traffic properly — not merely aim to "clear the hook." New stations worked should be informed of the amount of traffic you wish to clear and agree to handle the messages, *before* they are sent. Delays and non-deliveries result from giving an operator more than he can handle efficiently. Operators should *not* accept traffic when not in a position to continue operating their stations to give it proper handling.

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.

Tracing Messages

● *Tracing messages* is sometimes necessary to find where traffic was held or delayed. Tracing is usually accomplished by sending a copy of the message and a letter requesting that the time, date, and station calls of the stations from whom the message was received and to whom the message was given, be noted. Tracers are forwarded in rotation to all stations handling a message.

Amateur Stations at Exhibits and Fairs

● Where installation of an amateur radio station in a booth is planned, a *portable* amateur station can be installed. The station must operate under F.R.C. license of course. Since every amateur station owner can use his regular authorization for portable work under certain regulations, a local amateur already licensed can accept responsibility for the station. Of course the proper F.R.C. office must be notified of the location from which the equipment will be operated, and the dates of such operation, in advance, as provided in the regulations. No license for station equipment is required if the exhibit will not include a transmitter in actual operation. 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.

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.* The full coöperation of all local stations should be requested. However, be sure that the operators undertaking to help are qualified and have good schedules for distributing messages.

"Show stations" must avoid orgination of "poor traffic" by rigid supervision and elimination of meaningless messages with guessed-at, inaccurate and incomplete addresses right at the source. Misaddressed and rubber-stamp-type traffic will always be subject to serious delays and non-delivery, and especially so when the traffic load is so great that handling such messages becomes irksome and work instead of fun. What good is any message if it cannot be delivered?

The "Apparent Importance"

● The "apparent importance" of a dispatch has been proved to have a very direct bearing on the speed of relaying a message and the likelihood of its delivery, especially if the relaying is to be attempted through several unknown stations instead of between one or two known reliable stations keeping regular schedules. It may seem a strange commentary on amateur relaying that such is the case, but examination of delivery results proves the statement; and the very fact that amateur radio is a hobby, and that it is "human nature" to devote most time and effort to doing what seems most worthwhile, will afford sufficient explanation. In successful relaying work *all* factors must be taken into account.

Troubles to Avoid in Originating Traffic

● Incomplete preambles seem to be the most common fault in message handling. The city of origin, the station of origin, the number, the date, and the check are all a part of the preamble which goes at the beginning of every message. The *city* and *station of origin* are most essential. Without them it is impossible to notify the sender that his message could not be delivered and without this information it is not possible to route the reply speedily. The number and date are essential in servicing and tracing radiograms. All Official Relay Stations are instructed to refuse to accept messages without this necessary information. 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.

Many messages carry an insufficient address and cannot be delivered. Originating stations should refuse to accept messages to transmit when it is apparent that the address is too meagre.

Some stations lose track of the messages which they accept for delivery or transmission. They use scratch pads to copy signals on and they never clean up the operating table or have a place for things. The remedy is to adopt a few of the principles of neatness and to spend about two minutes each time you are through operating to put things in order. Write messages on message blanks of a uniform size when they arrive at the station. Keep together the messages to be sent. A good system to use is to mark the state of destination in the upper right hand corner of each message, arranging the messages in a heavy clip so that the names of the states are in easy view. A file box may be similarly arranged. 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.

Volumes vs. Deliveries

● In passing we should add that starting traffic in volume always results in lowering percentage deliveries simply because "operating enjoyment" becomes "work" and amateur operators with limited time are able to cope with only definite quantities of messages. While in emergencies traffic could and would be willingly moved at any sacrifice of time, thus giving great credit to the amateur, the transmission of less important material, especially in volume, meets resistance, due to the characteristics of human nature and the fundamental aspects of amateur radio as a hobby (not a job). This of course does not excuse any amateur from accepting messages he knows he cannot handle. *It is best to refuse traffic when not in a position to handle it, and especially if unwilling to accept proper responsibility for doing your best to see it on its way — or delivered — speedily.*

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.

Let us assume that a station in Hartford, Conn., receives a message whose destination is Oakland, Cal. The message is at once written out on a message blank, filling in the city and station of origin, leaving only the "number," "rec'd," and "sent" spaces vacant.

The operator does not hear any western stations so he decides to give a directional "CQ" as per A.R.R.L. practice. He calls, *CQ CALIF CQ CALIF DE W1MK W1MK W1MK*, repeating the combination three times.

He listens and hears W9CXX in Cedar Rapids calling him, *W1MK W1MK W1MK DE W9CXX W9CXX W9CXX AR.*

Then he answers W9CXX indicating that he wishes him to take the message. W1MK says *W9CXX W9CXX DE W1MK R QSP OAKLAND? K.*

After W9CXX has given him the signal to go ahead, the message is transmitted, inserting the "number" in its proper place, and assigning the next number indicated on the "number sheet." The message is sent in A.R.R.L. sequence.

"HR MSG FM HARTFORD CONN W1MK NR247 NOV 11 CK23 TO HAROLD J BURCHFIELD W6JTV 2940 106 AVE OAKLAND CALIF — . . . — COMMUNICATIONS DEPARTMENT SUPPLIES AND MEMBERSHIP LIST ARE GOING FORWARD TODAY PLEASE SEND YOUR REACTION TO GENERAL NUMBER 372 OUR ARMY FILE — . . . — SIG HOUGHTON AR W1MK K.

W9CXX acknowledges the message like this: *W1MK DE W9CXX NR 247 R K*. Not a single *R* should be sent unless the whole message has been correctly received.

The operator at W1MK writes in the number of the message, scratches off number 247 on the "number sheet," putting W9CXX after the number. In the "sent" space at the bottom of the message blank he notes *the call of the Cedar Rapids station, the date, time, and his own personal "sine."* At the same time he concludes with W9CXX something like this: *R QRU 73 GB VA W1MK*, meaning, "All received OK, I have nothing more for you, see you again, no more now, best regards, good-bye, I am through with you and shall at once listen for other stations who may wish to call me. W1MK is now signing off."

W9CXX will come back with *I R GB AR VA W9CXX*, meaning "I understand, received you OK, good-bye, I am through." Then he will listen a few minutes to see if anyone is calling him. He will listen particularly for California stations and try to put the message through W6JTV or a neighboring station. If he does not hear someone calling him, he can "CQ Calif."

Getting Fills

● Sometimes parts of a message are not received correctly or perhaps due to fading or interference there are gaps in the copy. The problem is to ask for "fills" or repeats in such a way as to complete the message quickly and with the minimum of transmission.

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, clumsy way of asking for fills which we have heard used by beginners. These have the one redeeming virtue of being understandable.

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. While these latter usages are approved, the earlier practice is still followed by some operators.

Delivering Messages

● The only service that we can render anyone by handling a message comes through "delivery." Every action of ours in sending and relaying messages leads up to this most important duty. Unless a message is delivered, it might as well never have been sent.

There is no reason for anyone to accept a message if he has no intention of relaying it or delivering it promptly. It is not at all discourteous to refuse politely to handle a message when it will be impossible for you to forward it to its destination.

Occasionally message delivery can be made through a third party not able to acknowledge the radiogram he overhears. When a third party happens to be in direct contact with the person addressed in the message he is able to hand him an unofficial confirmation copy and thus to make a delivery much sooner than a delivery could be made otherwise. It is *not* good radio etiquette to deliver such messages without explaining the circumstances under which they were copied, as a direct delivery discredits the operator who acknowledged the message but who through no fault of his own was not able to deliver so promptly. With a suitable note of explanation, such deliveries can often improve A.R.R.L. service and win public commendation.

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 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.

To help in securing deliveries, here are some good rules to follow:

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.

We are primarily a radio organization, and the bulk of our messages should go by radio, not by mail. The point is that messages should not be allowed to fall by the way, and that they should be sent on or delivered just as quickly as possible. 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 the accuracy and speed of each message handled so that we can each have reason to take personal pride in our operating work and so that we will have just cause for pride in our League as a whole. Do *your* part 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 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.

In line with the practice outlined above W3CA makes up a service message asking W7GE (station of origin of a message with insufficient address) to "give better address":

HR SVC FM ROANOKE VA W3CA NR 291 AUG 19
To RADIO W7GE
L C MAYBEE
110 SOUTH SEVENTH AVE
PASCO WASHN — . . . —
UR NR 87 AUG 17 TO CUSHING SIG BOB HELD HR UNDLD PSE GBA — . . . —
(sig) *WOHLFORD W3CA*

Counting Messages

● So that we can readily keep run of our messages and 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.

The message total shall be the *sum* of the messages originated, delivered and relayed. 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.L. 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 tests 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 (optional). The preamble goes "CITY-STN.-NR.-DATE-CK." The NCR uses tactical procedure, and cable count check. A.A.R.S. start traffic with "NR-STN-GR-CITY-TIME-DATE" and use a "text" check like wire services. *It is the correct thing to do to change the preamble to the form used by the service you are operating in.* This helps both accuracy and speed, and proves you a real operator.

A.A.R.S. and N.C.R. Traffic

● 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 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."

(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 as "1 delivered."

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.

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 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 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 to A.R.R.L. headquarters. Our magazine, *QST*, covers the entire amateur field, keeping a record of the messages handled in different sections of the country, giving mention of the outstanding work that is done in communicating over great distances using small amounts of power, and summarizing all types of activities in monthly reports.

We have mentioned the Official Relay Stations and the Communications Department organization. A section of *QST* is devoted to Communications Department reports. Form postals are sent the active stations in the relay system for reporting purposes. There is space to tell about the traffic handled, the frequency used during the reporting month, the "DX" worked, and other station records and activities, together with a list of the stations with which schedules are kept. Items of general interest, changes in the set, and addresses of new amateurs also come in on this card.

Every operator of an active amateur station in the United States and Canada is cordially invited to report. Each month on the 16th (the 1st in Hawaii and the Philippines) the active stations send reports to their local officials. These officials forward condensed reports to Headquarters. Representative space is given each section of the country depending on the number reporting. Reports must have the dead material edited out of them to allow room for as much active and interesting news as can be gotten in. The more worth while a report is, the more of it gets in print. Calls of active stations always get full space. Readers of this Handbook are invited to send in their reports to the local A.R.R.L. official just as soon as they have a station in operation. Write the nearest S.C.M. whose name appears on page 5 of each *QST*. Make your report informative and interesting.

Especially important work having a high news value should be reported direct to League Headquarters at Hartford.

Contributions to *QST* are welcomed by the Editors! Authors must remember that only a small percent of the received material can be printed and that it is impossible for an organization like ours to pay for articles. Ours is a "family" organization supported by and for the amateur. By carefully selecting material the members get the best magazine that can be made. *QST* is noted for its technical accuracy. "Breaking into print" in *QST* is an honor worth working for.

Operating on Schedules

● Traffic handling work can be most advantageously carried on by arranging and keeping a few schedules. By arranging schedules and operating the station in a business-like way, using an accurate frequency meter and a clock, it has been proven many times that a maximum amount of business can be moved in a minimum of time and effort. 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.

Every brass-pounder is urged to write letters to some of the reliable and regular stations heard, asking if some schedules cannot be kept a few times a week especially for traffic handling. The Route Manager is very frequently able to help in arranging schedules. Write your S.C.M. (see page 5, *QST*) and through him get lined up with your R.M. With reliable schedules in operation it is possible to advertise the fact that messages for certain points can be put through with speed and accuracy, and the traffic problem will take care of itself.

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 on 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.

A good way to select the four stations is to listen in and to pick out the stations heard most regularly, operating most consistently, and in the right direction. It is a good scheme to work these stations a few times. Write them letters and get acquainted; then try to arrange some schedules. Short schedules are the best. A half or quarter hour each day is enough. In an hour one can call four stations, clear traffic, and be free to work other groups of "five-pointers."

When there is no traffic, a few pleasantries are in order during the scheduled time of working. Several advantages of handling messages on schedule are evident from whatever angle the situation is approached.

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 performance depends 90% on operating ability, and 10% on the equipment involved, granting of course that station and operator are always inter-dependent. Experience in message handling develops a high degree of operating "intelligence."

Interest in relaying amateur radiograms has always been the important basic activity around which A.R.R.L. organization revolved. There are several good reasons why. 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 in message handling work.

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 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.

CHAPTER TWENTY-ONE

League Operating Organization

YOUR A.R.R.L. does not aim to reform or change the hobby of the 'phone man, the DX man, the traffic enthusiast, rag chewer, or the experimenter. All hams should know all aspects of our hobby and be tolerant of the other fellow's viewpoint. Most hams do and are. Sooner or later, an amateur who starts in one branch of the game aspires to DX, 'phone, traffic, or the novelty of ultra-high frequencies, abandoning, at least for the time, his first interest in amateur radio. When a DX test is on many hams go after the DX fun thus made available by A.R.R.L., soon returning to their regular bent. It is our aim to benefit all concerned along the lines of natural interest.

By operating our stations with useful ends in view we can increase the pleasure we get, at the same time justifying our existence. Better communication results in all aspects of our hobby, amateur radio, can be achieved through better operating. The Communications Department is concerned with the practical operation of the stations of League members. Its work includes arranging amateur operating activities, establishing standard operating procedure, encouraging good operation, improving message relaying, and concluding tests to these ends.

The aim of the Communications Department is to keep in existence an active organization of League stations made entirely of privately-owned radio stations covering the entire continent of North America. One of its objectives is to create a body of skilled operators whose services and abilities will further the general knowledge of the art of radio communication. The relaying of friendly messages between different parts of the country without charge is one of the important phases of the work coming under the supervision of the Communications Department. Amateur operators have also always been of great assistance to our country in times of emergency in which quick communication has been a factor, especially when other methods of communication have failed.

These objects of our organization must be kept in mind at the same time we, as individuals, are getting enjoyment from our chosen hobby.

The activities of the Communications Department are arranged and recorded through *QST* and by special correspondence. Tests and relays are arranged from time to time to develop new routes for traffic handling, to prepare ourselves to render emergency service in time of need, and to bring to light additional general radio information. In this way all members of the League benefit from the experience of certain individuals who excel along specified lines of work.

The policies of the Communications Department are those uging members to adopt uniform operating procedure and to use system in their station operating. The Communications Department constantly works to make our communication system as efficient as a non-commercial message-handling organization can be. Compliance with government regulations, orderly operating, and coöperation with each other and with outside interests for the advancement of the art are a part of its policies. The first duty of the department to member-stations is to supervise operating work so well that the amateur will continue to justify his existence in the eyes of his Government. Then he will be allowed a continuance of the privileges which he has received as his due in the past.

Records of tests are included in *QST*. Active stations in the A.R.R.L. organization receive special mimeographed bulletins on all new developments. Through such bulletins and a large volume of routine correspondence with individual members, the contact is kept good and the activities we have outlined are effectively carried out by the interested member-stations.

Official Broadcasting Stations have been appointed and regularly transmit addressed information to all amateurs by voice and in telegraphic code. This service of sending addressed messages to A.R.R.L. members on current matters of general interest is supplemented by official and special transmissions on timely subjects from Headquarters Station W1MK (schedule given on page 12).

In these pages we are going to explain the organization of the Communications Department, the proper message forms to use, and some special practices which experience has proved best. We urge that you help strengthen amateur radio by studying the operating practice suggested and by adopting uniform operating procedure.

Everyone at League Headquarters welcomes criticism that is accompanied by constructive suggestions. The fullest benefits of organization are realized only when every member participates freely in his organization and gives brother amateurs and his organization the benefit of his advice, suggestions, criticism, participation and coöperation in the common cause, amateur radio. In individual operating work as well, advancement comes as we learn to exchange constructive suggestions in the true amateur spirit.

In some department of the A.R.R.L.'s field organization there is a place for every active amateur who has a station. It makes no particular difference whether your interest lies in getting started and learning the code, traffic handling, DX, friendly contacts by 'phone, or other aspects of amateur radio. Whatever your qualifications, we suggest that you get into the game and coöperate with your Section Manager by sending him a monthly report of the particular work you are doing. As you become experienced in amateur work of different kinds it is likely that you will qualify for appointment as O.R.S. or O.P.S. or that you can accept other important responsibilities in connection with the conduct of A.R.R.L. work in the different sections. Operating work and the different official appointments will be explained in detail in this and the following chapter. We want to make it clear right at the start that the Communications Department organization exists to increase individual enjoyment in amateur radio work, and we extend a cordial invitation to every amateur and reader of this book to participate fully in the different enterprises undertaken by and for amateur operators.

W.A.C. for DX Operators

● In collaboration with the I.A.R.U. the A.R.R.L. issues W.A.C. (Worked All Continents) certificates to those member-amateurs whose DX achievements include two way communication on the ham bands with at least one other amateur station on each continent. It is only necessary to submit six QSL cards, one showing such communication with each continent, as proof of world-wide contacts, to receive this recognition for DX work.

Organization

● The affairs of the Communications Department in each Division are supervised by one or more Section Communications Managers, each of whom, elected by the A.R.R.L. members of his territory, has jurisdiction over his section of Division.

For the purpose of organization the A.R.R.L. divides the United States and Possessions (plus Cuba and the Isle of Pines) and Canada (plus Newfoundland and Labrador) into divisions as follows:

ATLANTIC DIVISION: Delaware, District of Columbia, Maryland, Pennsylvania, that sec-

tion of New Jersey within the Third Federal Inspection District, and that section of New York within the Eighth Federal Inspection District.

CENTRAL DIVISION: Illinois, Indiana, Kentucky, Michigan, Ohio and Wisconsin.

DAKOTA DIVISION: Minnesota, North Dakota and South Dakota.

DELTA DIVISION: Arkansas, Louisiana, Mississippi and Tennessee.

HUDSON DIVISION: The entire Second Federal Inspection District, consisting of certain counties of New Jersey and New York States.

MIDWEST DIVISION: Iowa, Kansas, Missouri and Nebraska.

NEW ENGLAND DIVISION: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont.

NORTHWESTERN DIVISION: Idaho, Montana, Oregon, Washington and the Territory of Alaska.

PACIFIC DIVISION: That portion of the state of California not included in the Southwestern Division, Nevada, the Territory of Hawaii and the Philippine Islands.

ROANOKE DIVISION: North Carolina, Virginia and West Virginia.

ROCKY MOUNTAIN DIVISION: Colorado, Utah and Wyoming.

SOUTHEASTERN DIVISION: Alabama, Florida, Georgia, South Carolina and the Island of Porto Rico. (*The Republic of Cuba and the Isle of Pines are attached to this Division for Communications Department activities.*)

SOUTHWESTERN DIVISION: The counties of Imperial, Inyo, Los Angeles, Mono, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara and Ventura of the state of California, and the state of Arizona.

WEST GULF DIVISION: New Mexico, Oklahoma and Texas.

MARITIME DIVISION: The provinces of New Brunswick, Nova Scotia and Prince Edward Island. (*Newfoundland and Labrador are attached to this Division for Communications Department activities.*)

ONTARIO DIVISION: Province of Ontario.

QUEBEC DIVISION: Province of Quebec.

VANALTA DIVISION: Provinces of Alberta and British Columbia and Yukon Territory.

PRAIRIE DIVISION: Provinces of Manitoba and Saskatchewan and the Northwest Territories.

Each United States Division elects a Director to represent it on the A.R.R.L. Board of Directors and the Canadian Divisions elect a Canadian General Manager who is also a Director. The Board determines the policies of the League.

A.R.R.L. operating territory is subdivided into Sections to facilitate the collection of reports, and more important, the efficient supervision of activities and appointments in the field organization.

The field officials (S.C.M.s) are listed on page 5, while the names and addresses of the Directors are printed on page 6, of each *QST*.

Whenever a vacancy occurs in the position of Section Communications Manager in any section of the United States, its island possessions or territories, or the Republic of Cuba, the Communications Manager announces such vacancy through *QST* or by mail notice to all members of the Section, and calls for nominating petitions signed by five or more members of the Section in which the vacancy exists, naming a member of the Section as candidate for Section Communications Manager. The closing date for receipt of such petitions is announced.

After the closing date, the Communications Manager arranges for an election by mail or declares any eligible candidate elected if but one candidate has been nominated. Ballots are sent to every member of the League residing in the Section concerned, listing candidates in the order of the number of nominations received. Section Communications Managers are elected for a two-year term of office.

The office of any Section Communications Manager may be declared vacant by the Executive Committee upon recommendation of the Communications Manager, with the advice and consent of the Director, whenever it appears to them to be in the best interests of the membership, and they may thereupon cause the election of a new Section Communications Manager.

Communications Department Officials and Appointments

● These S.C.M.s elected in each Section by the A.R.R.L. members in that Section, appoint active qualified amateur stations for special types of radio work in the A.R.R.L. field organization. Whether your activity is directed toward DX, experimenting, 'phone or traffic, there is a place for you in League work. Your S.C.M. welcomes a monthly report from every active ham. The following regulations will explain the duties of the S.C.M. and the specialized radio work of all stations honored by holding A.R.R.L. appointments.

Section Communications Manager

● 1. The Section Manager shall appoint Route Managers, 'Phone Activities Managers, Official Observers, Official Broadcasting Stations, Official Relay Stations, Official 'Phone Stations, and individuals and/or stations for specific work in accordance with the qualifications and rules for such appointments. He shall likewise make cancellations of appointments whenever necessary.

Appointees shall have full authority within the section over the activities indicated by their titles. They will report and be responsible to the Section Communications Manager for their work. With the consent of the Communications Manager the Section Manager may, if necessary, designate a competent League member to act for him in a particular matter in any part of his territory. He shall be careful to instruct such an appointee properly in the duties he is to execute while acting for the S.C.M.

2. His territorial limitations are determined by the Division Director (or C.G.M.) and the Communications Manager.

3. The Section Manager is responsible to the Communications Manager at League Headquarters for maintenance of records of all his appointments, and cancellations of such appointments either for violations of the regulations under which these are issued, or for violations of the F.C.C.'s amateur regulations. The Form 4 (appointment) and Form 4C (cancellation) cards provided, must be sent to Headquarters that A.R.R.L. mailing lists and records may be kept exactly in accordance with those of the S.C.M. office. Annual endorsement of O.R.S. and O.P.S. certificates (and S.C.M. notification — to Headquarters by Form 4) is required to keep these appointments in effect.

4. The Section Manager is responsible for the coöperation of active station-owners in A.R.R.L. activities, contests, traffic work, etc. and is authorized to devise and develop special plans in the furtherance of Section interest and esprit de corps.

5. The Section Manager is the Section executive. His leadership must take into consideration the proper distribution of basic and key appointments to those best qualified in the different cities and in each radio club in the Section. Such problems as the geographical distribution and coverage of stations (OBS) sending addressed information to members, the distribution of appointments in the different frequency bands for effective Section activities require careful study. The S.C.M. must in his decisions try to grant recognition to the best qualified operators and stations, and endeavor to insure A.R.R.L. representation and activity in each amateur group.

6. The S.C.M. may appoint *only League members* to any A.R.R.L. office. He must see that each O.R.S. and O.P.S. appointed has the proper qualifications, as indicated by actual operating radio tests and/or station inspection made by him or under his direction. The S.C.M. shall also conduct investigations of radio organizations and interference cases whenever such cases are referred to him by Headquarters or the Division Director. It is his duty to demonstrate Section leadership and coördinate all types of amateur operating work to make his Section as effective and active as possible.

7. The S.C.M. may requisition necessary Communications Department supplies provided for making appointments and supervising the work in his section. He may render an itemized postage expense account at intervals, for reimbursement. Section Managers are entitled to wear the distinctive A.R.R.L. pin with red background, similar in other respects to the regular black-and-gold A.R.R.L. membership pin.

8. The S.C.M. shall render a monthly report or activity summary to Headquarters. It shall be made up from all reports from all active stations, whether members or not, and include comprehensive information on each appointee. Reports shall be mailed to Headquarters by S.C.M.s on or before the 20th for the reporting month (16th to the 15th inclusive) in the mainland U. S. A. and Canada.

Official Observers

● Do you need a frequency check? Each volunteer observer is appointed by his S.C.M. to help all hams keep on the assigned frequencies and assist brother amateurs by calling attention to improper broadness, a.c. notes, poor spacing, violations of good practice, overmodulation, poor speech quality, etc., in the right way to obtain maximum coöperation in bettering operating conditions. Official Observers, to receive appointment must have an accurate frequency meter, or oscilloscope, or other equipment suitable for accurate observing work of the type in which he intends to specifically engage.

Each S.C.M. recommends for appointment one or more Observers who report regularly to the S.C.M. on off-frequency operation noticed, sending out notification forms (provided from Headquarters) to help amateurs in keeping within the assigned bands.

Observers' frequency meters shall be checked regularly against A.R.R.L. Standard Frequency Station transmissions and by government or commercial "marker" stations of known frequency operating adjacent to our own amateur channels. Observers are provided with notification postal card forms and report blanks. The stations notified are reported to A.R.R.L. (through the office of the S.C.M.) as rapidly as the blanks are filled out. Radio contacts with off-band stations shall be made by O.O.s wherever possible. Operators in different bands are needed to specialize on conditions in those bands, 'phone observers to help improve 'phone operating conditions, etc.

Observers also shall report harmonic or parasitic radiations and other operation of commercial or government telegraph services or broadcasting stations causing interference in the amateur bands, these being reported direct to Headquarters as promptly as possible so that remedial action may be taken.

The notification service to amateurs is designed as a friendly move to protect amateur privileges from official government restrictions. These are invited by careless or intentional disregard of regulations by individuals who may thus jeopardize the enjoyment of all amateurs. Observers also report all flagrant violations of good amateur practice, including improper procedure, poor spacing, "a.c." notes, unstable signals, overmodulation, unethical "music" broadcasting, or other abuses; all to the end that these things may be brought before the operators concerned, the effectiveness of stations improved, and high standards of amateur operating maintained. Observers also make station-distribution surveys showing actual density of stations and operating conditions in our different amateur bands.

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. Each R.M.'s territory and jurisdiction over special projects is determined by the S.C.M. who expects monthly progress reports. R.M.s may wear the League emblem with the distinctive deep-green background.

Special appointments are made of N.C.R. Liaison and A.A.R.S. Liaison Route Managers to link these systems and League organization in each Section. Since some reservists seem unaware that traffic handled in drills, on amateur frequencies, counts in A.R.R.L. totals, such appointments help all organizations work well together. The duties of such "liaison" R.M.s include getting reports from N.C.R. or A.A.R.S., and telling hams more about these organizations.

'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 nothing to do with "traffic" organizing whatsoever, but 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. appointment as directed. P.A.M.s wear the League emblem with the distinctive deep-green background in recognition of their official status.

Official Broadcasting Station

● The Official Broadcasting Station transmits information on timely subjects addressed to radio amateurs and A.R.R.L. members. This must be sent at scheduled times during the week following receipt of the information from A.R.R.L. Headquarters.

Applicants for this appointment must submit their qualifications to the Section Manager with the proposed dates, times and frequencies for transmission of the broadcasts. In deciding on the times of transmission schedules, preference should be given to those times when the largest number of amateurs are listening, that is, the hours between 6:00 p.m. and midnight. Station power, geographical location, frequent transmissions, ability to copy messages direct from W1MK in advance of mail, should all receive consideration by S.C.M.s in making appointments. Section Managers are instructed to cancel the appointments of stations not adhering to the schedules agreed upon, and the appointments of stations not returning information on current or revised schedules when periodic surveys of the broadcasting system are made.

Basic A.R.R.L. Appointments

● Both Official Relay Station and Official 'Phone Station appointees receive an appointment certificate to be displayed in the station, a quarterly bulletin from Headquarters, and Form 1 reporting cards on which to turn in the monthly reports to the Section Communications Manager.

Appointment certificates (O.R.S. and/or O.P.S.) must be returned to Section Managers annually for proper endorsement to keep these in effect more than one year. Any applicant who fails to qualify may again apply for appointment after three months have elapsed. In making application, forms indicating knowledge of recommended procedure must be filed with the S.C.M. on blanks available from each S.C.M. office. New applicants must communicate *by radio* with a Section official and receive approval of this official or his representative. Operators with personal responsibility and high standards of operating are recognized as O.R.S. and O.P.S., and appointed to these important basic posts in A.R.R.L. organization because they have the qualifications. As a result of operating appointments carefully supervised and given only to active men with demonstrated ability in technical and operating matters, the present effective field organization, in successful operation for many years, is maintained.

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.

O.R.S. and O.P.S. appointments are not transferable from one station-owner to another. When an appointee moves they may be transferred from one Section to another by arrangement with the S.C.M.s concerned who notify Hq. of cancellation and re-appointment. Appointments may be cancelled by S.C.M.s whenever three consecutive reports are missed, and evidence of regular work and reports for three months must be submitted before such a station may be reinstated. "Earned reinstatements" may be made within one year without filing new application papers. After this the filing of new application papers is desirable, and discretionary with the Section Manager.

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


The American Radio Relay League, Inc.
West Hartford, Conn., U.S.A.
OFFICIAL PHONE STATION APPOINTMENT
This certifies that

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 does* not *stress traffic handling by voice*, but aids 'phone operating enjoyment by helping to formulate good voice operating practices, not overlooking the emergency organization aspect. The operating standards established make voice work more enjoyable and systematic.

1. O.P.S. use circuit precautions that avoid frequency modulation and overmodulation, and employ indicators in their transmitters to detect maladjustments.

2. O.P.S. coöperate with each other, and with all amateurs, regardless of power, or frequency. No "monopolization" of a frequency channel by an individual operator is

permissible, excepting such a situation is demanded by emergency conditions at a station in an isolated area.

3. Major adjustment of transmitters is completed outside of heavy operating hours.

(No needless music playing under the guise of legitimate testing to increase QRM and constitute an exhibition of selfishness. Such tests should be performed using dummy antennas, and radiating antennas connected only for bona fide voice communication.)

4. O.P.S. endeavor at all times to make the operation of their stations an example to be looked up to by other amateurs; they will stand ready to assist other amateurs in observing frequency bands, in complying with F.R.C. regulations, in adopting and furthering common sense, effective, voice operating procedure as formulated and codified by the group of O.P.S. for the benefit of all, and the furtherance of radiotelephone work.

All operators who use voice should use the suggestions codified to improve operating conditions in the 'phone bands. Official 'Phone Station appointment differs from O.R.S. appointment in that the operators are *not appointed specifically to handle traffic*. Of course when traffic *is* handled these stations observe the same high standards of responsible operating work; they will therefore at all times coöperate with S.C.M.s and R.M.s by prompt dispatch or delivery of any traffic that may be sent via the 'phone bands. Stations holding O.P.S. appointment will, of course, insist on complete addresses, and give city of origin and number each message carefully in accordance with A.R.R.L. procedure.

The application for O.P.S. appointment does not require a 15-w.p.m. code speed such as prescribed in the test for O.R.S. applicants. Applicants must have had at least one year of amateur operating experience. A description of the station for which appointment is sought must be given the S.C.M. If the arrangement meets modern technique, if the operating experience is adequate, and if the adjustment of the station checked by inspection, or test over the air, is also approved, the A.R.R.L.-O.P.S. appointment may be granted by the S.C.M. and Headquarters so notified at the same time the appointee receives his certificate. The station signal, and its operation too, must meet satisfactory standards. Appointments may be cancelled for inactivity, or failure to meet prescribed qualifications (like all other A.R.R.L. appointments) to make the O.P.S. appointment really stand for something worth while to all voice-operated amateur stations.

A 'Phone Activities Manager may assist the S.C.M. in necessary station inspection or test-over-the-air for O.P.S. applicants.

This appointment is for every live-wire operator of a first class 'phone, working any 'phone band. Like all other C.D. appointments, one makes application to the Section Communications Manager for O.P.S. appointment, and receives the necessary application forms. A certificate of appointment is issued by the S.C.M. if and when an appointment is granted. Appointments are issued good for one year, but must be kept in effect by activity and annual endorsement by the S.C.M.

The O.P.S. group of appointees has voted that inactivity in *three consecutive* Official 'Phone Station parties or quarterly activities shall warrant cancellation. Such a requirement does not make a *big* showing of activity necessary, but merely gives an increased activity-objective increasing the meaning of the appointment and spreading its benefits through operating example by insuring more activity and enjoyment in the quarterly operating activities for the group which are scheduled by A.R.R.L.

If you have a year or more of radiotelephone operating experience behind you, and a well adjusted voice station of modern technique on the air, this is a cordial invitation to you to get in touch with your Section Manager. Tell him you are interested in the Official 'Phone Station appointment; ask him for application forms.

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. Operators with good signals and personal responsibility toward the communications they handle seek and hold Official Relay Station appointment. Traffic-awareness is often the sign by which mature and experienced amateurs may be distinguished from newcomers to the ranks of hamdom.

1. O.R.S. must be able to transmit and receive at least 15 words per minute.

2. O.R.S. coöperate with each other, and with all amateurs. They must make their stations and operating an example to other ama-

teurs. They must follow standard A.R.R.L. operating practices (use proper message form, finish signals, misc. abbreviations, etc., as set forth in the next Chapter).

3. Appointees must keep a transmitter and receiver in operative condition at all times. Consistent activity is required to keep appointments in effect and must be demonstrated by regular reports to the S.C.M.

4. O.R.S. must display a high degree of interest in relay traffic activities, nets, schedules, trunk lines, and such.

O.R.S. are the "minute men" of amateur radio — always organized, reporting, active, and holding their equipment in tip-top condi-


The American Radio Relay League, Inc.
Hartford, Conn., U. S. A.
Communications Department Appointment
OFFICIAL RELAY STATION APPOINTMENT
This certifies that

tion ready for instant service on any communicating problem, large or small. Official Relay Stations are, as the name implies, stations that can be depended on absolutely to see a hard job through. They are ready for every opportunity of service to the public or amateur radio that may come their way, whether a special emergency, test, experiment, or just in the line of ordinary operation. They deliver and relay promptly all traffic that comes their way. O.R.S. appointment is highly significant since it puts the station owner in a special position as respects the opportunities of service. The appointment certificate also has come to be known as the badge that shows an amateur station has "arrived" in the dependable class.

O.R.S. appointees are entitled to wear the distinctive blue A.R.R.L. pin which is similar to the regular membership pin except that it has a blue instead of a black background.

To secure an appointment as Official Relay Station is quite a simple matter if you have the qualifications and a little experience. After building the station, gaining some code speed, and reporting your activities to the S.C.M. as suggested, ask the S.C.M. to furnish you with an application for appointment as Official Relay Station (or use the one printed for your convenience in the rear of this book). The S.C.M. will be glad to send you the necessary forms to be filled out and returned to him, and to give you advice on the application as may be necessary. But you must be willing to accept a certain amount of "personal responsibility" in regard to regular reporting each month, and absolute reliability in forwarding and delivering a number of messages regularly through your station. The appointment is one made with advantage to yourself. Fill out the application form as soon as you can qualify!

An Invitation

● Any A.R.R.L. member who has a station and operator's license and wants to "do things" with his equipment will find it easy and very much worth while to earn an appointment in the Communications Department organization. As has been explained, knowledge and use of certain fundamentals of operating procedure are prerequisite to appointment to the important basic posts in our field organization. Study procedure. Put into practice the things that you read. Originate and relay some traffic regularly. Keep a few schedules with other amateurs. Report all your activities on time (the 16th) each month to your S.C.M. whose address is given on page 5, any *QST*, to prove your qualifications and interest. Regardless of whether you have yet applied for appointment, a postal to the S.C.M. will give him information to use in his report for *QST* and boost the standing of your station and Section.

"Being active" in amateur work should not mean sacrificing all the varied interests we have as individuals. A few hours daily spent in *planned* radio work, a postal to our S.C.M. once each month about our activities, and including traffic handled, gives us credit for all we attempt, contact with and news from fellow hams through *QST*, and adds the touch that makes the difference between organized ham radio and merely haphazard unchronicled work. All reports summed up, make the record for Section and Division. There are many kinds of amateur work; each has its benefits and its leaders. Friendships, DX, technical knowledge, proficiency in construction, ability to operate or communicate, all are important. Interest in a special phase of amateur work is all right if moderation is observed.

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 as a simple medium to get the thought "exact and concise." The development of systematic habits of work is beneficial and may extend to fields other than amateur radio with profit also. To get full value from amateur organization work you must take part in such work. 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.

Trunk Lines

● A.R.R.L. Trunk Lines to facilitate speedy and reliable traffic movement are maintained during each active radio season. These "main-line" routes are laid out East-West and North-South and connect with countless local networks and schedule chains. There are fourteen main lines, each operating on a separate "spot frequency" in the 3.5-mc. amateur band.

Every station on the main lines must be an Official Relay Station and must be crystal controlled. Each Trunk Line Station on the main routes must have an alternate to take over schedules whenever the regular station cannot be on the air. All these stations must maintain trunk line schedules at least five days per week. If you are interested in trunk line work, get your O.R.S. appointment first. Then drop a line to the Communication Department stating your availability for trunk line schedules. You will then be advised of any openings.

Radio Clubs

● 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. which suitably expresses its sympathy with and allegiance to the aims and policies of the League as determined by its Board of Directors, and which society, on investigation, receives the approval of the Division Director having jurisdiction. It is the constant aim of the A.R.R.L. to maintain a bond of affiliation with local radio societies of kindred aims and purposes, since at different times in the League's history this has made possible unity of action and strength in proceeding by various channels to represent amateur views successfully and forcefully in legislative and regulatory matters. The necessary forms for initiation of action looking toward affiliation with A.R.R.L. will be forwarded to any existing amateur society on application. Affiliated club news is recorded in a special department maintained in *QST* for the purpose. Achievement certificates are awarded by A.R.R.L. to club members participating in the annual DX and Sweepstakes contests, where three or more affiliated club members report participation. Such awards are signed both by the Club and by A.R.R.L. Special price schedules on A.R.R.L. supplies apply to the affiliated radio clubs.

A.R.R.L. Headquarters Station, W1MK

● As shown in the frontispiece to this *Handbook*, W1MK is a station using two 1-k.w. crystal controlled transmitters. The unit for 80- or 160-meter work consists of two '04A's driven by an RK28. The 40–20 meter set has a '61 output stage. Both sets are used simultaneously, 3825/3575 and 7150 kcs. being the frequencies on which constant-speed transmissions addressed to all radio amateurs are sent twice each night of operation. (Full schedules, page 14.) The automatic tape transmitter is installed just at the right of the operator's chair, as also the frequency meter monitor.

Station features: Crystal-switching in each transmitter, single signal reception, "automatic" transmissions at 13 and 22 w.p.m., full metering of transmitters (liberal use of jacks, fewer meters required), frequency-meter monitoring of signal in use at all times, low-drift crystals with enough units for flexibility, band-switching in antenna tuning units, provision for call lists, traffic files and other station records "built in," telephone, clock, and controls all within easy reach of the operator.

The single-signal receiver is above the "mill" in the photograph. Both transmitters are coupled to the feed lines by low voltage links terminating in tuning units directly below the antenna grounding switches.

The Signal Corps has authorized this station to use 3497½ and 6990 kcs. as W1MK to facilitate preparedness for any communication emergency. Located seven miles from the A.R.R.L. offices, W1MK is a busy station, works in all League operating activities, schedules and routes communications to and from all parts of the country, and is ready for a call from any ham.

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.

Abbre-viation	*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 .... kilometres).
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	Do you receive me well? Are my signals good?	I receive you well. Your signals are good.
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.

Abbreviation	Question	Answer
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 acknowledgement of receipt?	I give you acknowledgement 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 ....
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 .... telgrams 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).

Abbreviation	*Question*	*Answer*
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 .... kilometres) 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).

Special abbreviations adopted by the A.R.R.L.:

QST 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 emergency use only.

Miscellaneous Abbreviations

Abbreviation	*Meaning*
C	Yes.
N	No.
P	Indicator of private telegram in the mobile service (to be used as a prefix).
W	Word or words.
AA	All after .... (to be used after a note of interrogation to ask for a repetition).
AB	All before .... (to be used after a note of interrogation to ask for a repetition).
AL	All that has just been sent (to be used after a note of interrogation to ask for a repetition).
BN	All between .... (to be used after a note of interrogation to ask for a repetition).
BQ	A reply to an RQ.
CL	I am closing my station.
CS	Call sign (to be used to ask for a call sign or to have one repeated).
DB	I cannot give you a bearing, you are not in the calibrated sector of this station.
DC	The minimum of your signal is suitable for the bearing.
DF	Your bearing at .... (time) was .... degrees, in the doubtful sector of this station, with a possible error of two degrees.
DG	Please advise me if you note an error in the bearing given.
DI	Bearing doubtful in consequence of the bad quality of your signal.
DJ	Bearing doubtful because of interference.
DL	Your bearing at .... (time) was .... degrees, in the doubtful sector of this station.
DO	Bearing doubtful. Ask for another bearing later, or at .... (time).
DP	Beyond 50 miles, the possible error of bearing may amount to two degrees.
DS	Adjust your transmitter, the minimum of your signal is too broad.
DT	I cannot furnish you with a bearing; the minimum of your signal is too broad.
DY	This station is two-way, what is your approximate direction in degrees in relation to this station?
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).
ER	Here .... (to be used before the name of the mobile station in the sending of route indications).
GA	Resume sending (to be used more specially in the fixed service).
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)].
MN	Minute or minutes (to be used to indicate the duration of a wait).
NW	I resume transmission (to be used more especially in the fixed service).
OK	Agreed.
RQ	Designation of a request.
SA	Indicator preceding the name of an aircraft station (to be used in the sending of particulars of flight).
SF	Indicator preceding the name of an aeronautical station.
SN	Indicator preceding the name of a coast station.
SS	Indicator preceding the name of a ship station (to be used in sending particulars of voyage).
TR	Indicator used in sending particulars concerning a mobile station.
UA	Are we agreed?
WA	Word after .... (to be used after a note of interrogation to request a repetition).
WB	Word before .... (to be used after a note of interrogation to request a repetition).
XS	Atmospherics.

Abbreviation	*Meaning*
YS	Your service message.
ABV	Repeat (or I repeat) the figures in abbreviated form.
ADR	Address (to be used after a note of interrogation to request a repetition).
CFM	Confirm (or I confirm).
COL	Collate (or I collate).
ITP	Stops (punctuation) count.
MSG	Telegram concerning the service of the ship (to be used as a prefix).
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).
PBL	Preamble (to be used after a note of interrogation to request a repetition).
REF	Referring to .... (or Refer to ....).
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).

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 abreviations" 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
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

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-EIZ	Irish Free State	EI
ELA-ELZ	Liberia	EL
EPA-EQZ	Persia	EP
ESA-ESZ	Estonia	ES
ETA-ETZ	Ethiopia (Abyssinia)	ET
F	France:	
	France proper, Martinique, Tahiti	F3-F8
	New Caledonia	F7
	Algeria	FA
	Madagascar, Reunion	FB
	French Indo-China	FI
	Tunis	FT

G	United Kingdom:	
	Great Britain except Ireland	G
	Northern Ireland	GI
HAA-HAZ	Hungary	HAF
HBA-HBZ	Swiss Confederation	HB
HCA-HCZ	Ecuador	HC
HHA-HHZ	Republic of Haiti	HH
HIA-HIZ	Dominican Republic	HI
HJA-HKZ	Republic of Colombia	HJ-HK
HPA-HPZ	Republic of Panama	HP
HRA-HRZ	Republic of Honduras	HR
HSA-HSZ	Siam	HS
HVA-HVZ	Vatican City	
HZA-HZZ	Hedjaz	HZ
I	Italy and Colonies	I
J	Japan	J
K	United States of America:	
	Continental United States	[W] (N)[2]
	Puerto Rico and Virgin Islands	K4
	Canal Zone	K5
	Territory of Hawaii, Guam and U. S. Samoa	K6
	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
OEA-OEZ	Austria	OE
OFA-OHZ	Finland	OH
OKA-OKZ	Czechoslovakia	OK
ONA-OTZ	Belgium and Colonies	ON
OUA-OZZ	Denmark	OZ
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	Surinam	PZ
R	Union of Socialist Soviet Republics	[U]
SAA-SMZ	Sweden	SM
SOA-SRZ	Poland	SP
STA-SUZ	Egypt:	
	Sudan	ST
	Egypt	SU
SVA-SZZ	Greece	SV
TAA-TCZ	Turkey	TA
TFA-TFZ	Iceland	TF
TGA-TGZ	Guatemala	TG
TIA-TIZ	Costa Rica	TI
TKA-TZZ	France and Colonies and Protectorates	[F]
U	Union of Socialist Soviet Republics:	
	European Soviet Republic (Russia)	U1-2-3-4-5-6
	Asiatic Soviet Republics (Siberia)	U8-9-0
VAA-VGZ	Canada	VE
VHA-VMZ	Commonwealth of Australia:	
	Australia	VK-2-3-4-5-6-8
	Tasmania	VK7
	New Guinea	VK9
VOA-VOZ	Newfoundland	VO
VPA-VSZ	British Colonies and Protectorates:	
	British Honduras and Zanzibar	VP1
	Fiji Islands and Antigua	VP2
	Gilbert & Ellice Islands and British Guiana	VP3
	Trinidad and Tobago	VP4
	Jamaica and Cayman Islands	VP5
	Barbados	VP6
	Bahamas	VP7
	Bermuda	VP9
	Fanning Island	VQ1
	Northern Rhodesia	VQ2
	Tanganyika	VQ3
	Kenya	VQ4
	Uganda	VQ5
	Ascension Island and St. Helena	VQ8
	Mauritius and British Guiana	VR1-2
	Fiji and North Borneo	VR-2
	Solomon Islands	VR4
	Malaya	VS2-VS3
	Sarawak	VS5
	Hong Kong	VS6
	Ceylon	VS7
	Straits Settlements	VS8
VTA-VWZ	British India	VU
VXA-VYZ	Canada	[VE]
W	United States of America	[K] (N)[2] W
XAA-XFZ	Mexico	X[3]
XGA-XUZ	China	XT-XU
XYA-XZZ	British India	[VU]
YAA-YAZ	Afghanistan	YA
YBA-YHZ	Netherlands Indies	[PK]
YIA-YIZ	Iraq	YI
YJA-YJZ	New Hebrides	YJ
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
ZAA-ZAZ	Albania	ZA
ZBA-ZJZ	British Colonies and Protectorates:	
	Malta	ZB
	Transjordania	ZC1
	Palestine	ZC6
	Nigeria	ZD
	Southern Rhodesia	ZE
ZKA-ZMZ	New Zealand:	
	Cook Islands	ZK1
	Niue	ZK2
	New Zealand	ZL
	British Samoa	ZM
ZPA-ZPZ	Paraguay	ZP
ZSA-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
NX	Greenland
NY	Canal Zone
OM	Guam
PX	Andorra
V8	Mauritius

[2] Certain amateur stations licensed to members of the U. S. Naval Communications Reserve are authorized to use the prefix N.

[3] Improperly assigned by Mexico; it should have two letters to distinguish it from China, etc.

DX Time Chart

● When one works DX with his amateur station, the world is the limit. A large number of the stations worked will be in a different time zone. Time around the world is determined by geographical meridians, an hour to each 15 degrees of longitude. A convenient chart for time conversion between your station and that of stations worked in other countries has been prepared by Don Mix of W1TS. In the table, under West Longitude, 75th, 90th, 105th and 120th meridian time refers to Eastern, Central, Mountain, and Pacific standard time respectively. Following the chart is a list giving the "prefixes" of approximately 200 different countries where radio amateurs are active on the air, and the time meridian of each such country, so its time may be converted to your own direct from the table.

DIRECTIONS FOR USING DX TIME CHART

CASE 1. — To find time at distant station corresponding to any selected local time.

Pick out local time meridian on horizontal scale.

Follow column down to time meridian of distant station on vertical scale. Add or subtract number of hours indicated to or from local standard clock reading.

Example: My station is running on 75th west meridian time (E.S.T.).

When it is 9 a.m. here, what time is it in Japan?

From list of foreign countries, Japan is on 135th east meridian time. Follow column for 75th west down to 135th east on vertical scale. The table shows that 14 hours should be added to local clock reading. Therefore it is 11 p.m. of the same day.

CASE 2. — To find local time corresponding to any selected foreign time.

Pick out foreign time meridian on horizontal scale.

Follow column down to local time meridian on vertical scale. Add or subtract number of hours indicated to or from foreign clock reading.

Example: My station is running on 90th west meridian time (C.S.T.).

When it is 10 p.m. in Madagascar, what time is it here?

From list of foreign countries, Madagascar is on 45th east meridian time. Follow column for 45th east down to 60th west on vertical scale. The table shows that 9 hours should be subtracted. Therefore, when it is 10 p.m. in Madagascar, it is 1 p.m. C.S.T.

AC	China	150E to 75E
AC4	Tibet	90E
AR	Syria	45E
CE	Chile	75W
CM	Cuba	75W
CN	Morocco	0
CO	Cuba (fone)	75W
CP	Bolivia	60W
CR4	Cape Verde Islands	30W
CR5	Portuguese Guinea	15W
CR6	Angola	15E
CR7	Mozambique	30E
CR8	Portuguese India	75E
CR9	Macao	120E
CR10	Timor	120E
CT1	Portugal	0
CT2	Azores	30W
CT3	Madeira Island	15W
CX	Uruguay	60W
D	Germany	15E
EA	Spain	0
EA6	Balearic Islands	0
EA8	Canary Islands	15W
EA9	Spanish Morocco	0
EI	Irish Free State	0
EL	Liberia	15W
EP	Iran (Persia)	60E–45E
EQ	Iran (Persia)	60E–45E
ES	Estonia	30E
ET	Ethiopia (Abyssinia)	45E
F3	France	0
F3M	Martinique	60W
F3O	Tahiti	150W
F7	New Caledonia	165E
F8	France	0
FA	Algeria	0
FB8	Madagascar	45E
FB8	Reunion Island	45E
FI	French Indo-China	105E
FT	Tunis	15E
G	England	0
G	Scotland	0
GI	North Ireland	0
HAF	Hungary	15E
HB	Switzerland	15E
HC	Ecuador	75W
HH	Haiti	75W
HI	Dominican Republic	75W
HJ	Colombia	75W
HK	Colombia	75W
HP	Republic of Panama	75W
HR	Honduras	90W
HS	Siam	105E
HZ	Hedjaz	30E
I	Italy	15E
J	Japan	135E
J8	Chosen (Korea)	135E
K4	Porto Rico	60W
K4	Virgin Islands	60W
K5	Canal Zone	75W
K6	Hawaii	150W (minus ½ hour)
K6	Guam	150E
K6	Samoa	180
K7	Alaska	135W–150W–165W
KA	Philippines	120E
LA	Norway	15E
LU	Argentina	60W
LX	Luxemburg	0
LY	Lithuania	30E
LZ	Bulgaria	30E
MX	Manchukuo	135E
N	United States (USNR)	0
NX	Greenland	30W–45W
NY	Canal Zone	75W
OA	Peru	75W
OE	Austria	15E
OH	Finland	30E
OK	Czechoslovakia	15E
OM	Guam	150E
ON	Belgium	0
ON4	Belgian Congo	15E
OZ	Denmark	15E
PA	Netherlands	0
PJ	Curacao	60W
PK1	Java	105E plus 20 mins.
PK2	Java	105E plus 20 mins.
PK3	Java	105E plus 20 mins.
PK4	Sumatra	105E
PK5	Dutch Borneo	105E plus ½ hour
PK6	Celebes-New Guinea	120F
PX	Andorra	0
PY	Brazil	45W–60W
PZ	Surinam (Dutch Guiana)	60W
SM	Sweden	15E
SP	Poland	15E
ST	Sudan	30E
SU	Egypt	30E
SV	Greece	30E
SX	Greece	30E
TA	Turkey	30E
TF	Iceland	15W

LOCAL MERIDIAN

DX MERIDIAN		West Longitude													East Longitude										
		0	15	30	45	60	75	90	105	120	135	150	165	180	165	150	135	120	105	90	75	60	45	30	15
West Longitude	0	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1
	15	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2
	30	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3
	45	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4
	60	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5
	75	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6
	90	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7
	105	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8
	120	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9
	135	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10
	150	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	-22	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11
	165	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	-23	-22	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12
	180	+12	+13	+14	+15	+16	+17	+18	+19	+20	+21	+22	+23	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11
East Longitude	165	+11	+12	+13	+14	+15	+16	+17	+18	+19	+20	+21	+22	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
	150	+10	+11	+12	+13	+14	+15	+16	+17	+18	+19	+20	+21	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9
	135	+9	+10	+11	+12	+13	+14	+15	+16	+17	+18	+19	+20	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8
	120	+8	+9	+10	+11	+12	+13	+14	+15	+16	+17	+18	+19	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7
	105	+7	+8	+9	+10	+11	+12	+13	+14	+15	+16	+17	+18	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6
	90	+6	+7	+8	+9	+10	+11	+12	+13	+14	+15	+16	+17	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
	75	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14	+15	+16	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4
	60	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14	+15	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3
	45	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2
	30	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1
	15	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0

TG............Guatemala......................90W
TI............Costa Rica.....................90W
U.............Russia (USSR).............60E–30E
UE............Russia (USSR).............60E–30E
UK............Russia (USSR).............60E–30E
UX............Russia (USSR).............60E–30E
U-0, 8, 9........Siberia (USSR)............60E to 180
UE-0, 8, 9.......Siberia (USSR)............60E to 180
UK-0, 8, 9......Siberia (USSR)............60E to 180
UX-0, 8, 9......Siberia (USSR)............60E to 180
V8.............Mauritius.....................60E
VE1...........Canada........................60W
VE2...........Canada..................75W (EST)
VE3...........Canada.........75W(EST)–90W(CST)
VE4...........Canada.......90W(CST)–105W(MST)
VE5...........Canada................ 120W (PST)
VE5...........Northwest Territories.....120W to 60W
VK2...........Australia.......................150E
VK3...........Australia.......................150E
VK4...........Australia.......................150E
VK5...........Australia........135E (minus ½ hour)
VK6...........Australia.......................120E
VK7...........Tasmania.......................150E
VK8...........Australia........135E (minus ½ hour)
VK9...........New Guinea....................150E
VO............Newfoundland..................60W
VO............Labrador.......................60W
VP1...........British Honduras................90W

VP1...........Zanzibar........................45E
VP2...........Antigua.........................60W
VP3...........Gilbert and Ellice Islands..........180
VP4...........Trinidad........................60W
VP5...........Jamaica.........................75W
VP5...........Cayman Islands.................75W
VP6...........Barbados......................60W
VP7...........Bahamas........................75W
VP9...........Bermuda.........60W (minus 19 mins.)
VQ1...........Fanning Island.................165W
VQ2...........Northern Rhodesia...............30E
VQ3...........Tanganyika.....................30E
VQ4...........Kenya...........................30E
VQ5...........Uganda.........................30E
VQ8...........Ascension Island................15W
VQ8...........St. Helena Island..................0
VR1...........British Guiana..................60W
VR1...........Mauritius.......................60E
VR2...........British Guiana..................60W
VR2...........Fiji Islands....................180W
VR2...........North Borneo..................120E
VR3...........British Guiana..................60W
VR4...........Solomon Islands................150E
VS1...........Federated Malay States..........105E
VS2...........Federated Malay States..........105E
VS3...........Non-Federated Malay States......105E
VS5...........Borneo.........................120E
VS6...........Hongkong......................120E

GREAT CIRCLE DISTANCE CHART

THIS TABLE shows the great circle distances between principal points on the face of the globe. To approximate the radio distances between other points it is necessary to add or subtract a correction to the distance as obtained from the table.

In applying these corrections it must be remembered that the great circle distances between points will not necessarily be straight lines on the map. As they lie on the surface of the globe if plotted on the map they become curves. The Chicago-Tokio distance line, for example, curves upward through the center of Alaska. These peculiarities of great circle distances must be taken into consideration in making corrections to the table.

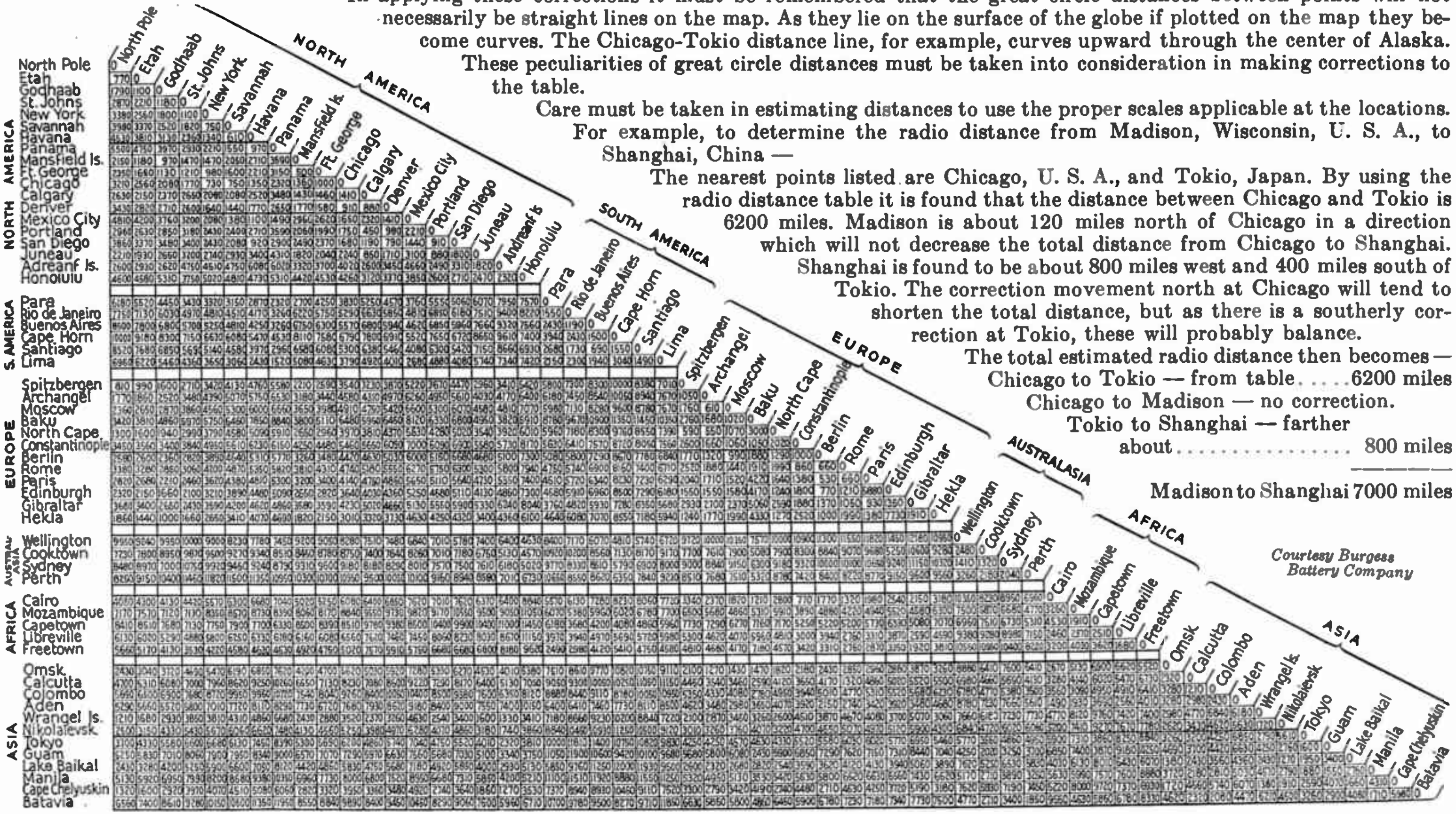
Care must be taken in estimating distances to use the proper scales applicable at the locations. For example, to determine the radio distance from Madison, Wisconsin, U. S. A., to Shanghai, China —

The nearest points listed are Chicago, U. S. A., and Tokio, Japan. By using the radio distance table it is found that the distance between Chicago and Tokio is 6200 miles. Madison is about 120 miles north of Chicago in a direction which will not decrease the total distance from Chicago to Shanghai. Shanghai is found to be about 800 miles west and 400 miles south of Tokio. The correction movement north at Chicago will tend to shorten the total distance, but as there is a southerly correction at Tokio, these will probably balance.

The total estimated radio distance then becomes —

Chicago to Tokio — from table . . . . 6200 miles
Chicago to Madison — no correction.
Tokio to Shanghai — farther about . . . . 800 miles

Madison to Shanghai 7000 miles



Courtesy Burgess Battery Company

VS7	Ceylon	75E (plus ½ hour)
VS8	Straits Settlements	105E
VU	India	75E–90E
W1	U. S. A.	75W (EST)
W2	U. S. A.	75W (EST)
W3	U. S. A.	75W (EST)
W4	U. S. A.	75W (EST)–90W (CST)
W5	U. S. A.	90W (CST)–105W (MST)
W6	U. S. A.	105W (MST)–120W (PST)
W7	U. S. A.	105W (MST)–120W (PST)
W8	U. S. A.	75W (EST)–90W (CST)
W9	U. S. A.	75W (EST)–90W (CST)–105W (MST)
X	Mexico	105W (MST)
XU	China	150E–135E–120E–105E–90E–75E
YA	Afghanistan	60E
YI	Iraq	45E
YJ	New Hebrides	165E
YL	Latvia	30E
YM	Danzig	15E
YN	Nicaragua	90W
YR	Roumania	30E
YS	Salvador	90W
YT	Jugoslavia	15E
YU	Jugoslavia	15E
YV	Venezuela	60W
ZA	Albania	15E
ZB	Malta	15E
ZC1	Transjordania	30E
ZC6	Palestine	30E
ZD	Nigeria	0
ZE	Southern Rhodesia	30E
ZK1	Cook Islands	165W
ZK2	Niue	165E
ZL	New Zealand	180 (minus ½ hour)
ZM	British Samoa	180
ZP	Paraguay	60W
ZS	Union of South Africa	30E
ZT	Union of South Africa	30E
ZU	Union of South Africa	30E

DX Tables

● We are indebted to Charlie Perrine, W6CUH, and to Don H. Mix, W1TS, for the suggestions for proper times to look for different countries. We hope our tables will prove helpful to the new DX man, and the old timer alike, since it has been brought up to date just as we go to press. These tables have been prepared looking to our annual 1936 DX tests. Of course the daily differences, seasonal fluctuations, and the long term changes in conditions which correspond closely to the sunspot cycle cannot be taken into account and absolute reliance should not be placed in tables for such. Tables are extremely helpful and useful for reference, to give all concerned an idea as to the most effective time to look for DX. For additional information, consult DX notes and seasonal tables which will appear in *QST* from time to time.

Two separate tables have been prepared, one for the average experience of amateurs on the west coast of North America, and another for the east coast of North America. Time in both tables is Greenwich, and should be converted to your own local time with reference of course to proper conversion for 120th meridian or 75th meridian respectively. Only two tables are presented since it is believed that DX conditions obtaining in the central part of the country correspond closely to the mean between conditions represented by the tables for the extreme east or west.

The tables give "best" times only. On monthly DX peaks, a considerable extension of the periods for working different countries may be expected. For example, on the west coast, on 14 mc. European stations may be good from 1330 to 0200 GMT (almost all day long) when conditions are at their best, instead of from 1400 to 1700, the "best" time shown in the table.

DX TIME TABLES FOR THE NORTH AMERICAN CONTINENT

("Best Times" Fall and Winter 1935–1936)

For Western Stations

	14 Mc.	*7 Mc.*
EUROPE:		
EA, CT1, CT3	0000–0200	0200–0500
F, G, ON, PA, OZ, SM, LA, EI, GI, HB, D, TF	1400–1700 & 2000–2200	0300–0700
OK, U, Y1, OE, LY, OH, SX	1400–1600	0600–1000
AFRICA:		
ZT, ZS, ZU	1400–1700	0400–0600 & 1430–1700
VQ4, ON4, ZD, ZE	2000–2130	
FM8, FA8, FT4	0100–0200	0400–0600
ZE, CR7, FB8	——	1430–1600
SOUTH AMERICA:		
AL1	2300–0100	0200–0900 & 1400–1500
LU, CX, CA, HC	1400–1600 & 2000–2100	
ASIA:		
XU, VU, VS1, VS6, J	1400–1700	1300–1500
VS2, 3, 5, 7		1300–1500
UO, J	0300–0400	1300–1700 & 0700–0900
OCEANIA:		
VK, F7, VR4	1300–1500 & 0300–0500	0500–1500
Z1	0300–0500	0500–1500
PK1, 2, 3, 4, 5, 6, VR 2, OM, KA	——	0100–1100
NORTH AMERICA:		
Central	2000–0300	0200–1500
Caribbean	1600–1800 & 2200–0100	0200–1500
Alaska	0000–0200	0100–1600

For Eastern Stations

	14 Mc.	*7 Mc.*
EUROPE:		
(Eastern) CT1-2-3, D, EA, EI, F, G, GI, HB, ON, PA, TF, YM, ZB	1100–1300 & 1900–2300	2400–0400
(Western) ES, HAF, I, LA, LY, OE, OH, OK, OZ, SM, SP, SX, U, YL, YT, YR	1000–1200 & 2000–2400	0100–0500

AFRICA:		
(North) CN, EA8, EA, FA, FT, SU	1100–1300 1900–2300	2400–0400
(Central and South) CR7, FB8, ON4, VQ2, 3, 4, 5, 8, ZD, ZE, ZS, ZT, ZU	1100–1300 1800–2000 (also around 0400)	
SOUTH AMERICA:		
CE, CP, CX, HC, HJ, OA, PY, YV, ZP	1100–1200 2100–0100	2100–0700
ASIA:		
(Western) AC, XU, J, MX, VS6	1100–1400	
(Eastern) AR, YI, ZC	2000–2300	
OCEANIA:		
F7, K6, KA, OM, PK, VK, VR4, VS1, 2, 3, 5, 7, 8, ZL	1100–1300	0500–1200
NORTH AMERICA:		
CM, F3M —, HH, HI, HP, HR, K4, 5, NY, TG, TI, VP1, VP2, 4, 5, 6, 7, 8, YN, YS	1000–1300 2100–0200	2100–0900

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.

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 .006 watts, or 6 milliwatts.

Standard Letter Symbols for Electrical Quantities

Admittance	Y, y
Angular velocity ($2\pi f$)	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
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

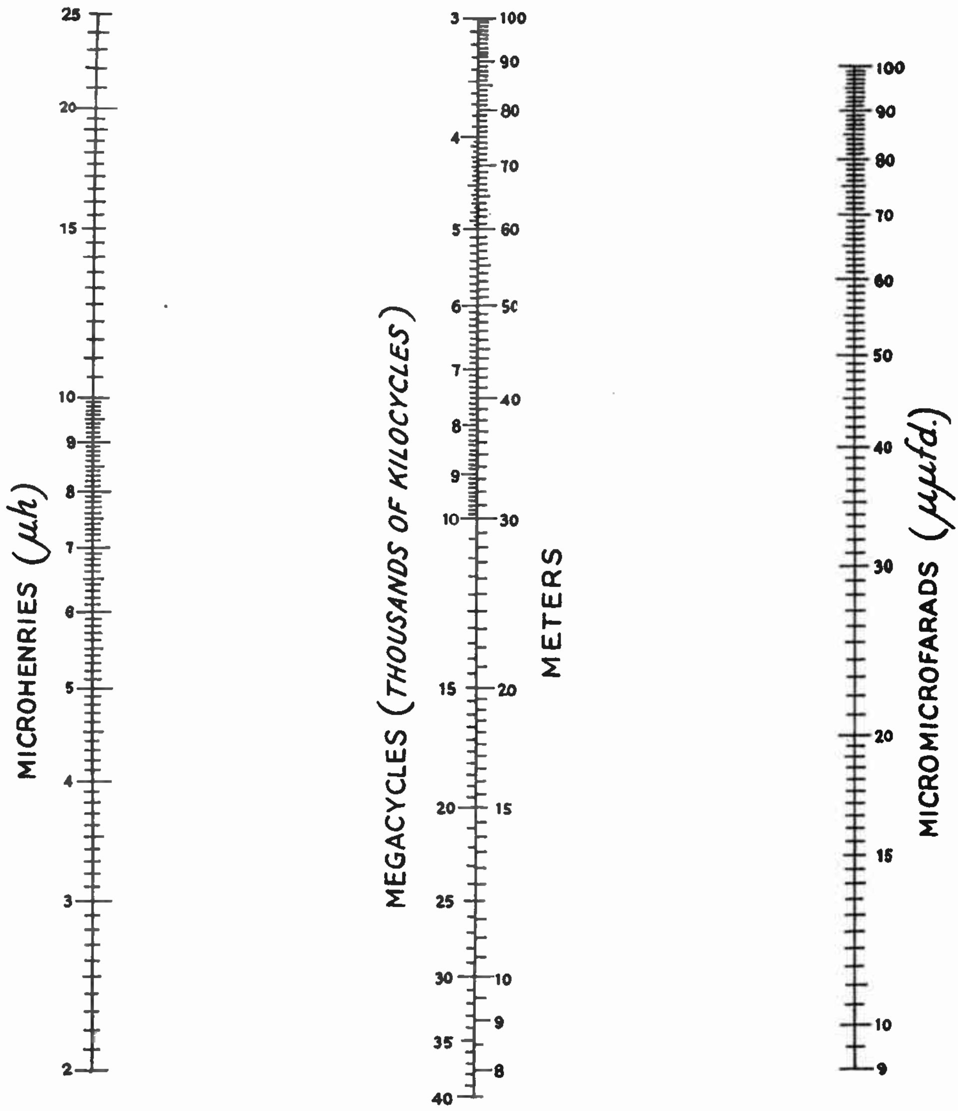
Letter Symbols for Vacuum Tube Notation

Grid potential	E_g, e_g
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_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
Filament supply voltage	E_a
Grid-plate capacity	C_{gp}
Grid-filament capacity	C_{gf}
Plate-filament capacity	C_{pf}
Grid capacity ($C_{gp} + C_{gf}$)	C_g
Plate capacity ($C_{gp} + C_{pf}$)	C_p
Filament capacity ($C_{gf} + C_{pf}$)	C_f

NOTE.—Small letters refer to instantaneous values.

Abbreviations Commonly Used in Radio

Alternating current	a.c.
Antenna	ant.
Audio frequency	a.f.
Continuous waves	c.w.
Cycles per second	~
Decibel	db.
Direct current	d.c.



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 μμfd. and a maximum capacity of 50 μμfd., 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.

COPPER WIRE TABLE

Guage No. B. & S.	Diam. in Mils[1]	Circular Mil Area	Turns per Linear Inch[2] Enamel	S.S.C.	D.S.C. or S.C.C.	D.C.C.	Turns per Square Inch[2] S.C.C.	Enamel S.C.C.	D.C.C.	Feet per Lb. Bare	D.C.C.	Ohms per 1000 ft. 250 C.	Correct Carrying Capacity at 100 C.M. per Amp.[3]	Diam. in mm.	Nearest British S.W.G. No.
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	45.3	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

Electromotive force	e.m.f.
Frequency	f.
Ground	gnd.
Henry	h.
Intermediate frequency	i.f.
Interrupted continuous waves	i.c.w.
Kilocycles (per second)	kc.
Kilowatt	kw.
Megohm	MΩ
Microfarad	μfd.
Microhenry	μh.
Micromicrofarad	μμfd.
Microvolt	μv.
Microvolt per meter	μv/m.
Milliampere	ma.
Milliwatt	mw.
Ohm	Ω
Power factor	p.f.
Radio frequency	r.f.
Volt	v.

Metric Prefixes Often Used with Radio Quantities

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-

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.

Inductance Calculatiou

● The lumped inductance of coils for transmitting and receiving is fairly easy to calculate:

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

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:

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

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

Figuring the Capacitance of a Condenser

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

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

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 of dielectric.

The Specific Inductive Capacity (k) is a property of the dielectric used in a condenser. It 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 above table. "k" is the ratio of the capacitance of a condenser with a given dielectric to the capacitance of the same instrument with air dielectric .

Table of Dielectric Constants

Dielectric	"k"	*Puncture voltage* *Kilovolts per cm.*	*Kilovolts per inch.*
Air (normal pressure)	1.00	7.8–9.0	19.8–22.8
Flint Glass	6.6 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	——	——

When the air dielectric in a variable condenser is replaced with some other fluid dielectric its maximum and minimum capacitance values are multiplied by "k" and the "sparking" potential is increased.

Fluid dielectrics repair themselves after a breakdown unless an arc is maintained that carbonizes the oil. Dry oil is a good dielectric with quite low losses. When solid dielectric is used it should be borne in mind that dielectric strength (breakdown voltage) becomes lower as temperature rises. Breakdown is a function of time as well as voltage. A condenser that stands up under several thousand volts for a few seconds might break down when connected to a 2000-volt line for a half-hour.

Example of finding condenser capacitance: We have 3 plates, 3″ × 5″, in air. The plates are separated ⅛″. 1″ = 2.54 centimeters.

$k = 1. A = 7.62 \times 12.70 = 96.8$ sq. cm.
$d = .3175$ cm. $n - 1 = 2$.

$$C = .0088\frac{1 \times 96.8}{.32}\,2 \times 10^{-5} = .00005325$$

μfd. or 53¼ micromicrofarads.

The capacity formula becomes as follows, when A is the area of one side of one plate *in square inches* and d is the separation of the plates *in inches*.

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

If we put the condenser of our example in castor oil the increase in capacitance, owing to the greater value of k, will make our condenser have a capacitance of

53¼ × 4.7 = 250 micromicrofarads.

The air condenser might spark over at about 7.8 × .3175 cm. = 2.475 kv. (2,475 volts).

In oil (castor oil) it would have 150/7.8 (or 381/19.8) times the breakdown voltage of air.

$$\frac{150}{7.8} = 19.25$$

$$19\tfrac{1}{4} \times 2475 = 47{,}600 \text{ volts}$$

We can find the same value directly:

150 × .3175 cm. = 47,600 volts (peak).

Using the formulas for "reactance" we can find what the voltage drop across this condenser will be when carrying current at a specified high frequency.

$$E_x = X_c I \qquad X_c = \frac{1}{2\pi f c}$$

where E_x is the reactance voltage drop, C is the capacitance of the condenser (farads),

f is the frequency (cycles per second), X_c is the reactance of the condenser in ohms.

Suppose we are using the 3-plate fixed air condenser in our antenna circuit, and that a radio-frequency ammeter is in series with it. We are operating on an 80-meter wavelength (3,750,000 cycles) and the meter right next the condenser reads 1.3 amperes. What is the voltage drop across the air condenser?

$$X_c = \frac{1}{2(3.1416) \quad (3{,}750{,}000) \quad (53.25)\ 10^{-12}}$$

$$= \frac{1}{1257 \times 10^{-6}} = \frac{10^6}{1257} = 797 \text{ ohms}$$

E_x = (797) (1.3) = 1034 volts (root mean square value).

If the wave is a sine wave, this value multiplied by 1.414 will give the "peak" or maximum value

$$1034 \times 1.414 = 1462 \text{ volts (peak)}$$

Our radio-frequency ammeter measures the heating effect of all the instantaneous values of current during the radio-frequency cycle. The direct current, the square of which equals the average of the squares of all the values of alternating current over a whole cycle, produces the same heat as the alternating current. Alternating current meters generally used for a.c. switchboard work read the *effective* or *root mean square values* which we mention above.

Extracts from the Radio Law

● The complete text of the Communications Act of June 19, 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, 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. . . .

Sec. 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.

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) Have authority to suspend the license of any operator for a period not exceeding two years upon proof sufficient to satisfy the Commission that the licensee (1) has violated any provision of any Act or treaty binding on the United States which the Commission is authorized by this Act to administer or any regulation made by the Commission under any such Act or treaty; . . . or (3) has willfully damaged or permitted radio apparatus to be damaged; or (4) has transmitted superfluous radio communications or signals or radio communications containing profane or obscene words or language; or (5) has willfully or maliciously interfered with any other radio communications or signals;

(n) Have authority to inspect all transmitting apparatus to ascertain whether in construction and operation it conforms to the requirements of this Act, the rules and regulations of the Commission, and the license under which it is constructed 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; . . .

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 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 communication 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; since the amateur regulations are not all in one group, the numbers are not necessarily consecutive. The number of each regulation is of no consequence to the amateur, except as a means of reference.

Every amateur should be *thoroughly familiar* with these regulations and their effect, although, of course, it is not necessary to know the exact wording from memory.

The regulations printed here are those which were in effect as of October 1, 1935.

RULES AND REGULATIONS GOVERNING AMATEUR RADIO STATIONS

1. Each application for an instrument of authorization shall be made in writing on the appropriate form prescribed by the Commission for the purpose. Separate application shall be filed for each instrument of authorization. The required forms except as provided in Rule 408 for amateur applicants, may be obtained from the Commission or from the office of any Inspector. For a list of such offices and related geographical districts, see paragraph 30.

2. (h) Each application for amateur facilities shall be filed in accordance with the following instructions:

(1) Applications for amateur station and/or operators' licenses from applicants residing within 125 miles of Washington, D. C., a radio district office of the Commission, or an examining city (see Rule 30): One copy to the Inspector-in-Charge of the Radio District in which the applicant resides.

(2) Applications for amateur station and/or operators' licenses from applicants residing more than 125 miles from Washington, D. C., a radio district office of the Commission, or an examining city (see Rule 30): One copy direct to the Federal Communications Commission, Washington, D. C., in accordance with the instructions specifically set forth on the application form.

14. Each application for new license, where a construction permit is not prerequisite thereto, shall be filed at least 60 days prior to the contemplated operation of the station.

16. 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.

20. The transfer of a radio station license, or the rights granted thereunder, without consent of the Commission shall be sufficient ground for the revocation of such license or denial of any application for its renewal. Amateur station licenses and call signals are not transferable.

22. The Commission may grant special authority to the licensee of an existing station authorizing the operation of such station for a limited time in a manner, to an extent, or for a service other or beyond that authorized in the license.

24. Any licensee receiving official notice of a violation of Federal laws, the Commission's rules and regulations, or the terms and conditions of a license, shall within three days from such receipt send a written reply direct to the Federal Communications Commission at Washington, D. C. The answer to each notice shall be complete in itself and shall not be abbreviated by reference to other communications or answers 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 apparatus is to be installed, the date such apparatus was ordered, the name of the manufacturer, and promised date of delivery.

26. 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.

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.

28. Insofar as practicable, call signals of radio stations will be designated in alphabetical order from groups available for assignment, depending upon the class of station to be licensed. Because of the large number of amateur stations, calls will be assigned thereto in regular order and requests for particular calls will not be considered, except on formal application the Commission may reassign calls to the last holders of record.

29. Call signals of stations will be deleted in each of the following cases:

(a) Where an existing instrument of authorization has expired and no application for renewal or extension thereof has been filed.

(b) Where a license has been revoked.

(c) Where a license is surrendered or cancelled.

(d) Other cause, such as death, loss of citizenship, or adjudged insanity of the station licensee. Such occurrences coming to notice should be reported to the Commission, preferably accompanied by the station license for cancellation, if available.

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) The following is a list of the cities where examinations will be held for radio operators' licenses in addition to Washington, D. C., and the radio district offices of the Commission. Other cities may also be designated from time to time for the purpose of conducting commercial operators' examinations only: (See Rules 2, 404, and 408.)

Schenectady, N. Y.	St. Louis, Mo.
Winston-Salem, N. C.	Pittsburgh, Pa.
Nashville, Tenn.	Cleveland, Ohio
San Antonio, Tex.	Cincinnati, Ohio
Oklahoma City, Okla.	Columbus, Ohio
Des Moines, Iowa	

Examinations for commercial and Class A amateur privileges will be conducted not more than twice per year in the following cities, which are not to be construed as examining cities under the rules which apply for Class B and C amateur privileges:

Albuquerque, New Mexico	Jacksonville, Florida
Billings, Montana	Little Rock, Arkansas
Bismarck, North Dakota	Phoenix, Arizona
Boise, Idaho	Salt Lake City, Utah
Butte, Montana	Spokane, Washington

188. The term "station" means all of the radio-transmitting apparatus used at a particular location for one class of service and operated under a single instrument of authorization. In the case of every station other than broadcast, the location of the station shall be considered as that of the radiating antenna.

192. The term "portable station" means a station so constructed that it may conveniently be moved about from place to place for communication and that is in fact so moved about from time to time, but not used while in motion.

(a) The term "portable-mobile station" means a station so constructed that it may conveniently be moved from one mobile unit to another for communication, and that is, in fact, so moved about from time to time and ordinarily used while in motion.

204. Allocations of bands of frequencies to services, such as mobile, fixed, broadcast, amateur, etc., are set forth in Article 5 of the General Regulations annexed to the International Radiotelegraph Convention and in the North American Radio Agreement. These allocations will be adhered to in all assignments to stations capable of causing international interference.

207. Licensees shall use radio transmitters, the emissions of which do not cause interference, outside the authorized band, that is detrimental to traffic and programs of other authorized stations.

210. Radio communications 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.

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.

214. Only an operator holding a radiotelegraph class of operators' license may manipulate the transmitting key of a manually operated coastal telegraph or mobile telegraph station in the international service; and only a licensed amateur operator may manipulate the transmitting key at a manually operated amateur station. The licensees of other stations operated under the constant supervision of duly licensed operators may permit any person or persons, whether licensed or not, to transmit by voice or otherwise, in accordance with the types of emission specified by the respective licenses.

220. Licensees of stations other than broadcast stations are authorized to carry on such routine tests as may be required for the proper maintenance of the stations, provided, however, that these tests shall be so conducted as not to cause interference with the service of other stations.

221. The original of each station license, except amateur, portable and portable-mobile stations shall be posted by the licensee in a conspicuous place in the room in which the transmitter is located. In the case of amateur, portable, and portable-mobile stations the original license, or a photostat copy thereof, shall be similarly posted or kept in the personal possession of the operator on duty.

(a) The original license of each station operator, except amateur and aircraft radio station operators, and operators of portable and portable-mobile stations, shall be posted in a conspicuous place in the room occupied by such operator while on duty. In the case of an amateur or aircraft radio operator, and operators of portable or portable-mobile stations, the original operator's license shall be similarly posted or kept in his personal possession and available for inspection at all times while the operator is on duty.

(b) When an operator's license cannot be posted because it has been mailed to an office of the Federal Communications Commission for endorsement or other change, such operator may continue to operate stations in accordance with the class of license held, for a period not to exceed sixty days, but in no case beyond the date of expiration of the license.

361. The term "amateur service" means a radio service carried on by amateur stations.

362. 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.

364. The term "amateur radio operator" means a person holding a valid license issued by the Federal Communications Commission who is authorized under the regulations to operate amateur radio stations.

365. The term "amateur radiocommunication" means radiocommunication between amateur radio stations solely with a personal aim and without pecuniary interest.

366. An amateur station license may be issued only to a licensed amateur radio operator who has made a satisfactory showing of ownership or control of proper transmitting apparatus; provided, however, that in the case of a military or naval reserve radio station 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 the person in charge of such station who may not possess an amateur operator's license.

(a) An amateur operator's license may be granted to a person who does not desire an amateur station license, provided such applicant waives his right to apply for an amateur station license for ninety days subsequent to the date of application for operator's license.

367. Amateur radio station licenses shall not be issued to corporations, associations, or other organizations; provided, however, that in the case of a bona fide amateur radio society, a station license may be issued to a licensed amateur radio operator as trustee for such society.

368. Licenses for mobile stations and portable-mobile stations will not be granted to amateurs for operation on frequencies below 28,000 kilocycles. However, the licensee of a fixed amateur station may operate portable amateur stations (Rule 192) in accordance with the provisions of Rules 384, 386 and 387; and also portable and portable-mobile amateur stations (Rules 192 and 192a) on authorized amateur frequencies above 28,000 kilocycles in accordance with Rules 384 and 386, but without regard to Rule 387.

370. Amateur stations shall be used only for amateur service, except that in emergencies or for testing purposes they 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.

371. Amateur stations 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.

372. Amateur stations may be used for the transmission of music for test purposes of short duration in connection with the development of experimental radiotelephone equipment.

373. Amateur radio stations shall not be used to transmit or receive messages for hire, nor for communication for material compensation, direct or indirect, paid or promised.

374. The following bands of frequencies are allocated exclusively for use by amateur stations:

1,715 to 2,000 kc.	28,000 to 30,000 kc.
3,500 to 4,000 "	56,000 to 60,000 "
7,000 to 7,300 "	400,000 to 401,000 "
14,000 to 14,400 "	

374a. The licensee of an amateur station may, subject to change upon further order, operate amateur stations on any frequency above 110,000 kilocycles, without separate licenses therefor, provided:

(1) That such operation in every respect complies with the Commission's rules governing the operation of amateur stations in the amateur service.

(2) That records are maintained of all transmissions in accordance with the provisions of Rule 386.

375. All bands of frequencies so assigned may be used for radiotelegraphy, type A-1 emission. Type A-2 emission may be used in the following bands of frequencies only:

28,000 to 30,000 kc.
56,000 to 60,000 "
400,000 to 401,000 "

376. The following bands of frequencies are allocated for use by amateur stations using radiotelephony, type A-3 emission:

1,800 to 2,000 kc.	56,000 to 60,000 kc.
28,000 to 29,000 "	400,000 to 401,000 "

377. Provided the stations shall be operated by a person who holds an amateur operator's license endorsed for class A privileges, an amateur radio station may use radiotelephony, type A-3 emission, in the following additional bands of frequencies:

3,900 to 4,000 kc. 14,150 to 14,250 kc.

378. The following bands of frequencies are allocated for use by amateur stations for television, facsimile, and picture transmission:

1,715 to 2,000 kilocycles
56,000 to 60,000 kilocycles

379. Transmissions by an amateur station may be on any frequency within an amateur band above assigned.

380. An amateur radio station shall not be located upon premises controlled by an alien.

381. Spurious radiations from an amateur transmitter operating on a frequency below 30,000 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 sub-multiple of the carrier frequency (harmonics and sub-harmonics), spurious modulation products, key clicks and other transient effects, and parasitic oscillations.

382. Licensees of amateur stations using frequencies below 30,000 kilocycles, shall use adequately filtered direct-current power supply for the transmitting equipment, to minimize frequency modulation and to prevent the emission of broad signals.

383. Licensees of amateur stations are authorized to use a maximum power input of one kilowatt to the plate circuit of the final amplifier stage of an oscillator-amplifier transmitter or to the plate circuit of an oscillator transmitter.

384. An operator of an amateur station shall transmit its assigned call at least once during each fifteen minutes of operation and at the end of each transmission. In addition, an operator of an amateur portable or portable-mobile radiotelegraph station shall transmit immediately after the call of the station, the break sign (BT) 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 BT3 W2DEF BT3 W2DEF BT3 AR.

Example 2. Fixed amateur station answers the portable or portable-mobile amateur station: W2DEF W2DEF W2DEF DE W1ABC W1ABC W1ABCK.

Example 3. Portable or portable-mobile amateur station calls a portable or portable-mobile amateur station: W3GHI W3GHI W3GHI DE W4JKL BT4 W4JKL BT4 W4JKL BT4 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.

384a. 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 reservist resides 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 kilocycles and 3500–4000 kilocycles in accordance with instructions to be issued by the Navy Department.

385. In the event that the operation of an amateur radio station causes general interference to the reception of broadcast programs with receivers of modern design, that amateur station shall not operate during the hours from 8 o'clock p.m. to 10:30 p.m., local time, and on Sundays from 10:30 a.m. until 1 p.m., local time, upon such frequency or frequencies as cause such interference.

386. Each licensee of an amateur station shall keep an accurate log of station operation to be made available upon request by authorized Government representatives, as:

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 name of the person manipulating the transmitting key of a radiotelegraph transmitter or the name of the person operating a transmitter of any other type (type A-3 or A-4 emission) with statement as to type of emission. (The name 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 name 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.)

387. Advance notice of all locations in which portable amateur stations will be operated shall be given by the licensee to the Inspector-in-Charge of the district in which the station is to be operated. Such notices shall be made by letter or other means prior to any operation contemplated and shall state the station call, name of license, the date of proposed operation and the approximate locations, as by city, town, or county. An amateur station operating under this rule shall not be operated during any period exceeding thirty days without giving further notice to the Inspector-in-Charge of the radio district in which the station will be operated. This rule does not apply to the operation of portable or portable-mobile amateur stations on frequencies above 28,000 kilocycles authorized to be used by amateur stations. (See Rule 368.)

400. 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.

401. 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 30,000 kilocycles.

402. Amateur station licenses and/or amateur operator licenses may, upon proper application, be renewed provided: (1) the applicant has used his station to communicate by radio with at least three other amateur stations during the three-month period prior to the date of submitting the application, or (2) in the case of an applicant possessing only an operator's license, that he has similarly communicated with amateur stations during the same period. Proof of such communication must be included in the application by stating the call letters of the stations with which communication was carried on and the time and date of each communication. Lacking such proof, the applicant will be ineligible for a license for a period of ninety days. This rule shall not prevent renewal of an amateur station license to an applicant who has recently qualified for license as an amateur operator.

403. There shall be but one main class of amateur operator's license to be known as "amateur class" but each such license shall be limited in scope by the signature of the examining officer opposite the particular class or classes of privileges which apply, as follows:

Class A. Unlimited privileges.

Class B. Unlimited radiotelegraph privileges. Limited in the operation of radiotelephone amateur stations to the following bands of frequencies: 1800 to 2000 kilocycles; 28,000 to 28,500 kilocycles; 56,000 to 60,000 kilocycles; 400,000 to 401,000 kilocycles.

Class C. Same as Class B privileges, except that the Commission may require the licensee to appear at an examining point for a supervisory written examination and practical code test during the license term. Failing to appear for examination when directed to do so, or failing to pass the supervisory examination, the license held will be cancelled and the holder thereof will not be issued another license of the Class C privileges.

404. The scope of examinations for amateur operators' licenses shall be based on the class of privileges the applicant desires, as follows:

Class A. To be eligible for examination for the Class A amateur operator's privileges, the applicant must have been a licensed amateur operator for at least one year and must personally appear at one of the Commission's examining offices, and take the supervisory written examination and code test. (See Rules 2 (2) a, 30 and 408.) Examinations will be conducted at Washington, D. C., on Thursday of each week, and at each radio district office of the Commission on the days designated by the Inspector-in-Charge of such offices. In addition, examinations will be held quarterly in the examining cities listed in Rule 30 on the dates to be designated by the Inspector-in-Charge of the radio district in which the examining city is situated. The examination will include the following:

(a) Applicant's ability to send and receive in plain language messages in the Continental Morse Code (5 characters to the word) at a speed of not less than 10 words per minute.

(b) Technical knowledge of amateur radio apparatus, both telegraph and telephone.

(c) Knowledge of the provisions of the Communications Act of 1934 as amended, subsequent acts, treaties, and rules and regulations of the Federal Communications Commission, affecting amateur licensees.

Class B. The requirements for Class B amateur operator's privileges are similar to those for the Class A, except that no experience is required and the questions on radiotelephone apparatus are not so comprehensive in scope.

Class C. The requirements for Class C amateur operator's privileges shall be the same as for the Class B except the examination will be given by mail. Applicants for Class C privileges must reside more than 125 miles airline from the nearest examining point for Class B privileges, or in a camp of the Civilian Conservation Corps, or be in the regular military or naval service of the United States at a military point or naval station; or be shown by physician's certificate to be unable to appear for examination due to protracted disability. (See Rules 2 (2) b, 30, and 408.)

405. An applicant for any class of amateur operator's privileges who has held a radiotelephone second class operator's license or higher, or an equivalent commercial grade license, or who has been accorded unlimited amateur radiotelephone privileges, within five years of the date of application may only be required to submit additional proof as to code ability and/or knowledge of the laws, treaties, and regulations affecting amateur licensees.

406. An applicant for the Class B or C amateur operator's privileges who has held a radiotelegraph third class operator's license or higher, or an equivalent commercial grade license, or who has held an amateur extra first class license within five years of the date of application may be accorded a license by passing an examination in laws, treaties, and regulations affecting amateur licensees.

407. An applicant for Class C amateur operator's privileges must have his application signed in the presence of a person authorized to administer oaths, by (1) a licensed radiotelegraph operator other than an amateur operator possessing only the Class C privileges or former temporary amateur class license, or (2) by a person who can show evidence of employment as a radiotelegraph operator in the Government service of the United States. In either case the radiotelegraph code examiner shall attest to the applicant's ability to send and receive messages in plain language in the Continental Morse Code (5 characters to the word) at a speed of not less than 10 words per minute. The code certification may be omitted if the applicant can show proof of code ability in accordance with the preceding rule.

408. Forms for amateur station and/or operator license shall be obtained by calling or writing to the Inspector-in-Charge of the radio inspection district in which the applicant resides. Upon completion of the forms they shall be sent back to the same office where the final arrangements will be made for the examination: *Provided*, however, in the case of

applicants for the Class C amateur operator's privileges, the forms and examination papers when completed shall be mailed direct to the Federal Communications Commission, Washington, D. C.

409. The percentage that must be obtained as a passing mark in each examination is 75 out of a possible 100. No credit will be given in the grading of papers for experience or knowledge of the code. If an applicant answers only the questions relating to laws, treaties, and regulations by reason of his right to omit other subjects because of having held a recognized class of license, a percentage of 75 out of a possible 100 must be obtained on the questions answered.

410. An amateur station license shall be issued so as to run concurrently with the amateur operator's license and both licenses shall run for three years from the date of issuance. If either the station license or the operator's license is modified during the license term, both licenses shall be reissued for the full three-year term, provided, however, if an operator's license is modified only with respect to the class of operator's privileges, the old license may be endorsed in which case the expiration date will not change.

411. No applicant who fails to qualify for an operator's license will be reëxamined within ninety days from the date of the previous examination.

412. Any attempt to obtain an operator's license by fraudulent means or by attempting to impersonate another, or copying or divulging questions used in examinations, or, if found unqualified or unfit, will constitute a violation of the regulations for which the licensee may suffer suspension of license or be refused a license and/or debarment from further examination for a period not exceeding two years at the discretion of the licensing authority.

413. Any licensee applying for a duplicate license to replace an original which has been lost, mutilated, or destroyed shall submit an affidavit to the Commission attesting to the facts regarding the manner in which the original was lost. Duplicates will be issued in exact conformity with the original, and will be marked "duplicate" on the face of the license.

414. Licenses are not valid until the oath of secrecy has been executed and the signature of the licensee affixed thereto.

415. All examinations, including the code test, must be written in longhand by the applicant.

UNITED STATES 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 New Post Office Bldg., Atlanta, Ga.
No. 7	The State of Florida, Puerto Rico, and the Virgin Islands.	P. O. Box 150, Miami, Fla.
No. 8	The States of Arkansas, Louisiana and Mississippi; and the city of Texarkana in the State of Texas.	Customhouse, New Orleans, La.
No. 9	The counties of Arkansas, Brasoria, 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.	209 Prudential Building, 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.	464 Federal Building, 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; the Hawaiian Islands, Guam and American Samoa.	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.	538 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.	410 Federal Building, 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.	2022 Engineering Building, Chicago, Ill.
No. 19	The State of Michigan except that part lying in District 16; the States of Ohio, Kentucky and West Virginia.	10th Floor, 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.	Aloha Tower, Honolulu, T. H.

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 among the following works, all of which have been gone over carefully and are recommended in their various fields.

Principles of Radio, by Keith Henney, is an excellent book for the amateur who wants to acquire a better understanding of the fundamentals of radio transmission and reception. The book is thoroughly modern and, generally speaking, is a "non-mathematical" treatment. Recommended to every amateur. Price, $3.50.

Radio Engineering, by Prof. F. E. Terman, is written from the viewpoint of the practical engineer engaged in design and experimental work on modern transmitters and receivers, and covers all phases of radio communication with the thoroughness of a complete reference book. A knowledge of advanced mathematics is helpful, but not necessary. Price, $5.00.

An excellent theoretical work, requiring some knowledge of mathematics (algebra, at least), is *Elements of Radio Communication*, by Prof. J. H. Morecroft, price $3.00. This is in the "first-year" student class. Perhaps the best known of all theoretical works is *Principles of Radio Communication*, by Morecroft, priced at $7.50, but a familiarity with mathematics is essential to anyone who expects to derive much benefit from this book. The *Manual of Radio Telegraphy and Telephony*, by Admiral S. S. Robison, U.S.N., and published by the Naval Institute, covers both the theoretical and practical fields.

A monumental work on vacuum tubes has been made available recently in Dr. E. L. Chaffee's *Theory of Thermionic Vacuum Tubes*, based on his research and study at Harvard University. This book is of an advanced nature, but is particularly recommended because of its exhaustive and competent presentation.

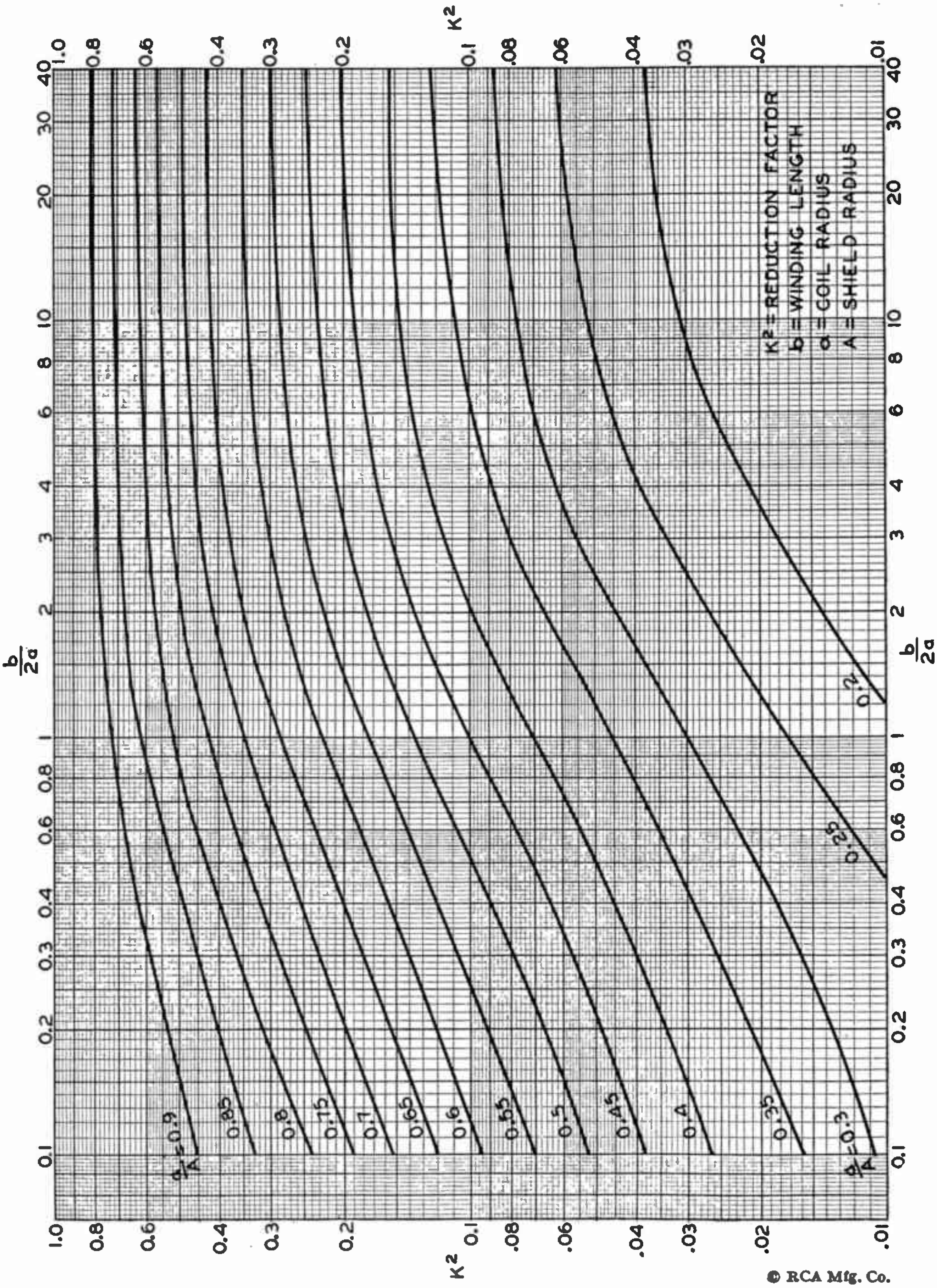
Fundamentals of Radio, Second Edition, by R. R. Ramsey. A modernized revision of the author's work which has been a favorite with amateurs and experimenters since 1929. 426 pages, 439 illustrations. Price, $3.50.

Measurements in Radio Engineering, by F. E. Terman. A comprehensive engineering discussion of the measurement problems encountered in engineering practice, with emphasis on basic principles rather than on methods in detail. A companion volume to the same author's Radio Engineering. 400 pages, including an appendix of outlines for laboratory experiments and a comprehensive index. 210 illustrations. Price, $4.00.

The Cathode-Ray Tube at Work, by John F. Rider. Every owner and user of a cathode-ray oscilloscope should have his copy of this book. The first 109 pages are devoted to cathode-ray tube theory, sweep circuits, a.c. wave patterns and description of commercial oscilloscope units (the author prefers to call them "oscillographs"); the next 205 pages are packed with practical information on how to use them, including actual photographs of screen patterns representing just about every condition likely to be encountered in audio- and radio-frequency amplifiers, power supplies, complete receivers and transmitters. 322 pages, 444 illustrations. Price, $2.50.

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 systems, avia-

CURVES FOR DETERMINATION OF DECREASE IN INDUCTANCE PRODUCED BY A COIL SHIELD



tion radio and marine communication. 754 pages, including an appendix of tabulated data and a complete topical index. 434 illustrations. Price, $5.00.

Radio Design Practice, by James Millen and M. B. Sleeper. A new type of book giving mechanical dimensions and electrical specifications of components and illustrating complete units of 10 manufacturers, with catalog listings appended. Over 150 pages, exclusive of the catalog section. Price, $1.00.

Two valuable books cover the general field of electricity and communications, with fitting emphasis on the radio aspects. *Electricity — What It Is and How It Acts*, by A. W. Kramer, is an easily understood treatment of modern electrical theory, including comprehensive discussions of vacuum-tube and electro-magnetic wave phenomena. It is written in two volumes, price $2.00 each. *Communication Engineering*, by Prof. W. L. Everitt, is a thorough treatment of all types of communications networks. A certain amount of training in d.c. and a.c. current theory as well as mathematics through calculus is needed for fullest appreciation of this work. The price is $5.00.

For the experimenter, there is Prof. R. R. Ramsey's *Experimental Radio*, price $2.75, which describes in detail 128 experiments designed to bring out the principles of radio theory, instruments and measurements. There are two excellent books on high frequency measurements, intended primarily for serious experimenters and engineers. *Radio Frequency Electrical Measurements*, by H. A. Brown, is priced at $4.00, while *High Frequency Measurements* by August Hund costs $5.00.

Radio Data Charts, an English publication by R. T. Beatty, is a series of abacs (graphic charts) which enables most of the problems connected with radio design to be solved easily without recourse to mathematical calculations.

Any of the above books may be obtained from the Book Department of the A.R.R.L. at the prices stated. Readers are referred to the Book Department's advertisement, in the advertising section of this Handbook, for a list which includes additional volumes of interest to amateurs.

QST is the official organ of the American Radio Relay League. It is published monthly, containing up-to-date information on amateur activities and describing the latest developments in amateur radio. It is a magazine devoted exclusively to the radio amateur. Written by and for the amateur, it contains knowledge supplementary to the books we have mentioned. *QST* is found on the bookshelves of earnest amateurs and experimenters everywhere. Good books are a worth-while investment. A subscription to *QST* is equally valuable.

Effect of Coil Shields on Inductance

● Most amateurs are familiar with the fact that enclosing a coil in a shield decreases the inductance of the coil, but there has not, to our knowledge, heretofore been available a simple method for determining the extent of the decrease. An easily-applied graphical method of solving this problem has been worked out by the Radiotron Division of RCA Manufacturing Company and published as a tube application note.[1]

Considering the shield as a single turn having low resistance compared to its reactance, the following formula for inductance of the coil within the shield can be worked out:

$$L = L_o(1 - K^2)$$

where L is the desired inductance, L_o is the inductance of the coil outside the shield, and K^2 is a factor depending upon the geometric dimensions of the coil and shield. Values of K^2 have been plotted as a family of curves in the chart reproduced on the opposite page. The notations are as follows:

b—length of winding of coil
a—radius of coil
A—radius of shield

The curves are sufficiently accurate for all practical purposes throughout the range shown *when the length of the shield is greater than that of the coil by at least the radius of the coil.* If the shield can is square instead of circular, A may be taken as 0.6 times the width of one side. The reduction factor, K^2, is plotted against $b/2a$ (ratio of length to diameter of coil), for a series of values of a/A, the ratio of coil radius to shield radius (or coil diameter to shield diameter).

The following example will illustrate the use of the chart. Assume an r.f. coil 1½ inches long and ¾ inch in diameter to be used in a shield 1¼ inches in diameter. The inductance-reducing effect of the shield is to be calculated. The values are:

$$b = 1.5$$
$$a = 0.375$$
$$A = 0.625$$
$$b/2a = 1.5/0.75 = 2$$
$$a/A = 0.375/0.625 = 0.6$$

From the curves, K^2 is 0.28; the inductance of the coil is therefore reduced 28% by the shield, or conversely, the inductance of the shield coil is 72% of its unshielded value.

[1] Application Note No. 48, Copyright, 1935, RCA Manufacturing Co., Inc.

It is interesting to note from inspection of the chart that the reduction in inductance does not start to become serious with coils of $b/2a$ ratios of 2 or less, ordinarily used by amateurs, until the shield diameter becomes less than twice the coil diameter. With an a/A ratio of 0.5, the reduction in inductance will be of the order of 15%.

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 U. S. and five Canadian districts. In order to secure such foreign cards as may be received for you, send your district manager a standard No. 8 *stamped* envelope. If you have reason to expect a considerable number of cards, put on an extra stamp so that it has a total of six-cents 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*. When you receive cards, you should immediately furnish your QSL manager with another such envelope to replace the used one. List of managers is printed in each issue of *QST* and it is advisable to consult the current issue for this information, since changes occasionally take place. The managers as of October 15, 1935, were as follows:

W1 — J. T. Steiger, W1BGY, 35 Call Street, Willimansett, Mass.
W2 — H. W. Yahnel, W2SN, Lake Ave., Helmetta, N. J.
W3 — R. E. Macomber, W3CZE, 418 10th St. N. W., Washington, D. C.
W4 — B. W. Benning, W4CBY, 520 Whiteford Ave., Atlanta, Ga.
W5 — E. H. Treadaway, W5DKR, 2749 Myrtle St., New Orleans, La.
W6 — C. E. Spitz, W6FZQ, Box 1804, Phoenix, Ariz.
W7 — L. Q. Kelly, W7BPC, 4919 So. Prospect St., Tacoma, Wash.
W8 — F. W. Allen, W8GER, 324 Richmond Ave., Dayton, Ohio.
W9 — George Dammann, W9JO, 319 Sherman Ave., Evanston, Ill.
VE1 — J. E. Roue, VE1FB, 84 Spring Garden Rd., Halifax, N. S.
VE2 — W. H. Oke, VE2AH, 5184 Mountain Sights Ave., N. D. G., Montreal, P. Q.
VE3 — Bert Knowles, VE3QB, Lanark, Ont.
VE4 — Dr. J. J. Dobry, VE4DR, Killam, Alberta.
VE5 — E. H. Cooper, VE5EC, 2024 Carnarvon St., Victoria, B. C.
K4 — F. McCown, K4RJ, Family Court 7, Santurce, Puerto Rico.
K7 — Frank P. Barnes, K7DVF, Box 297, Wrangell, Alaska.

INDEX

To Handbook Readers Who Are Not A.R.R.L. Members

AMATEUR RADIO OF TODAY 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.

To:

Save yourself 50c a year (newsstand copies of *QST* cost $3).

Be sure of getting your copy of *QST* first.

Be sure of getting your copy of *QST* (newsstands are often sold out).

Be eligible for appointment or election to A.R.R.L. offices.

Be eligible to sign petitions for your Director, your representative on the A.R.R.L. Board.

Be eligible to vote for Director and Section Comm. Manager (only A.R.R.L. members receive ballots).

Lend the strength of your support to the organization which represents YOU at Madrid, at Washington — at all important radio conferences.

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 ....

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. XIV, XV, XVI), 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 on page 5 of *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 specified on my license from..........................*kilocycles*

to..............*kilocycles. Actual frequency in use*........................*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 forth-eight (48) hours when possible, mailing to destination when ever 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 to my S.C.M. in connection with this application.

Signed..

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.

INDEX OF MANUFACTURERS

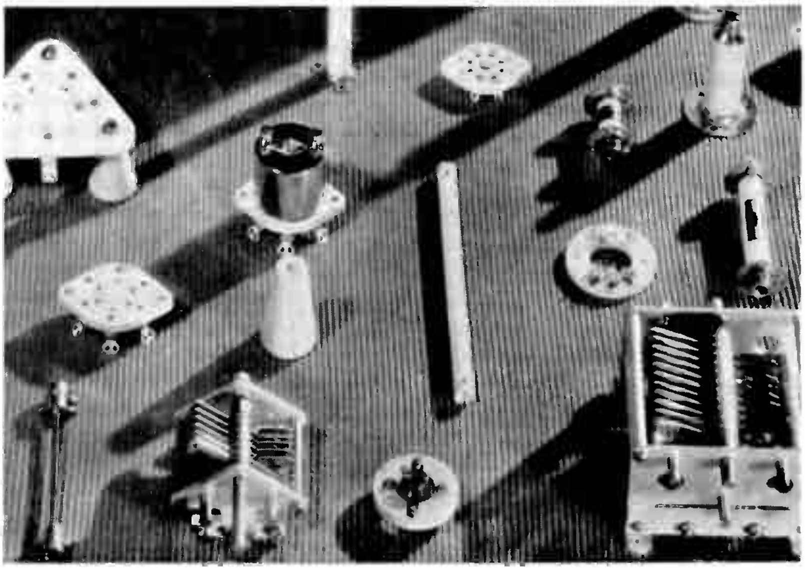
Catalog Section

THE RADIO AMATEUR'S HANDBOOK

DESCRIPTIVE PRICE LIST

BULLETIN NO. 250A

NATIONAL Radio Products

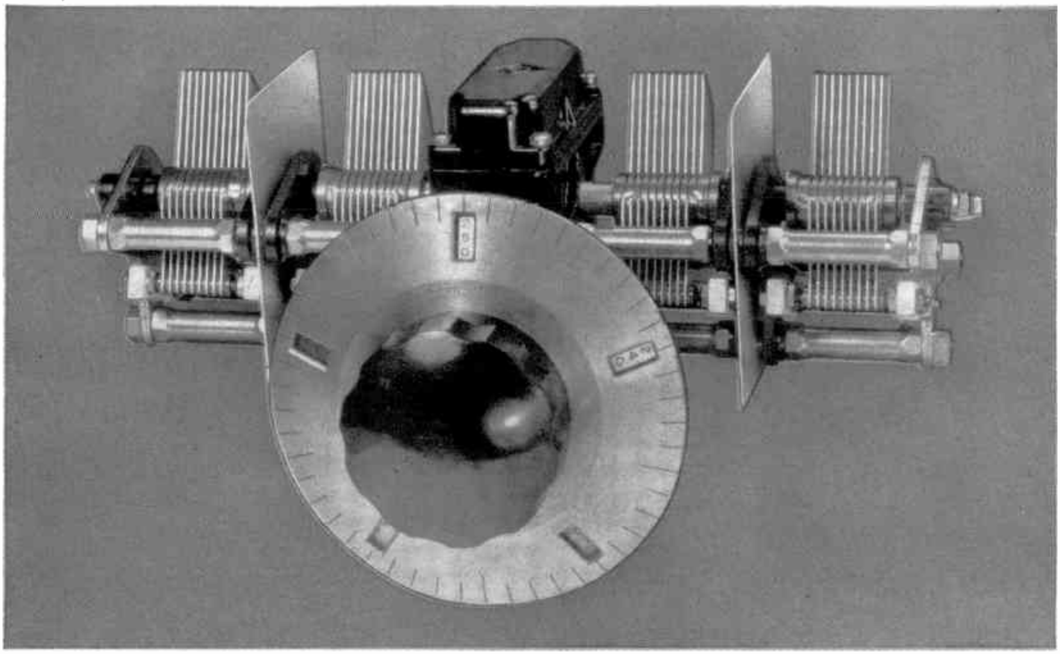


ESTABLISHED 1914

61 SHERMAN STREET • MALDEN • MASSACHUSETTS

NATIONAL COMPANY, INC. • ENGINEERS AND MANUFACTURERS

NATIONAL *Ganged* CONDENSER



PRECISION GANGED CONDENSER

The PW Precision Condenser has been particularly designed for use in H.F. circuits. It is available with 2, 3 or 4 ganged sections for use in receivers, and in a new single section model for use in laboratory equipment. The sizes available are listed at the right.

The condenser is of extremely rigid construction, with four bearings on the rotor shaft. The drive, at the midpoint of the rotor, is through an enclosed pre-loaded 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 multi-fingered brush type. Stator insulation is Steatite.

The Micrometer dial is of a new type and reads direct to one part in 500. Division lines are approximately 1/4" apart. As is evident from the illustration above, the dial is read in the usual way. However, 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. As the illustration shows, the numbers rotate with the division lines at the top of the dial, and change rapidly at bottom of the dial where they are out of the operator's line of sight. As the dial has only two moving parts, both rotating, the dial is very smooth in operation and does not interfere with delicate tuning adjustment.

The dial and enclosed worm drive is listed separately, for use in driving transmitting condensers and similar equipment.

SPECIFICATIONS

PW Ganged Condensers are available in 2, 3 or 4 sections, in either 150 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.

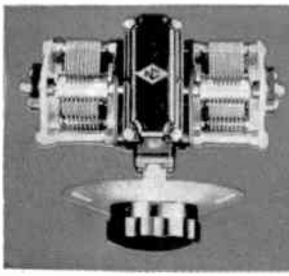
Single Section
PW-1 **List Price $13.50**

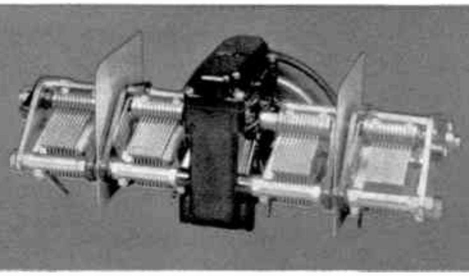
Two Section
PW-2 **List Price $17.00**

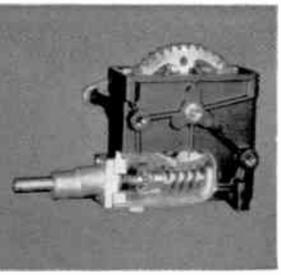
Three Section
PW-3 **List Price $20.50**

Four Section
PW-4 **List Price $24.00**

Drive Unit
PW-0 **List Price $13.50**







NATIONAL COMPANY, INC., MALDEN, MASS.

NATIONAL DIALS

"VK" DIAL — FIG. 1

Full Vision Dial, Type VK, has become well known through its use on SW-58 and FB-7 Receivers. The long illuminated seven-inch scale permits accurate logging, and the travelling pointer remains vertical at all times. Ratio is 10 to 1. It is available with either 2, 3 or 6 scale. **List Price, each $4.50**

"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. It is available with either 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. Available with either 2, 3, 4 or 5 scale. **List Price, each $15.00**

"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. Available with either 2, 4 or 5 scale in 4" diameter. Available with 2 scale in 3⅜" diameter. **List Price, each $3.00**

"B", "BM", & "BX" DIALS — FIGS. 5, 6, 7

"Velvet Vernier" Dial, Type B (Fig. 7) provides a compact variable-ratio drive that is smooth and trouble free. The mechanism is inclosed in a black bakelite case, the dial being read through a window. Available with 1 or 5 scales. **List Price, each $2.75**

If illuminator is desired, add $.50 to List Price.

The Type BX Dial (Fig. 6) is mechanically identical to the Type B Dial, but is equipped with an etched dial scale and vernier reading to 1/10 division. Available with 4 scale only. **List Price, each $3.50**

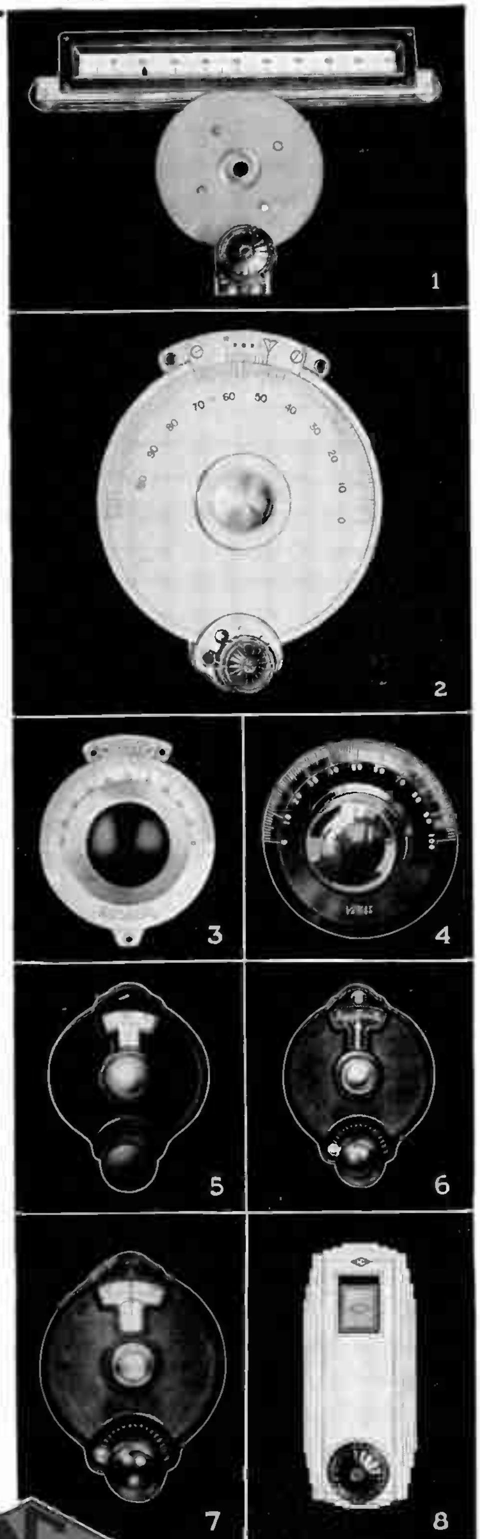
The Type BM Dial (Fig. 5) is a smaller version of the Type B Dial for use where space is limited. It is similar to the Type B Dial in appearance and mechanism, but does not have the variable-ratio device. Available with 1 or 5 scales. **List Price, each $2.50**

"H" DIAL — FIG. 8

Projection Drum Dial, Type H, employs the proved and popular non-conducting cord drive with spring take-up. The dial scale is optically projected in illuminated figures on a ground-glass screen, considerably enlarged. Parallax is entirely absent. Condenser shaft must be parallel to panel. Available with either 2, 3 or 4 scale. **List Price, each $5.50**

DIAL SCALES

Scale Type	Divisions	Degrees 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

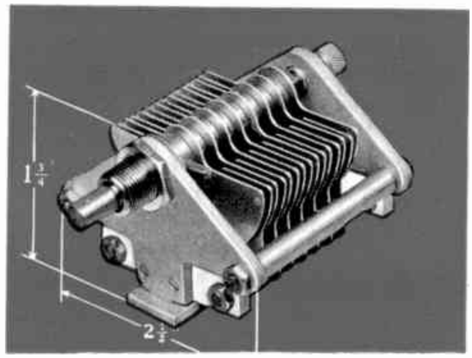


1 2 3 4 5 6 7 8

NATIONAL COMPANY, INC.

NATIONAL *Transmitting* CONDENSERS

TMS *{Low Power, Compact, Inexpensive}*

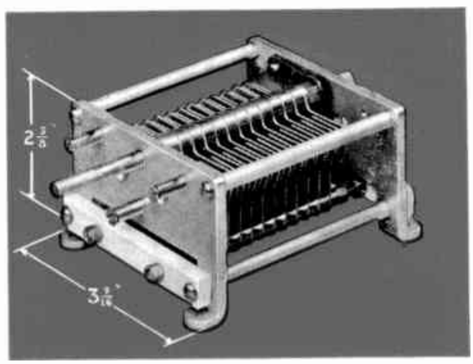


Type TMS is a new condenser designed for transmitter use in low power stages. It is compact, rigid, and dependable. Provision has been made for mounting either on the panel, on the chassis, or on two stand-off insulators.

Front bearing is conical, rear bearing radial with single-ball thrust. Insulation is Steatite-Isolantite. Voltage ratings listed are conservative.

Capacity	*Peak V*	*Length*	*Plates*	*Cat. Symbol*	*List Price*
FOR OSCILLATORS, BUFFERS, DOUBLERS, ETC.					
100 Mmf	1000 v	2¾″	10	TMS-100	**$2.25**
150 Mmf	1000 v	2¾″	14	TMS-150	**2.50**
250 Mmf	1000 v	2¾″	23	TMS-250	**2.75**
50-50	1000 v	2¾″	5-5	TMS-50D	**3.50**
100-100	1000 v	2¾″	9-9	TMS-100D	**4.25**
FOR LOW C, TYPE 210 AMPLIFIERS					
35 Mmf	2000 v	2¾″	8	TMSA-35	**2.75**
50 Mmf	2000 v	2¾″	11	TMSA-50	**3.00**

TMC *{Moderate Power, Compact}*



Also of new design, the TMC is designed for use in the power stages of transmitters, where peak voltages do not exceed 3000. The frame is extremely rigid and arranged for mounting on panel, chassis or stand-off insulators. The plates are aluminum, with buffed edges. The front bearing is conical, rear bearing radial with single-ball thrust. Insulation is Steatite-Isolantite, located outside of the concentrated electrostatic field. The stator in the split stator model is supported at both ends.

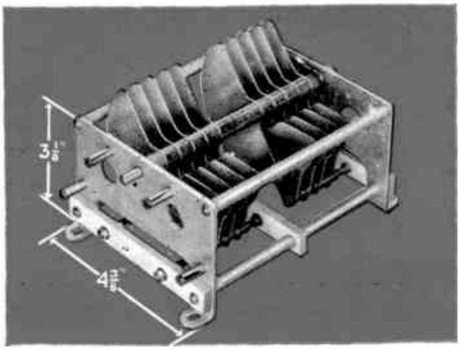
Capacity	*Peak V*	*Length*	*Plates*	*Cat. Symbol*	*List Price*
FOR RK-18, RK-20, RCA-800, 830, 203A, 210, ETC.					
50 Mmf	3000 v	3″	7	TMC-50	**$4.00**
100 Mmf	3000 v	3½″	13	TMC-100	**4.25**
150 Mmf	3000 v	4⅝″	21	TMC-150	**4.75**
100-100 Mmf	3000 v	6¾″	13-13	TMC-100D	**7.50**
	Air Gap=.077″				

A device for clamping the rotor shaft of any of our transmitting condensers can be supplied at a List Price of $.85

NATIONAL COMPANY, INC., MALDEN, MASS.

NATIONAL *Transmitting* CONDENSERS

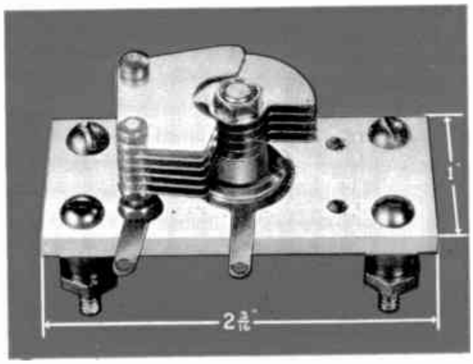
TMA *{Heavy Duty}*



Newly designed, the TMA is a larger model of the popular TMC. The frame is extremely rigid and arranged for mounting on panel, chassis or stand-off insulators. The plates are of heavy aluminum with rounded and buffed edges. The front bearing is conical: rear bearing radial with single-ball thrust. Insulation is Isolantite, located outside of the concentrated field.

Capacity	*Peak V*	*Length*	*Plates*	*Cat. Symbol*	*List Price*
300 Mmf.	3000 v	4 9/16″	23	TMA-300	**$11.00**
200–200	3000 v	6 7/8″	16–16	TMA-200D	**13.50**
50	6000 v	4 9/16″	9	TMA-50A	**6.00**
100	6000 v	6 7/8″	16	TMA-100A	**9.00**
150	6000 v	6 7/8″	23	TMA-150A	**11.00**
230	6000 v	9 5/16″	35	TMA-230A	**14.50**
50–50	6000 v	6 7/8″	9–9	TMA-50DA	**10.00**
100–100	6000 v	9 5/16″	15–15	TMA-100DA	**16.00**
100	9000 v	9 1/4″	23	TMA-100B	**12.00**
150	9000 v	12 1/2″	35	TMA-150B	**15.50**
60–60	9000 v	12 1/2″	15–15	TMA-60DB	**17.00**
50	12000 v	7 1/8″	13	TMA-50C	**7.25**
100	12000 v	12 7/8″	27	TMA-100C	**11.00**
40–40	12000 v	12 7/8″	11–11	TMA-40DC	**12.00**

UM *{Ultra-Midget}*



Designed for Ultra High Frequency use, these condensers are small enough to mount inside shield cans, and are particularly useful for tuning receivers, transmitters and exciters. A long shaft extension is provided, which may be cut off if not required. A balanced stator model is available, in which two stators act upon a single rotor.

The UM Condensers can be mounted either by the angle foot supplied, or by spacers and bolts as illustrated.

Capacity	*Symbol*	*List Price*
Single-Spaced		
15 Mmf.	UM-15	**$1.25**
35	UM-35	**1.50**
50	UM-50	**1.60**
75	UM-75	**1.70**
100	UM-100	**1.90**

Capacity	*Symbol*	*List Price*
Double-Spaced		
25	UMA-25	**$1.85**
Balanced Stator, Single-Spaced		
25	UMB-25	**1.85**

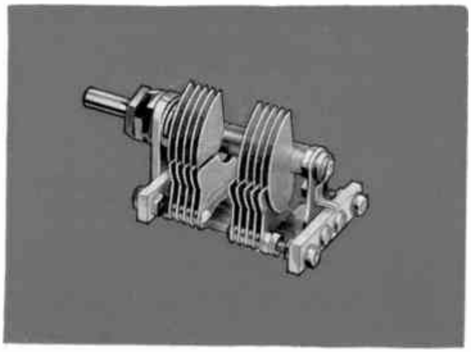
NATIONAL COMPANY, INC., MALDEN, MASS.

NATIONAL *Receiving* CONDENSERS

ST 180° Straight-Line-Wavelength

The ST Condenser is very similar to the SE Condensers described below, but has 180° Straight-Line-Wavelength plates. Also, the use of 180° plates permits a more compact frame with less overall height. In all other details, the two condensers are identical.

A single bearing model is also available in the smaller sizes, in which overall length is reduced to a minimum. The split-stator model is illustrated; the single stator models have a frame similar to the SE condenser illustrated below.

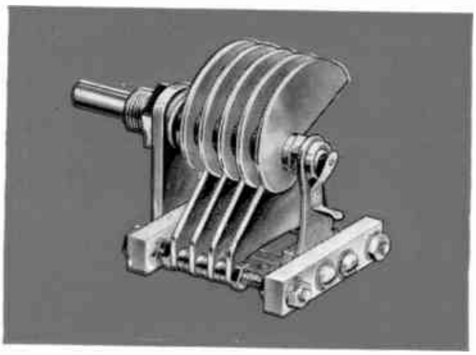


Cap	Air Gap	No. Plates	Length	Cat. No.	List Price
Single Bearing Models					
15	.018″	3	1 3/16″	STHS 15	$1.40
25	.018″	4	1 3/16″	STHS 25	1.50
50	.018″	7	1 3/16″	STHS 50	1.60
Double Bearing Models					
35	.026″	9	2 1/4″	ST 35	1.50
50	.026″	11	2 1/4″	ST 50	1.80
75	.026″	15	2 1/4″	ST 75	2.00
100	.026″	20	2 1/4″	ST 100	2.25
140	.026″	28	2 3/4″	ST 140	2.50
150	.026″	29	2 3/4″	ST 150	2.50
200	.018″	27	2 1/4″	STH 200	2.75
250	.018″	32	2 3/4″	STH 250	3.00
300	.018″	39	2 3/4″	STH 300	3.25
335	.018″	43	2 3/4″	STH 335	3.50
Split-Stator Double Bearing Models					
50–50	.026″	11–11	2 3/4″	STD 50	3.50
100–100	.018″	14–14	2 3/4″	STHD 100	4.50

SE 270° Straight-Line-Frequency

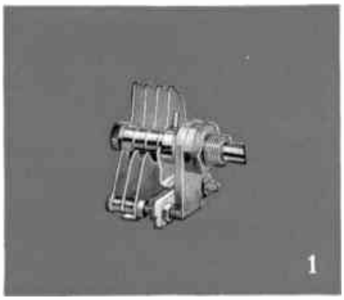
The well known Type SE Midget Condenser has 270° Straight-Line-Frequency plates. The plates and frame are of aluminum. Insulation is Steatite. The rotor has two bearings in all models, the front bearing being insulated to prevent noise from ground currents in the frame. The rotor contact is through a quiet constant impedance pigtail.

The SEU-15, SEU-20 and SEU-25 condensers have thick plates with rounded and polished edges, and are suitable for high voltages. The SEU-25 is illustrated below. The other SE models do not have polished edges on the plates.



Cap	Air Gap	No. Plates	Length	Cat. No.	List Price
15	.055″	6	2 1/4″	SEU 15	$2.50
20	.055″	7	2 1/4″	SEU 20	2.75
25	.055″	9	2 1/4″	SEU 25	2.75
50	.026″	11	2 1/4″	SE 50	3.00
75	.026″	15	2 1/4″	SE 75	3.25
100	.026″	20	2 1/4″	SE 100	3.50
150	.026″	29	2 3/4″	SE 150	3.75
200	.018″	27	2 1/4″	SEH 200	3.75
250	.018″	32	2 3/4″	SEH 250	4.00
300	.018″	39	2 3/4″	SEH 300	4.00
335	.018″	43	2 3/4″	SEH 335	4.25

NATIONAL *Special Purpose* CONDENSERS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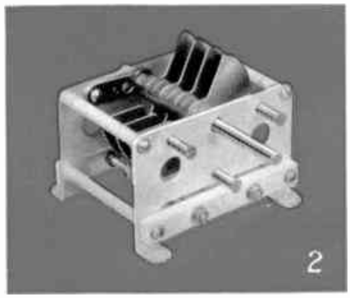
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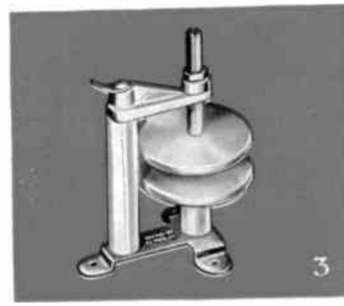
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NEUTRALIZING CONDENSERS

STN (Fig. 1) A compact, rigid, and efficient condenser particularly suitable for neutralizing 245, 247, 210 and similar tubes in amplifier, buffer or doubler stages. Very low minimum capacity. Isolantite insulation. Maximum capacity 18 mmf. Peak voltage breakdown — 3000v. **List Price, $2.00**

TCN (Fig. 2) A heavy duty neutralizing condenser having a peak voltage rating of 6000 volts. Suitable for use with 203A, 852, 204A and similar tubes. Maximum capacity 25 mmf. **List Price, $3.50**

NC 800 (Fig. 3) A high voltage neutralizing condenser. Particularly suitable for use with the RCA-800. Both plates are insulated from ground on Isolantite pillars. **List Price, $3.00**

PADDING CONDENSERS


7

National Air-Dielectric Padding Condensers (Fig. 4) are extremely compact, and have very low temperature coefficient. The aluminum shield is 1¼" dia. by 1¼"–1½" high.

A very small mica Padding Condenser (Fig. 7) is also available, mounted on Steatite and designed to be supported by circuit wiring. Maximum Capacity is 30 mmf., and overall dimensions are 13/16" long x 9/16" wide, x 1/2" high.

W75	(75 Mmf. Air)	**List Price $2.25**
W100	(100 Mmf. Air)	**List Price 2.50**
M30	(30 Mmf. Mica)	**List Price .35**

GENERAL PURPOSE

EMC (Fig. 5.) National EMC Condensers have high electrical efficiency, and calibrations may be relied on. Insulation is Isolantite, and Peak Voltage Rating is 1000 volts. Plate Shape is SLW.

Capacity	*No. of Plates*	*Cat. Symbol*	*List Price*
150	9	EMC 150	**$3.00**
250	14	EMC 250	**3.50**
350	18	EMC 350	**3.75**
500	26	EMC 500	**4.00**
1000	56	EMC 1000	**6.50**
Split-Stator Models			
350–350	18–18	EMCD–350	**6.75**

FREQUENCY METER CONDENSER

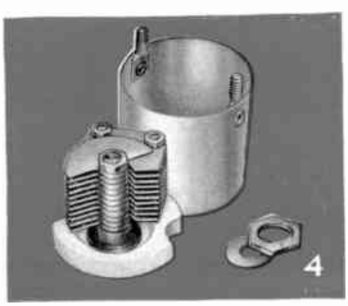
A special purpose condenser designed for amateur frequency meters and monitors. On the 80 or 160 meter bands the special rotor provides a spread of 80 divisions (on a 100 division dial). Minimum Capacity is 40 mmf., Maximum 75 mmf. Not illustrated, but same frame as EM.

Type 40-75 **List Price $5.50**

I.F. TRANSFORMERS

In the better H.F. Receivers, it has become standard practice to tune I.F. Transformers with air condensers. National units (Fig. 6) employ Steatite Insulation, Aluminum Plates, and Litz-wound Coils. Adjustments are on top of shield, knob tuning on Oscillators. Two models, 450–550 K.C. or 175 K.C.

List Price, Transformers or Oscillators, $5.00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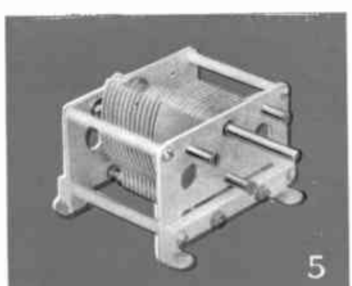
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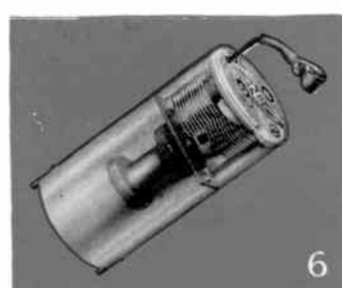

6

PARTS

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, $.75

R-152 and R-154. These two universal transmitter chokes have windings of the honeycomb type, divided in five sections, and are rated to carry 0.6 amperes continuously. Inductance 4 m.h., D.C. resistance 10 ohms. The R-152 is designed to give maximum impedance in the 160 meter band, and the R-154 in the 40 meter band.
R-152 or R-154. **List Price, $2.25**

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

CLASS B TRANSFORMERS

CLASS B INPUT TRANSFORMER. Designed for coupling two 45's in push-pull to a pair of 210's or 46's working Class B. The transformer has excellent frequency characteristics. Primary Inductance, 20 henries. Primary Resistance (total), 150 ohms. Secondary Resistance (total), 200 ohms.
Type BI. **List Price, $6.50**

CLASS B OUTPUT TRANSFORMER. Designed for coupling a Class B amplifier employing 210's or 46's to various load impedances. The secondary is not designed to carry R.F. amplifier plate current. Insulated for 5000 volts. Primary Inductance, 20 henries. Primary Resistance (total), 115 ohms.
Type BO. **List Price, $8.50**

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, $5.50**

STANDARD CABINETS

National Receiver cabinets for use in constructing special equipment are illustrated above. Left to right, are the cabinets regularly used for the SRR and FB-7 receivers, the PSK Preselector, and the SW-3 receiver. Available plain or with panels and sub-bases punched for standard assemblies. List prices include sub-base and bottom cover:

Type C-SRR	**$3.50**	Type C-PSK	**$6.00**
Type C-FB7	**$7.00**	Type C-SW3	**$5.50**

HRO KNOB

This large knob, 2⅜" in diameter, is standard equipment on the HRO. It is equipped with a hub to take ¼" shafts.
Symbol HRK. **List Price, $.85**

TUBE AND COIL SHIELDS

Aluminum shields for experimental and custom set work.

Catalog Symbol	List Price
HRO Coil Shield, Rectangular in cross-section (1 13/16" x 2⅜") and 4⅛" high. UM Condensers will fit in top of this can	**$.35**
J30 Coil Shield, 2½" dia., 3¾" high—square flange at bottom 2¾"	**.35**
B30 Coil Shield, 3" dia., 3¾" high	**.35**
B30 Coil Shield, as above with mounting base	**.50**
TS Tube Shield with Top Cap and Bottom Mounting Plate	**.40**
T58 Tube Shield with Top Cap and Bottom Mounting Plate (For dome-top tubes such as the 57, 58, 77, 78, etc.)	**.40**
T78, Tube Shield with top cap and mount. This shield is a snug fit on tubes such as the 57, 58, 77, 78, etc. and will not accommodate larger tubes	**.30**

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 flashlight cells in the case provide filament and plate current.
Type CPO, without battery or tubes. **List Price, $6.00**

NATIONAL COMPANY, INC., MALDEN, MASS.

LOW-LOSS COIL FORMS

TRANSMITTER COIL FORMS. In addition to the three low-loss Steatite coil forms listed below, National offers two low-price forms for use where high efficiency is not essential. Though not comparable to Steatite, these less expensive forms are not to be confused with ordinary porcelain forms.

XR-10, Steatite, 20 or 40 meter. **List Price, $3.75**

XR-11, Steatite, 80 meter. **List Price, $6.50**

XR-12, Steatite, 160 meter. **List Price, $8.00**

XR-10A, Low-Loss Ceramic, same dimensions as XR-10. **List Price, $1.50**

XR-12A, Low-Loss Ceramic, same dimensions as XR-12. **List Price, $2.25**

RECEIVER COIL FORM. These well-known R-39 forms are machinable, permitting the experimenter to groove and drill them to suit individual requirements. They are available in 4-, 5- and 6-prong types, and plug into the sockets shown on this page. Length, 2¼". Dia. 1½".
XR-4, XR-5, or XR-6. **List Price, $.75**

RECEIVER COIL FORM. Smaller in size than the R-39 forms listed above and made of Steatite, these forms are drilled for leads and left unglazed to provide a tooth for coil dope. They have 4, 5 or 6 prongs.
Type XR-20. **List Price, $.35**

PLUG-IN COIL FORMS. These R-39 coil forms, originally used in the FB-7, are designed for plugging-in through the front panel of a receiver, monitor, etc. A padding condenser mounts inside the coil, and a special bakelite sleeve protects the winding. 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**

COIL FORM. This Steatite Choke Coil Form is ideally suited for small choke coils and precision resistors. The winding is divided in four sections by partitions. A slot is provided for leading the wire from section, and to the terminals.
Type XT-8. **List Price, $.50**

GRID GRIPS. This convenient little Grid-Grip is the most simple method of attaching a wire to the metal top-cap terminal of multi-element tubes. Easy to operate, never works loose, makes continuous electrical contact. Eliminates possibility of loosening cap on tube when removing lead. Made in three sizes.

Type 24 — to fit broadcast set tubes. **List Price, $.05**
Type 12 — to fit large type tubes. **List Price, $.10**
Type 8 — to fit metal tubes. **List Price, $.05**

NATIONAL COIL DOPE

National Coil Dope is a special Victron base R.F. lacquer, specially prepared to give low power factor. It may be used as a cement for holding windings in position without spoiling the low-loss features of the coil support. It provides a tough, protective film, seals surface pores, and gives a moisture-repellent surface. The Coil Dope is applied with a brush, and dries in air without baking.
Per can. **List Price, $1.50**

NATIONAL VICTRON

A synthetic material, possesses almost incredible electrical properties. Its Loss Factor (0.2) is one-eighth that of "Low Loss" Hard Rubber, and one-ninetieth that of the usual R.F. Insulators. Its Power Factor is .06%–.08%, compared to .09%–.20% for Steatite. In color it is a transparent amber. It may be readily drilled or sawed. Being non-hydroscopic, it is suitable for outdoor use. Its Tensile Strength is about 6,500 lbs. per sq. in.
Standard sheets are 6" x 12".
Victron, 3/16" thick, per sheet, **List Price, $6.00**
Victron, 1/8" thick, per sheet, **List Price, $5.00**

VICTRON IN SMALL SHEETS. Because Victron is usually used in small quantities in experimental work, we are now listing quarter-size sheets, 3" x 6" approximately.
Victron 3/16" thick, per sheet, **List Price, $1.50**
Victron 1/8" thick, per sheet, **List Price, $1.25**

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 K.C. with .00041 Mfd.
Type OSR. **List Price, $1.50**

MIDGET COIL FORM. Made of low-loss R-39, these small coil forms are designed with excellent form factor, contributing to high efficiency in H. F. circuits. Diameter, 1"; Length, 1½"; Wall thickness, 1/16". They are available with 4 prongs, or plain.
Tyoe XR-1, four prongs. **List Price, $.50**
Type XR-2, without prongs. **List Price, $.35**

NATIONAL COMPANY, INC., MALDEN, MASS.

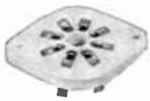
PARTS

LOW-LOSS SOCKETS

RECEIVING SOCKETS. National Receiving Sockets are available in either Isolantite or Steatite, to fit all standard receiving tubes. The special coil sockets for National 6-pin coils are square with four mounting holes. Tube sockets are as illustrated.

Tube Sockets, all models. **List Price, $.60**
Square Coil Sockets. **List Price, $.75**

OCTAL SOCKETS



A new low loss socket designed to fit metal tubes.
Type XC-8. **List Price, $.60**

ACORN TUBE SOCKETS

Two low-loss sockets to fit acorn tubes are available. One is designed primarily for the triode and has the five contact clips mounted on Isolantite. The other model has an aluminum base with all contacts directly by-passed to ground. On both models the socket contacts are of a new design providing very short leads and having a current path nearly independent of tube position.

Isolantite base, for triodes. Type XCA. **List Price, $1.50**
Aluminum base, for pentodes.
Type XMA. **List Price, $1.50**

POWER PENTODE SOCKET

For the new RK-28 and RCA-803 power pentodes, this big JX-100 wafer-type socket is available. Triangular in shape for rigid three point mounting, Isolantite insulated, and equipped with rugged side-wipe contacts, it is as modern as the tubes it serves.

Type JX-100S, as illustrated. **List Price, $3.60**
As above but without stand-off insulators.
Type JX-100. **List Price, $3.00**

50 WATT SOCKET. National offers two fifty watt sockets. The model illustrated above is all Steatite, providing safety from arc-over as well as low losses. The contacts themselves are the only metal in the assembly. Illustrated below is the newer metal shell socket for use where voltages and frequency are not high enough to warrant the more expensive model. Both sockets employ sturdy side-wipe contacts.

Type XC-50, all Steatite.
List Price, $3.50
Type XM-50, metal shell
List Price, $2.00

SHAFT COUPLINGS

The small coupling illustrated at the left has Steatite insulation, providing high electrical efficiency when used to isolate circuits.
Type TX-9. **List Price, $1.00**

The small coupling illustrated at the right is well known and liked for its small size and freedom from backlash. Insulation is canvas bakelite.
Type TX-10. **List Price, $.55**

FLEXIBLE SHAFT COUPLING

This new and extremely useful coupling combines Isolantite insulation with a short length of flexible shafting. It provides a driving means between offset shafts, or shafts at any angle up to 90 degrees. It virtually eliminates alignment problems. The shafting is of the highest quality (not speedometer cable), reducing backlash to an almost imperceptible amount. It is not recommended for high precision drives however. It is available with plain hubs without insulation, as well as with the Isolantite insulation illustrated above. Hubs take 1/4 inch shaft.

Type TX-12. **List Price, as illustrated, $1.25**
Type TX-11. **List Price, plain hubs, $.60**

HIGH VOLTAGE COUPLING

This coupling provides high insulation with compact size. The insulation is glazed Isolantite. TX-1 has a leakage path of 1", and TX-2 a leakage path of 2½".

Type TX-1. **List Price, $1.00**
Type TX-2. **List Price, $1.10**

CRYSTAL HOLDER

The National Crystal Holder mounts the crystal in a vertical position which permits it to vibrate freely. Crystals may be changed very readily. The cover is of metal and is used for protection and shielding only. The body of the holder is molded R-39, and has two prongs on the base for connections.

Resonator Type CHR, without crystal. **List Price, $2.50**
Transmitting Type CHT, without crystal.
List Price, $2.50

NATIONAL COMPANY, INC., MALDEN, MASS.

GADGETS

FIG 1

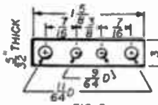


FIG 2

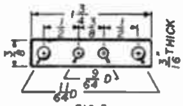


FIG 3

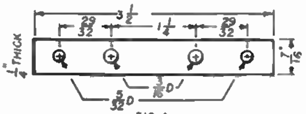


FIG 4

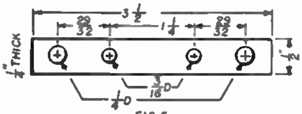


FIG 5

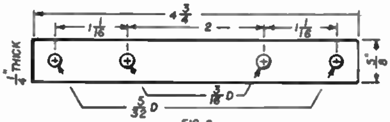


FIG 6

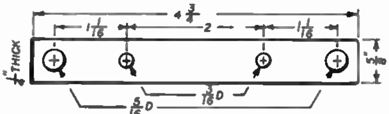
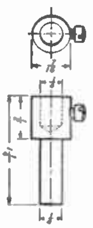
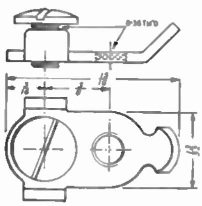


FIG 7

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.

	List Price
Fig. 1.	$.30
Fig. 2. (Fits ST Condenser), each	.15
Fig. 3. (Fits SE Condenser), each	.15
Fig. 4. (Fits TMC Condenser), each	.30
Fig. 5. (Fits TMC Condenser), each	.30
Fig. 6. (Fits TMA Condenser), each	.40
Fig. 7. (Fits TMA Condenser), each	.40





SHAFT EXTENSION. **List Price $.25**
SCREW LUG. **List Price $.15**

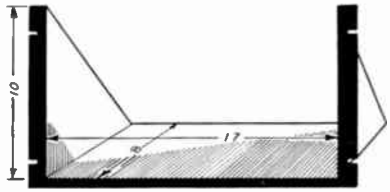


FIG. 10

RELAY RACK SHELF: This recessed shelf will fit any standard relay rack, and is particularly useful for supporting portable equipment, instruments, test equipment, etc. **List Price $4.00**

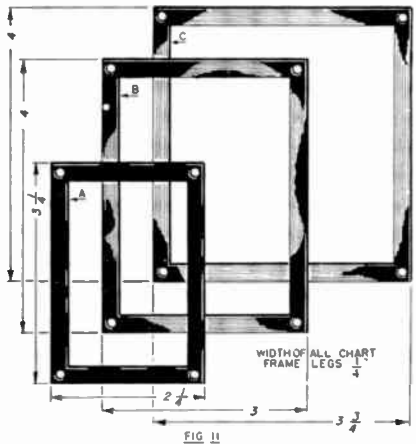


FIG 11

COIL CHART FRAMES: Nickel Silver Chart Frames are available in the sizes shown above. 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**

"AUDIO GAIN" Calibrated 0 to 10, for 310° rotation

"R.F. GAIN" Calibrated 0 to 10, for 300° rotation.

"C.W. OSC." Calibrated 0 to 10 over 180° rotation, **"OFF"** position beyond "0".

"PHASING" Calibrated 0 to 10 for 180° rotation.

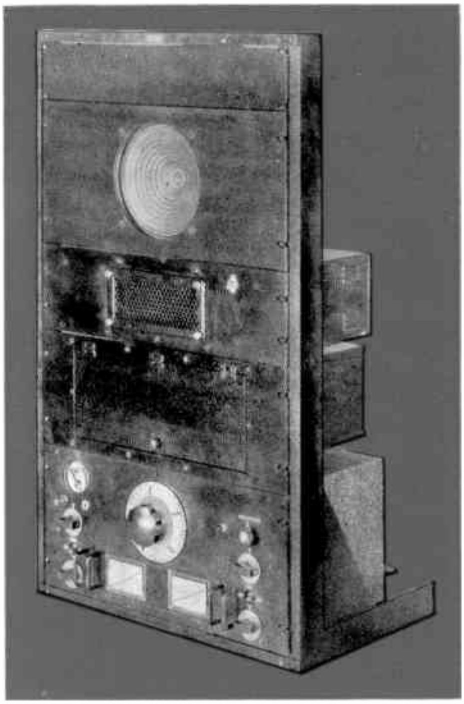
FIG. 12

HRO DIALS: Small Nickel Silver control dials, with knob attached, are available. These dials are used on the HRO, and all fit a ¼" shaft. They are available in four styles, with the above markings.

List Price, any type, $.75

NATIONAL COMPANY, INC., MALDEN, MASS.

NATIONAL RELAY RACKS & INSULATORS



RELAY RACK UNITS

At the left is illustrated a convenient Relay Rack assembly featuring the HRO. A brief description of the other units follows: *(The units are described in order, starting at the bottom of the rack.)*

1. The rack illustrated is the small National Bench-type rack, which will receive all standard panels up to its capacity, Type LRR. *Shipping wt. 28 lbs.* **List Price, $22.50**

2. HRO Receiver, see pages 12 and 13.

3. Coil Rack. A convenient storage space for HRO coils, equipped with a hinged door. Type HCRP. *Shipping wt. approx. 15 lbs.* **List Price, $27.50**

4. Rack mounted packs either single or double, and for either 2½ volt or 6 volt tubes.
Type GRSPU, single. *Shipping wt. 39 lbs.* **List Price, $49.50**
Type GRDPU, double. *Shipping wt. 48 lbs.* **List Price, $79.50**

5. This Monitor Speaker Panel employs a dynamic speaker of the permanent magnet type, requiring no power supply. The speaker is mounted on a standard panel (8¾" x 19") and is provided with an impedance matching transformer and connecting cord.
Monitor Speaker Panel, Type RFS. **List Price, $30.00**

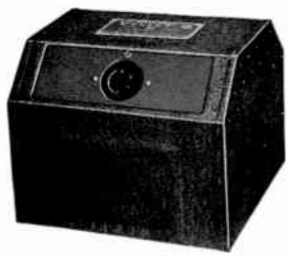
6. Blank Panels, finished in leatherette enamel and made of 3/16" aluminum are available at the following prices:

1¾" wide	**List Price, $3.25**
3½" wide	**List Price, 4.50**
5¼" wide	**List Price, 5.75**
7" wide	**List Price, 7.00**
8¾" wide	**List Price, 8.25**
10½" wide	**List Price, 9.50**

STANDARD RELAY RACKS

This six foot rack, built to Government Specifications and drilled and tapped to receive standard panels of all sizes, is of steel, finished in black gloss Duco. Relay Rack, Type RR. **List Price, $65.00**

POWER UNITS



National Power Units have exceedingly low inherent hum. They employ a double section filter using large chokes and ample condenser capacity. An electrostatically shielded transformer and a special R.F. filter are among the factors resulting in the complete elimination of so-called "tunable hums."

Power units for National Receivers are equipped with a receptacle for plugging in the power cable from the set, and filament windings are designed to compensate for voltage drop in the power cable, giving correct voltage at the socket terminals. Receiver packs are listed below.

Type 5897. HRO or FB-7 Receivers.................. **List Price, $26.50**
Type 5886. SRR or 1–10 Receivers.................. **List Price, $26.50**
Type 5880. SW-3 Receiver........................ **List Price, $26.50**

A general purpose power unit is also available providing 35 MA. at 180 volts, and also three adjustable taps 22–45 V, 45–90 V, and 90–135 V.

Type 3580.................................... **List Price, $16.50**

Above Prices do not include Rectifier tube. Shipping wgt. 17 lbs.

NATIONAL COMPANY, INC., MALDEN, MASS.

NATIONAL *High Frequency* RECEIVERS

THE HRO

The HRO is a 9 tube communication-type superheterodyne for amateur use providing extreme band-spread on amateur bands as well as a continuous frequency coverage from 500 K.C. to 30 M.C. An additional range 175–400 K.C. is also available. Two stages of preselection are used. A booklet describing the HRO will be mailed on request.

THE NC-100

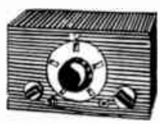
The NC-100 is particularly notable for its coil shifting mechanism. Turning a knob on the panel moves the desired coils to operating position and plugs them in. Six coil ranges provide continuous coverage from 500 K.C. to 30 M.C. approximately. The NC-100 is a superheterodyne with one stage of preselection. A descriptive booklet will be mailed on request.

THE FB-7

The well-known FB-7 receiver is a seven tube superheterodyne with optional single signal equipment. There is no preselection. Plug-in coils provide continuous coverage from 900 K.C. to 34 M.C. and additional coils are available for band spread on 10, 20, 40, 80 and 160 meter amateur bands. A descriptive booklet is available.

THE ONE-TEN

The Type 110 receiver is a new design covering the range from one to ten meters. It employs the special tuning unit described on page fourteen, and marks a definite advance in ultra-High Frequency design. A booklet is now in preparation.

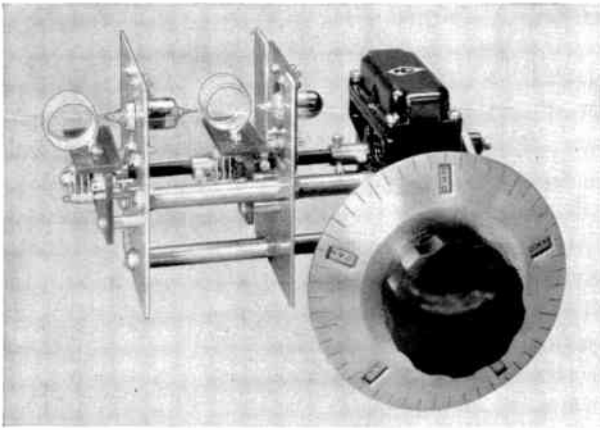


THE SW-3

This famous little receiver is still a favorite after many years. One RF stage, regenerative detector, and impedance coupled audio. Ask any amateur about it.

NATIONAL COMPANY, INC., MALDEN, MASS.

NATIONAL *Experimental* EQUIPMENT



ULTRA H.F. TUNING UNIT

This H.F. Tuning Unit, developed for the One-Ten receiver, is an ideal chassis for experimental work. It is suitable for superheterodyne or superregenerative circuits. The two-section Victron-Insulated condenser employs the PW dial and drive. Plug-in coils and acorn tubes are mounted directly above the stators, providing extremely short leads. Rotors are individually insulated, with very small capacity to ground. Standard capacity is 15 mmf. per section.

Type PWC, without acorn tubes or coils.
List Price, $23.50

CATHODE RAY OSCILLOSCOPE

Providing an instantaneous graphic picture of the actual operating conditions in transmitter circuits, the Cathode Ray Oscilloscope gives important information not readily obtainable by other means. Percentage Modulation, Signal Distortion and Peak Voltages, for instance, are indicated directly.

The Cathode Ray Tube is the 3-inch diameter RCA-906. No linear sweep device is provided, as it has been found more desirable to use an audio signal from the transmitter for this purpose.

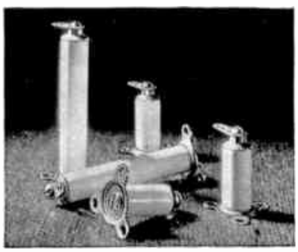
The unit is entirely self-contained, the power supply and control devices being built-in.

Tubes required: One RCA-906 and one 80.

A booklet describing the Cathode Ray Oscilloscope will be mailed on request.

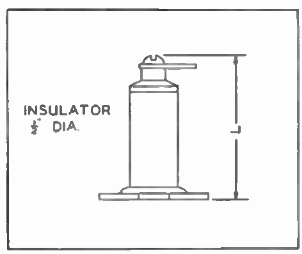
Type CRO Cathode Ray Oscilloscope, without tubes. **List Price, $29.50**

Shipping weight 23 pounds



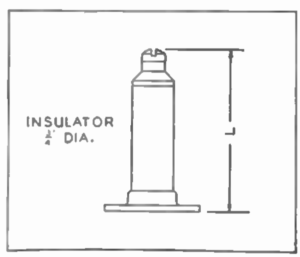
STAND-OFF INSULATOR. This well-known little insulator is now offered in two lengths. Long and slender, the larger model is shaped for extreme electrical efficiency. It is an excellent core for H.F. solenoid chokes. (Isolantite)

Type GS-1 (L = 1⅜") . . . **List Price, $ .25**
Type GS-2 (L = 2⅞") . . . **List Price, $ .35**



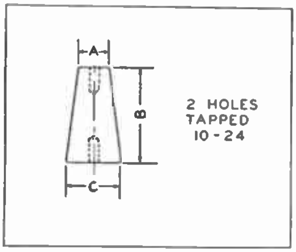
STAND-OFF INSULATOR. Metal mounted like the smaller units, these heavy Isolantite stand-offs combine electrical efficiency with strength and convenience. The insulator is ¾" diameter and is available in two lengths.

Type GS-3 (L = 2⅞") . . . **List Price, $ .80**
Type GS-4 (L = 4⅞") . . . **List Price, $1.00**



NATIONAL COMPANY, INC., MALDEN, MASS.

H. F. DIELECTRICS

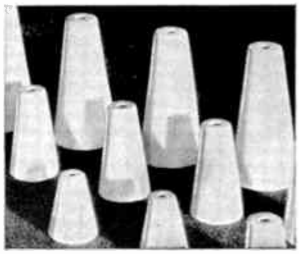


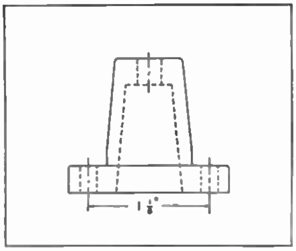
STAND-OFF INSULATOR. This popular style of insulator is offered in three sizes, all of low-loss Steatite. The smallest model is tapped 8-32 each end, the larger 10-24.

Type GS-5 (A=½", B=1¼", C=1")............. **List Price, $ .25**

Type GS-6 (A=⅝", B=2", C=1⅛")........... **List Price, $ .35**

Type GS-7 (A=¾", B=3", C=1½")........... **List Price, $ .65**

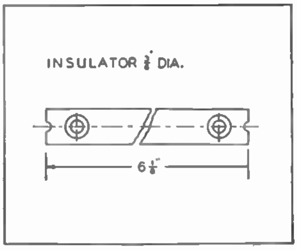




STAND-OFF INSULATOR. Another small insulator suitable for a variety of applications. Being made of Steatite, it is eminently suited for Low Loss H.F. circuits. It is available in a special model with a jack for mounting plug-in inductances.

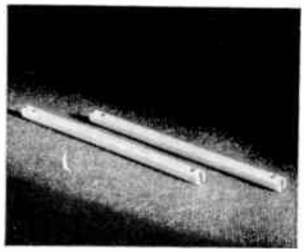
GS-8.................. **List Price, $ .25**

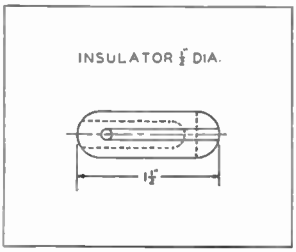
GS-9 (with jack)........ **List Price, $ .35**



SPREADER. Conventional in design, unusual in efficiency, these Steatite spreaders will more than justify their slight extra cost. They are at present available only in the six inch length.

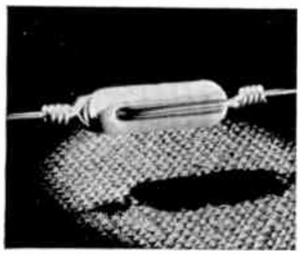
Type AA-3............ **List Price, $ .30**

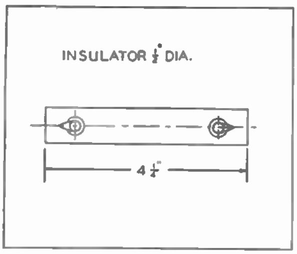




STRAIN INSULATOR. This aircraft-type insulator, in spite of its short leakage path, has a variety of uses in small portable, mobile and police installations. Being loaded in compression, the insulator provides great mechanical strength.

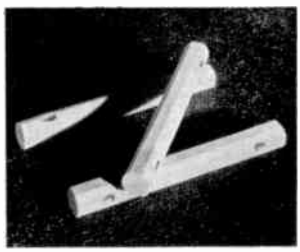
Type AA-5............ **List Price, $ .20**





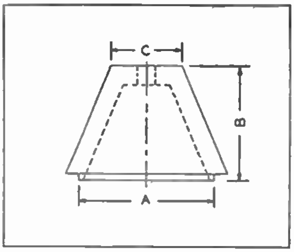
ANTENNA INSULATOR. This insulator is particularly suited for general use by the amateur. Its length provides ample leakage path, while its cross-section provides ample strength for all but the heaviest loads. The use of Steatite assures excellent electrical performance.

Type AA-6............ **List Price, $ .25**



NATIONAL COMPANY, INC., MALDEN, MASS.

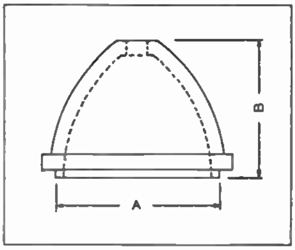
H. F. DIELECTRICS



H.F. BUSHING. This small Steatite bushing has a variety of uses in transmitter construction, not only as a neat and efficient means of bringing H.F. leads through partitions, but as a support for coils, etc. Each pair of cones includes suitable metal fittings.

Type XS-1 (A=1", B=1 1/16")
per pair............. **List Price, $ .60**

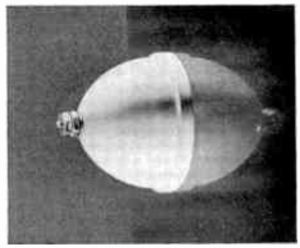
Type XS-2 (A=1½", B=1 3/16")
per pair............. **List Price, $ .80**

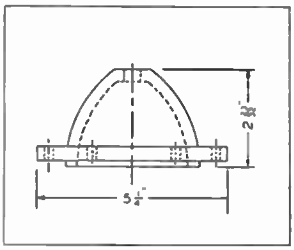


H.F. BUSHING. Larger in size than the bushings described above, and shaped to conform to the lines of electrical stress, these Steatite insulators are suitable for higher H.F. voltages. Prices are per pair, with metal fittings.

Type XS-3 (A=2¾", B=2 5/16")
List Price, $ 3.30

Type XS-4 (A=3¾", B=2 25/32")
List Price, $ 6.00

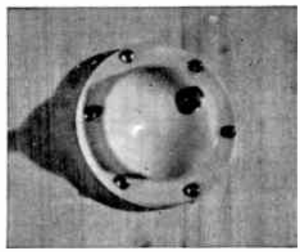


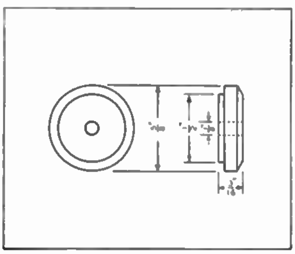


H.F. BUSHING. A heavy bowl-type lead-in, suitable for large transmitters, this Steatite insulator provides a weatherproof joint for antenna lead-in purposes. Leakage Path 3¼".

Type XS-5 each........ **List Price, $ 7.50**

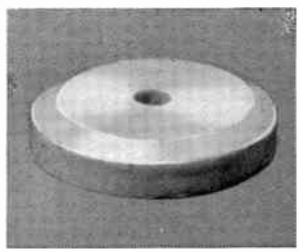
Type XS-5, with fittings, per pair
List Price, $15.50

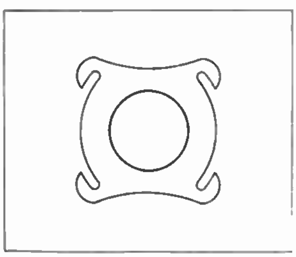




H.F. BUSHING. A small, inexpensive Steatite bushing that has a variety of uses in H.F. Transmitters. Convenient as well as efficient, they give a professional appearance to amateur equipment.

Type XS-6........ **List Price, each, $ .10**

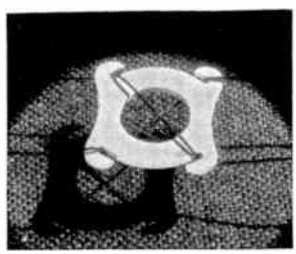




TRANSPOSITION BLOCK. In addition to the popular AA-1 Victron Block, National now offers a smaller Steatite Block. Both are light in weight, both are highly efficient. The Victron Block AA-1 separates feeders 1½", the Steatite Block, AA-2, provides 1" separation.

Type AA-1........... **List Price, $ .35**

Type AA-2........... **List Price, $ .20**



NATIONAL **COMPANY**
61 SHERMAN STREET **MALDEN, MASS.**

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EQUIPMENT designed and engineered in the foremost radio laboratories of the world. When you buy RCA, you buy with the assurance that you are getting the benefits of the experience of the greatest group of radio engineers.

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AMATEUR RADIO SECTION

RCA Manufacturing Co., Inc., Camden, N. J., *A subsidiary of the*

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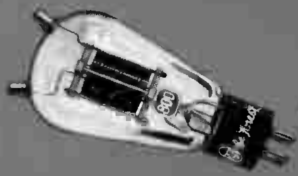
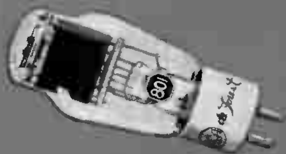


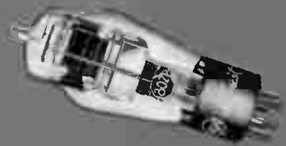
RCA 800

RCA-800—triode—35 watts plate dissipation; useful as buffer, doubler or final amplifier; full rating to 60 megacycles; operated with reduced input up to 200 megacycles; two RCA-800's in Class B will deliver 100 watts of audio power.



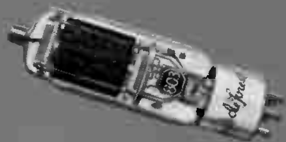
RCA 801

RCA-801—triode—rugged, heavy-duty, graphite-anode type similar to type 10. Useful as buffer, doubler or amplifier also good in Class B modulators; full ratings up to 60 megacycles makes this tube particularly good for 5-meter transmitters.



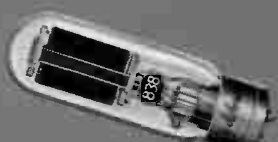
RCA 802

RCA-802—pentode—a low-powered tube having many applications; superior to types 46, 47 and 59 as a crystal oscillator, buffer or doubler. The RCA-802 can also be suppressor modulated for 'phone work; generally requires no neutralization.



RCA 803

RCA-803—pentode—a rugged, graphite-anode high-power tube suitable for suppressor modulated applications; capable of 50 watts carrier output suppressor or grid modulated, 200 watts as Class C amplifier in telegraphic service; generally requires no neutralization.

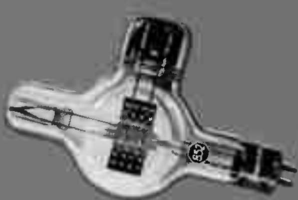


RCA 838

RCA-838—triode—a new type similar in ratings to RCA-203-A and 211, but designed for zero-bias operation in Class B modulators; two 838's in Class B will deliver 260 watts of audio power; very useful in r-f applications since less bias than for other types is required.

RCA 841

RCA-841—triode—an economical tube to use as buffer or doubler; having a high-mu this type requires low bias; easily driven; may also be used as a-f amplifier.

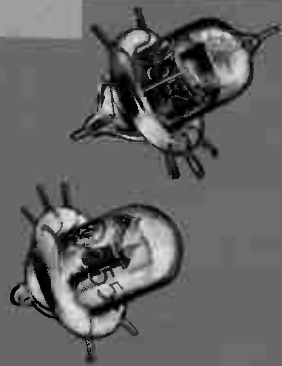


RCA 852

RCA-852—triode—the stand-by for high-power, high-frequency applications; may be operated at frequencies up to 150 megacycles; may be used as Class B modulator; in Class C telegraphic service an RCA-852 will deliver 165 watts output.

RCA RADIOTRON

SPECIAL TUBES



RCA 954-955

RCA-954—pentode; 955—triode—acorn type—the first tubes commercially available for ultra-high frequency applications. Capable of operation at frequencies up to 450 and 750 megacycles respectively, these tubes are indispensible to the ultra-high frequency experimenter for receiver design.

RCA-866—rectifier—a rugged, high-voltage rectifier built to exacting commercial standards. Every station needs these tubes in the high-voltage power supply.

RCA-906—Cathode-Ray Tube—The first tube of its type commercially available. Cathode-ray tubes find almost unlimited applications in the radio station; as modulation indicators they permit adjustments hitherto unattainable.

OTHER RCA POWER AND SPECIAL TUBES

Type	Description	Electrodes	Max. Plate Dissipation Watts	Cathode Type	Cathode Volts
203-A	R-F Power Amplifier, Oscillator, Class B Modulator	3	100	Filament	10.0
204-A	Oscillator, R-F Power Amplifier, Class B Modulator	3	250	Filament	11.0
211	R-F Power Amplifier, Oscillator, A-F Power Amplifier, Modulator	3	100	Filament	10.0
831	Oscillator, R-F Power Amplifier	3	400	Filament	11.0
840	R-F Pentode	5	—	Filament	2.0
842	A-F Power Amplifier, Modulator	3	15	Filament	7.5
843	Power Amplifier, Oscillator	3	15	Heater	2.5
844	Screen-Grid R-F Power Amplifier	4	15	Heater	2.5
845	Modulator, A-F Power Amplifier	3	75	Filament	10.0
849	Modulator, A-F and R-F Power Amplifier, Oscillator	3	400	Filament	11.0
850	Screen-Grid R-F Power Amplifier	4	100	Filament	10.0
851	Modulator, A-F and R-F Power Amplifier, Oscillator	3	750	Filament	11.0
860	Screen-Grid R-F Power Amplifier	4	100	Filament	10.0
861	Screen-Grid R-F Power Amplifier	4	400	Filament	11.0
864	Amplifier (Low Microphonic Design)	3	—	Filament	1.1
865	Screen-Grid R-F Power Amplifier	4	15	Filament	7.5
868	Phototube	2	—	—	—
918	Phototube (High Sensitivity)	2	—	—	—

RECTIFIERS

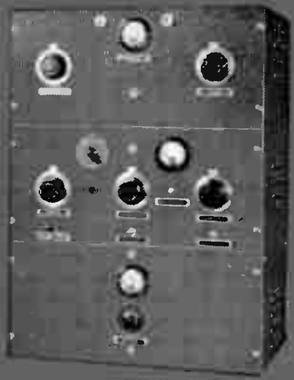
Type	Description	Electrodes	Max. Peak Inverse Volts	Cathode Type	Cathode Volts
217-A	Half-Wave, High-Vacuum	2	3,500	Filament	10.0
217-C	Half-Wave, High-Vacuum	2	7,500	Filament	10.0
866-A	Half-Wave, Mercury-Vapor	2	10,000	Filament	2.5
872	Half-Wave, Mercury-Vapor	2	7,500	Filament	5.0
872-A	Half-Wave, Mercury-Vapor	2	10,000	Filament	5.0
878	Half-Wave, High-Vacuum for Cathode-Ray Tubes	2	20,000	Filament	2.5
879	Half-Wave, High-Vacuum for Cathode-Ray Tubes	2	7,500	Filament	2.5
885	Gas-Triode for Cathode-Ray Sweep-Circuit Control	3	300	Heater	2.5

CATHODE-RAY TUBES

Type	Description	Electrodes	Max. Anode No. 2 Volts	Cathode Type	Cathode Volts
904	5 in., Electrostatic-Magnetic Deflection, High-Vacuum	5	4,600	Heater	2.5
905	5 in., Electrostatic Deflection, High-Vacuum	4	2,000	Heater	2.5
907	5 in., Electrostatic Deflection, High-Vacuum, Short Persistence Screen	4	2,000	Heater	2.5
908	3 in., Electrostatic Deflection, High-Vacuum, Short Persistence Screen	4	1,200	Heater	2.5

DIVISION

AMATEUR



ACT-40

ACT-200

ATR-219

ACT-40 (40-WATT PHONE AND C-W TRANSMITTER)

This highly efficient transmitter employs an RCA-47 as crystal oscillator, an RCA-802 as a buffer or doubler, and 2 RCA-801's as amplifiers. The modulator system employs an RCA-57, an RCA-56, 2 RCA-45's, and 2 RCA-801's. Transmitter may be purchased complete or unit by unit. Amateur net prices, f. o. b. factory are:

ACT-40 (Complete phone and c-w transmitter)	$235.00
ACT-40-A (Antenna Unit)	37.50
ACT-40-R (R-F Unit)	110.00
ACT-40-M (Modulator Unit)	84.50
ACT-40-C (Metal Cabinet)	20.75
Extra coils, per set	7.50

ACT-200 (200-WATT PHONE, 260-WATT C-W TRANSMITTER)

Using the same 40-watt exciter stage as is used in the ACT-40, this transmitter employs a pair of RCA-838's in the power amplifier. The modulator system is similar to that employed in the ACT-40 except that a pair of RCA-838's are used to modulate the RCA-838 Class C amplifiers. A high voltage power supply is included on a separate panel. The ACT-200 may be purchased complete or one unit at a time. Amateur net prices, f. o. b. factory are:

ACT-200 (Complete phone and c-w transmitter)	$475.00
ACT-200-A (Antenna Unit)	49.50
ACT-200-P (R-F Power Amplifier Unit)	99.50
ACT-200-M (Modulator Unit)	99.50
ACT-200-S (Power-Supply Unit)	96.50
ACT-200-C (Metal Cabinet)	34.50
Extra coils, per set	7.50

Note: The ACT-40 and ACT-200 are supplied with one set of coils for one amateur band. Coils are available for the 160, 80, 40, and 20 meter bands. Prices shown are less tubes, crystals, microphones, and all other accessories.

ATR-219 TRANSCEIVER

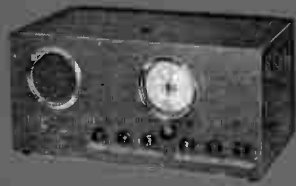
Employs an RCA-19 as a unity-coupled oscillator, another RCA-19 as a Class B modulator and an RCA-30 as a speech amplifier. Space is provided within the case for the necessary batteries. Amateur net price, less batteries, microphone, head-phones, tubes, etc., $19.95 f. o. b. factory.

RCA VICTOR

APPARATUS

ACR-136 AMATEUR COMMUNICATIONS RECEIVER

This well-known seven-tube superheterodyne receiver is typical of RCA values in amateur apparatus. Covering from 540 to 18,000 kilocycles, the ACR-136 possesses many outstanding features seldom found in a receiver in its price class. Comes complete with tubes, speaker, power supply, etc. Amateur net price, f. o. b. factory, $69.50.

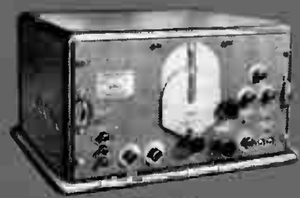


ACR-136

AR-60 COMMUNICATIONS RECEIVER

This receiver was designed to meet the exacting requirements of commercial operation. Ruggedly built to withstand hard commercial service, the AR-60 also has many outstanding technical features. It appeals to those amateurs who demand and can afford the best in apparatus. Available in three styles: rack mounting, table model, and de luxe table model. Amateur net prices, f. o. b. factory are:

AR-60-R (Rack mounting) . .	$475.00
AR-60-T (Table model) . . .	485.00
AR-60-S (De luxe finish) . . .	495.00



AR-60

TMV-135-A "V"-CUT CRYSTALS AND HOLDERS

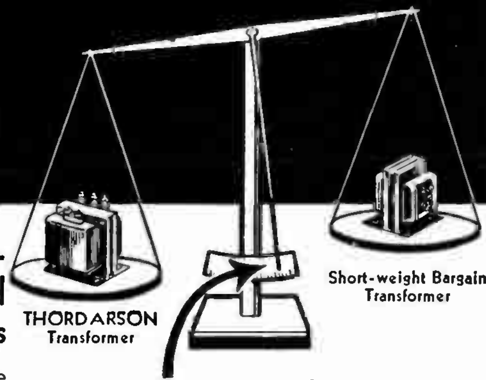
The RCA V-cut Crystal brings a new standard of excellence to the crystal art. Giving high output, the RCA V-cut Crystal is remarkable for its frequency stability. The temperature coefficient is only two cycles or less per million per degree centigrade. The TMV-135-A Crystal Holder is designed to secure maximum output from any crystal with maximum frequency stability. Amateur net prices, f. o. b. factory:

TMV-135-A V-cut Crystal and Holder .	$12.00
Holder alone	2.50

TMV-135-A

DIVISION

Short-weight Over-rated Transformers Are Costly *at any price!*



THORDARSON'S extra "factor-of-safety" assures full voltage and keeps down operating temperatures

● A transformer's rating is determined by the load it can carry at full voltage without overheating. The heat generated is due to the copper loss in the coil, and the core loss in the iron. Skimping on either copper or iron results in dangerously high temperatures and insulation burn-outs, not to mention poor voltage regulation and low efficiencies. Beware of transformer "bargains"! THORDARSON transformers are conservatively rated. Consequently, they develop full voltage and are exceptionally long-lived.

up to 38% more copper and iron in

THORDARSON TRANSFORMERS

Rating against rating, actual weight tests conclusively prove that THORDARSON transformers contain this extra "factor-of-safety." Play safe by using THORDARSONS.

THORDARSON AMATEUR TRANSFORMERS

Fig. 2S

—the most complete line on the market

There are 158 transmitting transformers in the THORDARSON line—a transformer for every application. Power transformers, audio transformers, and filter chokes for the latest tubes and the latest circuits. Write for catalog No. 343.

Plate Supply Transformers

THORDARSON plate transformers are of a special "AIR-COOLED" construction. Voltage regulation is especially good. Complete line includes 17 plate and 12 combination plate and filament transformers.

Fig. 2M

T-7041—the basis of a low-price power supply for medium power transmitters. 525 volts D. C. at 250 m.a., 15 lbs. Fig. 2L.

T-6411—1000 or 1250 volts D. C. through filter at 280 m.a. Primary voltage changing tap. 36 lbs. Fig. 2M.

T-6284—2000 v. D.C. at 500 m.a. Primary for 110 or 220 v. Secondary can be reduced 50% for testing by using 220-v. taps on 110 v. Wt. 71 lbs. Fig. 2S.

Fig. 2L

THORDARSON

THORDARSON engineers will gladl

THORDARSON

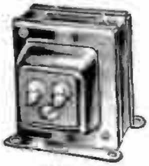


Fig. 2R

Filament Transformers

An enlarged line of single and multiple-secondary, as well as plate and filament units.

T-6433—for two 866 tubes. 2.5 volts at 10 amp. c.t. 7500-v. insulation. Fig. 2R.

T-6416—for 203A, 852, 845, etc., tubes. 10 volts at 6.5 amp. Has primary taps for 105, 110, 115 volts. Secondary c.t. 1600-v. ins. Fig. 2R.

Filter Chokes

Fig. 2J

Line includes swinging chokes designed to give exceptional supply voltage regulation and low resistance smoothing chokes.

T-6315—Input choke. Rated current 280 m.a. Inductance 12.3 to 19 henries. Fig. 2J.

T-6409—Smoothing choke. Inductance 19.7 henries at 150 m.a. D. C. resistance 275 ohms. Fig 2R.

Fig. 2A

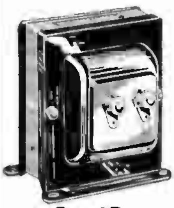


Fig. 2D

Class B Input Transformers

Designed to match the grid impedances of Class B tubes. Low resistance secondaries of ample current carrying capacity assure maximum undistorted output.

T-5289—for coupling a single 46 or 59 to Class B 46 or 59 grids. Shielded construction. Solder lugs. Fig. 2A.

T-7510—for coupling plates of push-pull 2A3's to 838 Class B grids. Shielded construction. Fig. 2D.

Class B and AB Output Transformers

Designed and constructed to reflect the proper load on output tubes. High insulation, ample copper and iron, and sturdy construction make these the choice of experienced operators.

Fig. 2Q

T-6426—for coupling Class B 46 or 59 tubes to 5000 or 10,000-ohm load. Max. sec. D.C., 100 m.a. Fig. 2D.

T-7861—to modulate both plate and screen of one RK20 with Class B 46's. Fig. 2Q.

These Transformers and 144 more are available at your THORDARSON distributors

Build a THORDARSON High Quality Speech Amplifier

with special foundation unit and standard THORDARSON transformers

- High fidelity
- Full power output
- 114.9 D.B. gain with crystal microphone
- Integral pre-amplifier
- Input for all mikes
- Rack or table mounting
- Build-it-yourself and save $20 to $40
- Available in 6, 18, and 30-watt sizes

The latest design speech amplifier developed by THORDARSON engineers, W9SGA and W9-UVP. Provides high fidelity amplification and high gain, with a low hum level. Realizes its full-rated power output without distortion.

All parts, including the Foundation Unit, drilled and ready for assembly with complete assembly instructions, can be obtained from your THORDARSON dealer.

Ask your THORDARSON dealer for Free Catalogs 219-220-224 or write

THORDARSON ELECTRIC MFG. CO.
500 W. Huron St., Dept. P. Chicago, Ill.

NEW 1936 THORDARSON TRANSFORMER MANUAL No. 340

including

TRANSMITTER GUIDE
SOUND AMPLIFIER MANUAL
SERVICEMEN'S GUIDE

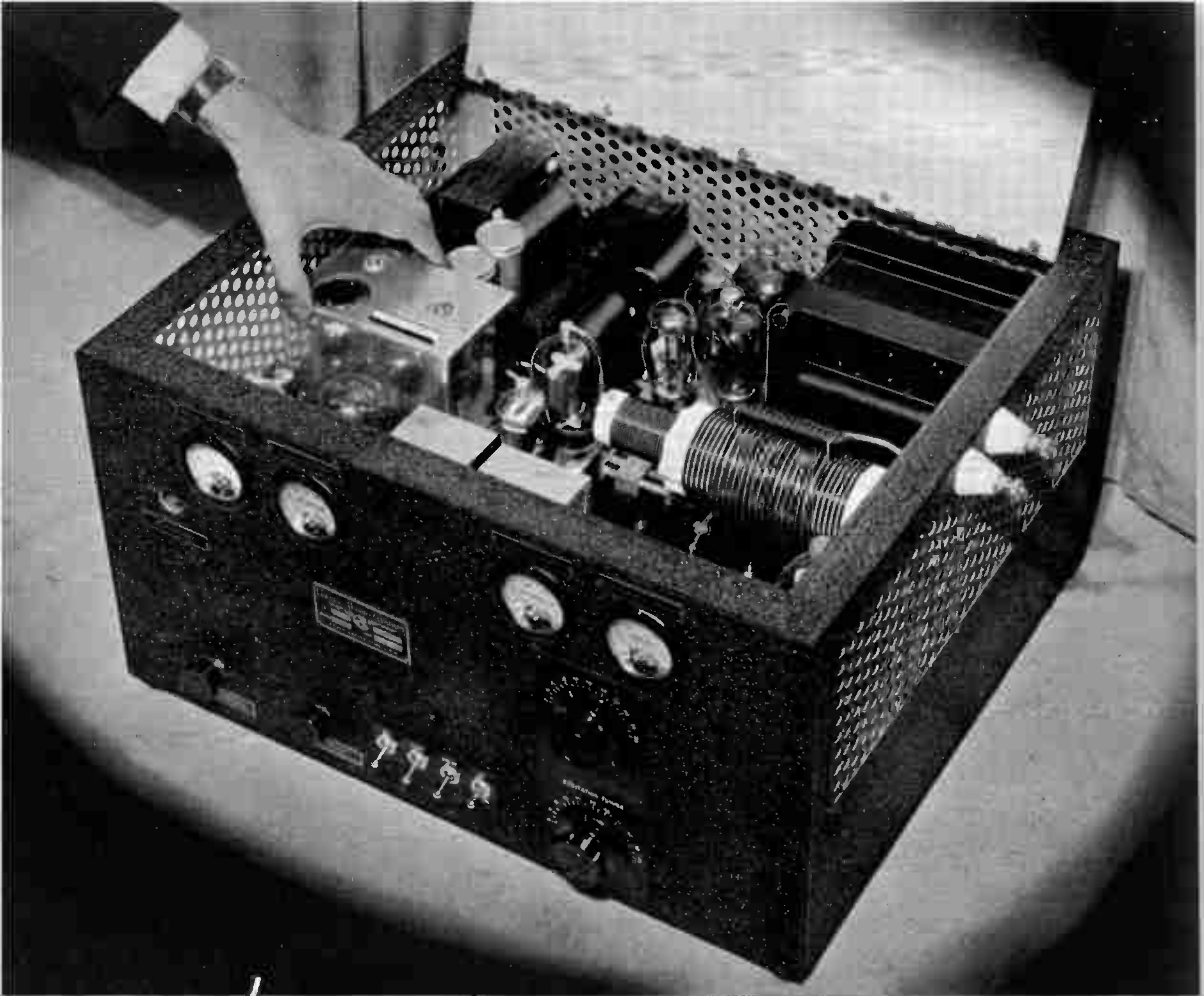
Send for NEW 32-page Transmitter Guide No. 344—new circuits, new tubes, new data—15¢ postpaid. New 32-page Sound Amplifier Manual No. 346, 15¢ postpaid. New 24-page Servicemen's Guide No. 342, 10¢ postpaid. Complete Transformer Manual in heavy cover No. 340, 50¢ postpaid.

FREE CATALOGS

#343—Transmitter Transformers.
#345—Amplifier Transformers.
#341—Replacement Transformers.

THORDARSON

elp solve your transformer problems



The *Accepted* Standard of Excellence

the 45A transmitter, a high-performance, low cost transmitter is illustrated above. The various COLLINS models and new developments are described currently in a technical bulletin and catalogue, the COLLINS SIGNAL. A post card will serve to place your name on the mailing list without obligation.

45A

Amateurs the world over know by experience that each COLLINS transmitter is not only a beautiful piece of apparatus, but also that its clever design and skillful construction result in greater output, clearer signals and more reliable operation.

There is no surer, less costly way to get real results, than to make a complete COLLINS installation.

Collins Radio Company

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Depend on BLILEY CRYSTALS *for Frequency Stability*

Bliley products have earned an enviable reputation because of their high quality, assured by the use of the best materials available, the employment of men skilled in their respective duties, and maintenance of rigid standards in every step of production.

All Bliley crystals are supplied mounted only, as experience has shown that a high degree of accuracy and dependability can be maintained only when crystals are tested and calibrated in the individual holders in which they will be used.

TYPE LD2 CRYSTAL UNIT

This new crystal unit operates with unbelievable efficiency due to the development of an entirely new crystal manufacturing principle. Temperature control equipment is not essential as the frequency drift is guaranteed to be less than 8 cycles/megacycle/°C, which is approximately ⅜ less than that of an X-cut.

Available for 40, 80, and 160 meter bands. Supplied to within 0.1% of your desired frequency, or choice from dealer's stock for only $4.80. Exact specified amateur frequencies can be supplied on special order for $9.50.

TYPE BC3 CRYSTAL UNIT

This is a special size X-cut power-size crystal mounted in an efficient molded bakelite holder and specifically designed for the amateur bands. The crystal is unusual in its ability to oscillate powerfully and to handle relatively large loads, a feature that is appreciated if accidental overloading should occur. Frequency drift is slightly under 23 cycles/megacycle/°C. Supplied for the 40, 80, or 160 meter bands.

Mc Band	Supplied to specified freq. within* 10 Kc	5 Kc	1 Kc	Exact F.
7.0, 3.5	$3.95	$4.90	$5.90	$7.50
1.7	4.80	5.80	6.80	8.40

*Or choice of dealer's stock.

STANDARD FREQUENCY CRYSTALS

A 100KC standard is the ideal frequency meter. A snap of the switch and the amateur bands are fully outlined and subdivided every 100KC. Easily built, it offers the progressive amateur dependable accuracy. It is also valuable for calibrating receivers, monitors, frequency meters and test oscillators. Only one tube is necessary. Instructions furnished with each unit. Completely mounted — type BC5 — $9.50. For greatest accuracy, it is supplied in the type BC6 oven for $16.50.

TYPE BC6 CRYSTAL OVEN

This scientifically designed constant temperature oven holds its temperature to within one degree Centigrade of any desired temperature between 40 °C. and 55 °C., provided the ambient temperature does not fall below 0 °C. Temperature adjustment is easily made by resetting the thermostat adjusting screw which is accessible through the side of the oven. Plugs into any standard 5 prong tube socket. Ideal for portable and aircraft installations. Rating 7.5 volts at ¾ amperes. Other ratings between 5 and 15 volts available at a small additional cost.

Price each $7.50

SINGLE SIGNAL FILTERS

The finest single signal receivers use BLILEY quartz filters. A precision product, scientifically designed and rigidly tested, it insures maximum efficiency. Supplied completely mounted in a durable low-loss molded bakelite holder for intermediate frequencies of 456, 465, 500 or 525KC.

Type BC3-SSF $5.90

BLILEY GENERAL COMMUNICATION FREQUENCY CRYSTAL UNITS are manufactured to exacting specifications between 20KC and 15MC. Quotations and technical recommendations will be gladly given upon receipt of a description of your requirements.

COMPLETE NEW BLILEY CATALOGUE giving full technical data on these and other Bliley crystals and mountings is now ready. Write for technical bulletin G-8.

All progressive distributors of Amoteur Equipment carry BLILEY CRYSTALS

BLILEY ELECTRIC CO., ERIE, PA.

MEMBER R.M.A.

NEW BURGESS PRODUCTS

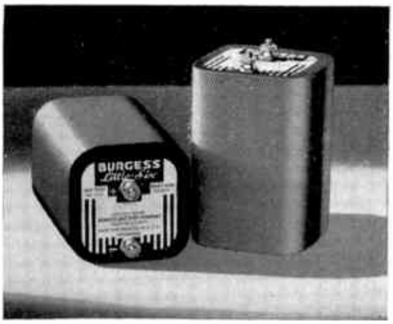
Of Particular Interest to Radio Amateurs

BURGESS RIBBON BATTERIES

An exclusive Burgess development in high voltage batteries in which numerous voltage taps and lightness in weight are the outstanding features. They may be spread, rolled or folded into various odd shapes. Are particularly adapted to portable applications for "B" power.

NO. Z30P "B" BATTERY

A small 45 volt "B" battery, specially suited for portable work. Made of penlite size cells containing a special high drain mix.



THE FAMOUS BURGESS LITTLE-SIX

In replacing the old Model T type No. 6 cell, it saves 40% in weight and 30% in space, yet retains all the electrical energy. Besides this it is moisture-proof and leak-proof, and has 12% more active zinc area. For portable work it's just the thing you want for a dependable "A" supply.

BURGESS MIDGET "A" AND "B" BATTERIES

Extremely small batteries, admirably suited for all portable uses—yet full of the same dependable power which has made their big brothers famous for years. Made up into 3 volt "A" and 45 volt "B" sizes.

BURGESS "HEX" BATTERIES

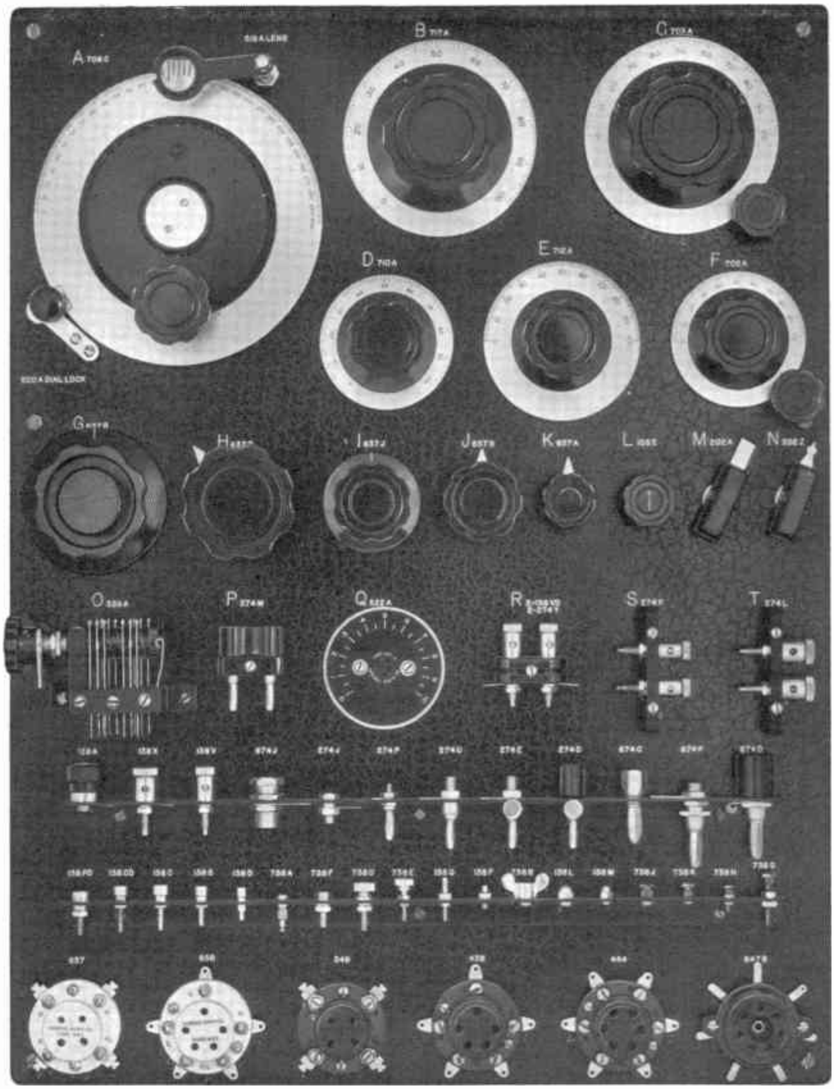
A class of hexagonally shaped batteries especially designed for efficient packing in circular containers. The cells are soldered together in parallel in one integral unit in groups of either 18 or 36. When you need a battery that will really hold up under tough service, a Burgess "Hex" Battery will just fill the bill.

All these new Burgess Developments of course contain the same "Chrome" protected cells as the standard black and white striped batteries. For further information about them write to

BURGESS BATTERY COMPANY

CHICAGO FREEPORT, ILL. NEW YORK

ACCESSORIES



"PARTS FROM GENERAL RADIO" . . . how many times have you seen this specified in the current radio literature! Standardized accessories, designed and manufactured by General Radio, have been invaluable aids to the amateur, experimenter, laboratorian and commercial worker for over twenty years. Correctly designed, carefully manufactured and rigidly inspected General Radio *standardized* parts can be relied upon for a lifetime of useful service.

Write for Catalog 936-HB for Complete Details

GENERAL RADIO COMPANY

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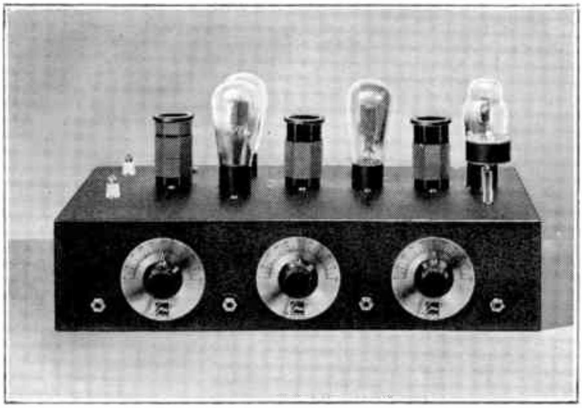


CW-25 Crystal Control TRANSMITTER

Output: 25–30 Watts

COMPLETE KIT, LESS TUBES AND CRYSTAL

$14.95

The CW-25 Crystal Control Unit is designed both for the beginner who is using crystal control for the first time and the old timer who wants good workmanship, fine appearance and dependable operation. It may be used effectively as a medium low powered crystal controlled transmitter or for exciting a larger tube such as a 203-A, 211, 242-A, 800, and the RK-18. Used either as transmitter or exciter, it operates efficiently on the 1.7, 3.5, 7 and 14 mc. bands with an output of from 25 to 30 watts.

For amateurs, however, who wish to achieve the last word in station appearance and reliable, efficient operation, we suggest that they use the CW-25 in combination with the F-25 Rack, frame and meter panel and the P-25 Power Supply. Each of these pieces of equipment has been especially designed in unit form for just such a combination.

Circuit and Tube Lineup: The circuit has been specially designed for operation on all bands with utmost efficiency. It employs a 47 type tube as crystal oscillator; a 46 used as a buffer or doubler and two 46's in the third stage which may be operated as a straight amplifier or doubler depending upon the frequency of the crystal used.

Power Supply Requirements: Filament voltage, 2½ volts at 6 amperes. The same plate voltage, from 350 to 450 volts, may be employed for all stages.

Coils: One complete set of three coils for operation on any one of the amateur bands is furnished as standard equipment. Coils for the 1.7, 3.5, 7 and 14 mc. may be purchased separately.

Power Connections: Contributing to the efficiency and trim appearance of the Unit are the socket and plug and cable-type outlets for all power connections.

Crystal Holder: A standard Gross crystal holder is included in the price of the Unit.

Metering: Four jacks are provided on the front of the chassis for metering all plate circuits and the grid circuit of the amplifier. The grid jack can also be used for keying. The entire unit can be tuned up efficiently, with only one milliammeter.

Size: Overall dimensions of the Unit are height, 4½ in.; width, 11 in.; length, 19 in.

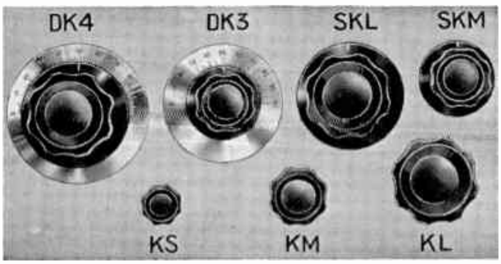
P-25 POWER SUPPLY—for CW-25 transmitter with matching chassis—450 volts at 200 MA, choke input—complete kit, less tube.......... $11

DeLuxe Dials and Fluted Knobs

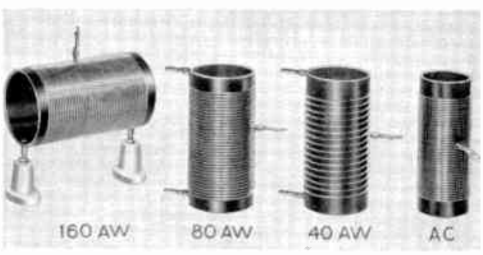
These are the trimmings you have noticed of late on the finest equipment, now available at *these* prices. Dial plates made of circular finished solid nickel silver (not plated brass or aluminum). Fluted knobs are finest quality genuine bakelite.

DK-3. 3¼" Dial and Knob.......................... $.70
DK-4. 4" Dial and Knob............................ $.85

PRICES ON KNOBS WILL BE GLADLY FURNISHED



BUILDING OR REBUILDING—
IT'S THE VOGUE TO USE GROSS COILS



They are better — they are more convenient to use — they can be plugged in — they can be interchanged — they can be clipped on — they are attractively priced. The Gross series of AW plug in coils fill every requirement in coils for any RF stage from the crystal, buffer and output stage, up to and including 200 watts input. The AC type coil (without plugs) is particularly useful for Impedance Matching Antenna Networks. All coils are the same length, 5¼" long overall. Plugs on the 160-AW, 80-AW, 40-AW fit into the same mounting space and are plugged into GR type jacks. Each turn can be clipped onto thru novel slot in the form. One new type clip is supplied and included in the price of the coil. These coils are wound on Natural color threaded XX Dielecto, winding is of bright plated wire.

AW-40 Meter Coil $1.35 — will tune with 50 mmf condenser
AW-80 Meter Coil $1.50 — will tune with 50 mmf condenser
AW-160 Meter Coil $1.60 — will tune with 70 mmf condenser
AC Antenna Coil $1.25. Jack Insulators 10c each

20% DEPOSIT WITH ALL C. O. D. ORDERS *REMIT BY M. O. INCLUDE POSTAGE* *Cable Address:* GROSSINC

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WESTINGHOUSE RADIO INSTRUMENTS

Type MX

BODY DIAMETER........................2 1/16"
FLANGE DIAMETER.....................2 1/4"
SCALE LENGTH.........................1.8"
ACCURACY......................WITHIN 2%
ACCURACY RECTOX TYPES.........WITHIN 5%
MOLDARTA CASE
FLUSH MOUNTING WITH CLAMP

Type NX

BODY DIAMETER........................2 3/4"
FLANGE DIAMETER.....................3 1/2"
SCALE LENGTH.........................2.4"
ACCURACY......................WITHIN 2%
ACCURACY RECTOX TYPES.........WITHIN 5%
MOLDARTA CASE
FLUSH MOUNTING WITH BOLTS THROUGH FLANGE

Westinghouse Radio Instruments are the last word in accuracy, durability, and ease of reading. They offer the widest range in size and shape, and are available in a complete line of voltmeters, ammeters, radio-frequency ammeters, etc. Made with the same high degree of quality that has characterized Westinghouse instrument manufacturing since 1888, these radio instruments are available at reasonable prices. No logical reason exists for accepting lower quality.

Following is a partial listing of the Westinghouse d-c. line. Should you want an a-c. instrument or a square-type instrument, we will be glad to send you further information.

All standard MX and NX instruments are calibrated for use on non-magnetic panels. If they are to be used on steel panels, please specify panel thickness on order.

D-C. AMMETERS
Self-Contained
Approximately 50-Mv. Drop Across Terminals

	Type MX		Type NX	
Rating	*Scale Div.*	*Style No.*	*Scale Div.*	*Style No.*
0—1§	20	818 488	50	820 191
0—5§	50	724 654	50	818 926
0—15§	30	818 498	30	820 200
0—50§	50	818 503	50	820 205

§Any of these ammeters can be furnished with a center zero at the same price.

D-C. AMMETERS
Calibrated for 50-Mv. External Shunts

	Type MX	Type NX
	Style No.	*Style No.*
Left Zero*†	818 486	820 189
Center Zero*†	818 487	820 190

D-C. MILLIAMMETERS
Double Range with Three Binding Posts

Type NX	
Rating	*Style No.*
0—15—150	836 110
0—30—150	836 111

*The above styles of d-c. ammeters can be calibrated for any external shunt from 5 to 10,000 amperes, and for standard or special length leads.

†Specify rating of shunt required. List price includes leads, but not the shunt. When ordering specify Style No. 553583 leads for Type MX and Style No. 356835 leads for Type NX.

Please order by Style Number

IT PAYS TO BUY QUALITY INSTRUMENTS

WESTINGHOUSE RADIO INSTRUMENTS

All standard MX and NX instruments are calibrated for use on non-magnetic panels. If they are to be used on steel panels, please specify panel thickness on order.

D-C. MILLIAMMETERS

	Type MX			Type NX		
Rating	*Scale Div.*	*Resistance, Approx. Ohms*	*Style No.*	*Scale Div.*	*Resistance, Approx. Ohms*	*Style No.*
0—1 ¶	20	110	**818 504**	50	57.2	**820 207**
0—5 ¶	50	10.1	**818 510**	50	3.7	**820 213**
0—10 ¶	20	2.37	**724 652**	50	2.1	**818 924**
0—15 ¶	30	2.44	**818 514**	30	1.5	**820 216**
0—50 ¶	50	1.00	**818 519**	50	1.00	**820 221**
0—100 ¶	20	.50	**818 522**	50	.50	**820 224**
0—150 ¶	30	.33	**818 523**	30	.33	**820 225**
0—200 ¶	40	.25	**818 524**	40	.25	**820 226**
0—300 ¶	30	.17	**818 525**	30	.17	**820 228**
0—500 ¶	50	.10	**818 527**	50	.10	**820 230**
0—800 ¶	40	.062	**818 529**	40	.062	**820 232**

¶For special requirements, it is usually possible to make milliammeters of lower resistance than the values shown here.

D-C. MICROAMMETERS*

0—20	40	2180	**820 159**	40	2180	**820 233**
0—100	20	121	**818 530**	50	71	**820 235**
0—200	40	154	**818 532**	40	154	**820 236**
0—300	30	154	**818 534**	30	154	**836 165**
0—500	50	110	**818 536**	50	110	**820 237**
0—800	40	61	**818 538**	40	61	**836 168**

*Microammeters below **500** microamperes depend upon the external circuit for damping.

D-C. VOLTMETERS

Full-Scale Current—5 Milliamperes **Resistance—200 Ohms per Volt**

	Type MX		Type NX	
Rating	*Scale Div.*	*Style No.*	*Scale Div.*	*Style No.*
0—1	20	**818 539**	50	**820 238**
0—2	40	**818 541**	40	**820 240**
0—5	50	**818 545**	50	**820 244**
0—10	20	**818 548**	50	**820 247**
0—25	25	**818 551**	25	**820 250**
0—50	50	**818 554**	50	**820 253**
0—100	20	**818 557**	50	**820 256**
0—200	40	**818 559**	40	**820 257**
0—500†	50	**821 572**	50	**821 641**
0—1000†	20	**821 575**	50	**821 644**
0—1500†	30	**821 576**	30	**821 645**
0—2000†	40	**821 577**	40	**821 646**
0—2500†	25	**821 578**	25	**821 647**
0—3000†	30	**821 579**	30	**821 648**
0—5000†	50	**821 581**	50	**821 650**

†This rating is supplied with an external resistor. When an external resistor is required, the voltmeter is made self-contained for **150** volts (**30,000** ohms) and the balance of the resistance is external.

VOLTMETERS

Resistance—1000 Ohms per Volt

0—50	50	**821 597**	50	**821 633**
0—150	30	**821 601**	30	**821 637**
0—300*	30	**821 604**	30	**821 612**
0—500*	50	**821 606**	50	**821 614**
0—800*	40	**821 608**	40	**821 616**
0—1000*	20	**821 609**	50	**821 617**

*Supplied with external resistor.

Please order by Style Number

IT PAYS TO BUY QUALITY INSTRUMENTS

WESTINGHOUSE RADIO INSTRUMENTS

All standard MX and NX instruments are calibrated for use on non-magnetic panels. If they are to be used on steel panels, please specify panel thickness on order.

RADIO-FREQUENCY AMMETERS¶

Calibrated for Use with External Thermocouple

Type MX *Style No.*	Type NX *Style No.*
818 558	820 281

List price includes the ammeter calibrated, but not the thermocouple.

¶Radio-frequency ammeters are available with external thermocouples in all ranges from 1 to 50 amperes, inclusive. When long leads are used between the instrument and the thermocouple, it is usually necessary to place proper by-pass condensers and radio-frequency chokes in the circuit at the thermocouple to prevent damage to the thermocouple by radio-frequency in the instrument leads. Additional information on this subject will be furnished on request.

RADIO-FREQUENCY MILLIAMMETERS

Self-Contained

Rating	Type MX *Style No.*	Type NX *Style No.*
0—100	724 657	818 929
0—300	818 588	820 285
0—500	818 590	820 287
0—800	818 592	820 289

RECTOX MILLIAMMETERS

0—1	818 595	820 292
0—2	818 596	820 293
0—10	818 598	820 295

VOLT-OHMMETERS

Dial Calibration Volts	*Dial Calibration* Ohms	*D-C. Volts Required*	Type NX *Style No.*
0—1.5	0—1000	1.5	836 193
0—1.5	0—3000	1.5	836 194
0—4.5	0—10000	4.5	836 195
0—4.5	0—30000	4.5	836 196
0—4.5	0—100000	4.5	836 197
0—15	0—500000	15	836 198
0—90	0—2000000	90	836 199

RADIO-FREQUENCY AMMETERS

Self-Contained

Rating Amperes R.F.	Type MX *Style No.*	Type NX *Style No.*
0—1	818 572	820 270
0—2	818 574	820 272
0—5	724 656	818 928
0—10	818 581	820 278
0—15	818 582	820 279
0—20	818 583	820 280

RECTOX MICROAMMETERS

Rating	Type MX *Style No.*	Type NX *Style No.*
0—80*	....	930 264
0—200	818 593	820 290

*This range is particularly suited for use as an a-c. galvanometer.

RECTOX VOLTMETERS

Resistance—1000 Ohms per Volt

0—4†	724 655	818 927
0—10†	818 601	820 297

†Below 4 volts, Rectox voltmeters should have a resistance of 2000 or 5000 ohms per volt.

Resistance—2000 Ohms per Volt

0—1.5	818 604	820 300
0—2.0	818 605	820 301

Resistance—5000 Ohms per Volt

0—0.5	818 608	820 304
0—1	818 609	820 305

MULTI-RANGE RECTOX VOLTMETER

Resistance—1000 Ohms per Volt

Rating	Type NX *Style No.*
0—5—10—200—1000*	838 324

*External resistor is used.

EXTERNAL THERMOCOUPLES

Air Type

Capacity Amperes	*Style No.*	*Capacity Amperes*	*Style No.*	*Capacity Amperes*	*Style No.*
2	878 640	8	878 646	30	878 651
4	878 643	10	878 647	35	878 652
5	878 644	15	878 648	40	878 653
6	878 645	20	878 649	50	878 654
		25	878 650		

External thermocouples can be used with uncalibrated radio-frequency ammeters designed for the purpose and listed with the various types of instruments. Each instrument and thermocouple must be calibrated together.

Please order by Style Number

IT PAYS TO BUY QUALITY INSTRUMENTS

Westinghouse Radio Instruments

ALTERNATING CURRENT—The complete line of MA and NA instruments includes voltmeters, ammeters, and milliammeters. Like the MX and NX, these instruments have many new features which result in unusually sturdy movements and a large reduction of energy consumption. C. S. 43-346 describes these instruments.

A-C., D-C., AND RESISTANCE—Developed specifically for radio work, the NX Universal Rectox Instrument has a built-in Rectox unit that makes it suitable for a-c. as well as d-c. *No shunt or special connection is required for changing from a-c. to d-c.* In addition ohms may be read easily and quickly. For complete information, obtain C. S. 43-341.

RX instruments, an exclusive Westinghouse development for radio and communication equipment. These *miniature* instruments have the desirable appearance heretofore found only in *large* switchboard instruments. They facilitate mounting in metal panels, and assure a balanced pleasing appearance with considerable saving in space not possible with round instruments. They have new solder-type terminals as shown, or conventional studs. Ask for C. S 34-344.

IT PAYS TO BUY QUALITY INSTRUMENTS

SOME OF OUR REPRESENTATIVE DISTRIBUTORS

You may buy Westinghouse Radio Instruments from any of the following:

Collins Radio Company . . . . Cedar Rapids, Iowa
Northwestern Agencies . . . . Seattle, Wash.
Electrical App. Sales Co. . . . . Boston, Mass.
F. Edwin Schmidt Co. . . . . New York, N. Y.
Electric Supplies & Dist. Co. . . . . San Diego, Cal.
Straus Frank Company . . . . Houston, San Antonio, Tex.

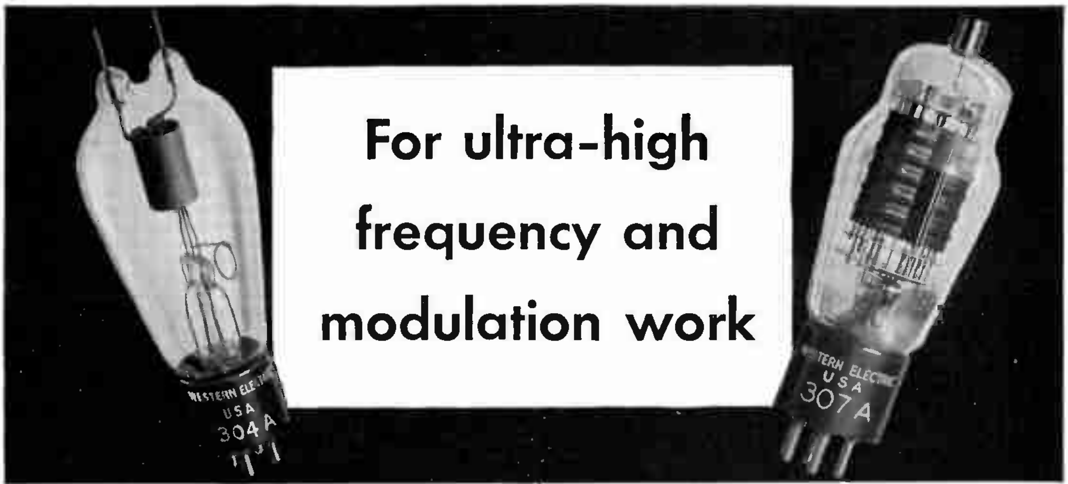
Or write to the nearest Westinghouse Sales Office

SINCE 1888
METERS INSTRUMENTS RELAYS

Westinghouse

Plane and Orange Streets

Newark • New Jersey



The Western Electric 304A is a triode developed especially for ultra-high frequency work. As a radio-frequency oscillator or power amplifier, it may be used at full rating at frequencies up to 100 megacycles—at reduced ratings up to 300 megacycles. Also suitable for use at audio frequencies, particularly in Class B audio amplifiers or modulators.

CHARACTERISTICS

Filament Voltage	7.5 Volts
Nominal Filament Current	3.25 Amperes
Average Characteristics with Plate Voltage of 1000 Volts D. C. and Plate Current of 50 Milliamperes:	
Amplification Factor	11
Grid Plate Transconductance	2300 Micromhos
Plate Resistance	4800 Ohms
Approximate Direct Interelectrode Capacities:	
Grid to Plate	2.5 μμf.
Grid to Filament	2.0 μμf.
Plate to Filament	0.7 μμf.

(See article in QST: November, 1934.)

The Western Electric 307A is a filamentary power amplifier pentode for use as a modulating amplifier, with carrier input applied to control grid and modulating voltage to suppressor grid. Suitable also as an oscillator or high frequency power amplifier.

Features: Small suppressor grid swing for essentially 100% modulation. Comparatively large modulated output without driving suppressor grid positive. Small high frequency driving voltage required. Comparatively high power output at low supply voltage. Quick warm up.

CHARACTERISTICS

Filament Voltage	5.5 Volts
Filament Current	1.0 Ampere
Maximum D. C. Plate Voltage	500 Volts
Maximum D. C. Plate Current	
Continuous, Class C Telephony	45 Milliamperes
Intermittent, Class C Telegraphy	60 Milliamperes
Maximum Plate Dissipation	15 Watts
Maximum Screen-Grid Voltage	250 Volts
Mutual Conductance for Plate Current of 45 Milliamperes (approx.)	4000 Micromhos
Control Grid to Plate Capacitance	0.55 μμf.
Input Capacitance	15 μμf.
Output Capacitance	12 μμf.

ACTUAL SIZE

Non-Directional Mike . . . $70

(In U. S. A., including jack and 20′ of shielded cord)

Western Electric's new non-directional dynamic mike gives you highest grade pick-up *regardless of direction of sound approach.* It gives you in even greater degree, the advantages of former Western Electric dynamic types. Its frequency range is from 40 to approximately 15,000 cycles per second. Engineered by Bell Telephone Laboratories—Western Electric's *finest* microphone—priced so low that no station can afford to be without Western Electric quality.

Western Electric

BROADCASTING EQUIPMENT

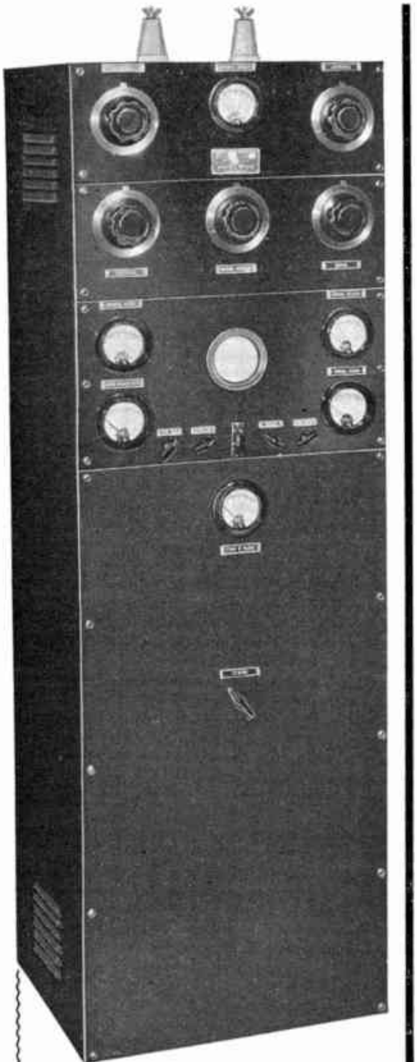
Distributors:

Graybar Electric Company, Graybar Building, New York

In Canada: Northern Electric Co., Ltd., 1261 Shearer St., Montreal, P. Q.

Foreign: International Standard Electric Corporation, 67 Broad St., N.Y.

Marine Transmitting Equipment



VISUAL OSCILLOSCOPIC MODULATION CONTROL

THE persistent demands of amateurs throughout the country for transmitters, built along the quality lines of the 140B has persuaded the Marine organization to introduce at this time, a series of seven crystal controlled models. The amateur's pipe dream of the perfect rig is fulfilled in this Marine apparatus. Many of these transmitters were designed for Police, Broadcast, Portable broadcast, or commercial use. *They have now been made available to the amateur for the first time.*

MARINE TYPE 140B 100 watt Ultra-Modern High Frequency X-mitter. The rig hams have been talking about for years. There isn't a night that will go by, that you won't hear some fellow, who is working his station, admiring the exclusive features of the 140B.
Cathode-ray modulation control, permanent neutralization, high fidelity audio channel and one hundred and one other items that make this x-mitter the favorite among the amateurs who are in the "know."

MARINE 750B The most powerful transmitter permitted by the government for amateur use. 1000 watt phone and CW. Built along the Marine quality standards, this rig is the finest of its type available today. All of the latest developments in transmitter design are incorporated in this unit.

MARINE 270B 250 Watts Phone and CW. This x-mitter incorporates the same electrical features as the 140B in the moderate power field. The transmitter for those who want power at low cost.

MARINE 60G
A moderately priced, high quality, 200 watt CW, 60 watt phone x-mitter, having the same electrical features as the 140B.

MARINE 83B
50 watts phone and CW.
A handy compact unit at an interesting price.

MARINE 18A
40 watts phone. 125 watts CW.
A low power high quality unit.

MARINE 22BP Boys — here's the job you were waiting for — a portable AC operated x-mitter. Light weight, compactly built, of exceptional ruggedness, the rig you can work in the country without fear of damage. Here are a few of the characteristics — They're interesting — aren't they?

- **1500 to 15,000 KC (Special model available for 1500 to 30,000 KC).**
- **100% Class B Modulation.**
- **Antenna impedance matching network. (optional) For matching the antennas the traveling ham runs across.**
- **5-tube regenerative receiver with built-in dynamic speaker. Wave length ranges from 10 to 17,000 meters, available on special order. Cabinet supplied with firmly anchored handles. Space provided for log, headphones, and other incidentals.**

MARINE 35B 30 watt phone and CW. A low cost compact receiver for the ham breaking in. Also convenient for the old timer on low power work.

Because of lack of space it really is impossible to do justice to these rigs. Why not write for descriptive literature giving the full dope.

TRANSMITTERS

Remember . . . **you are assured of complete satisfaction on all Marine equipment. Our unconditional guarantee absolutely protects you.**

Manufacturers of transmitters for airway, broadcast, commercial, governmental, police, and all other purposes.

MARINE Radio Company

General Offices and Plant:

124–11 101st Avenue
RICHMOND HILL, NEW YORK

NEW PRODUCTS ADVANCED DESIGNS LOWER PRICES

HERE'S a brand new line to better fit the engineering requirements and pocketbook of amateur radio. Fresh from the ground up — manufactured in three new basic insulating materials, Victron G, Vitrolex and Micoroid — it is vastly better and lower in price.

First, there's a complete commercial type transmitter frame that you'll accept on sight. Simply turn the bars on the Universal Coil Form and you have a support for 10 to 160 meter coils in a single article. It takes 5800 volts to flash over "Butt-Ins," tiny lead-in insulators so inexpensive you can use them everywhere.

There has long been a need for a 50 Watt Socket for securing above and below mounting surfaces. It is now available, designed like the finest commercial sockets used in Government equipment. Our new "Beehive" Lead-In Assembly is good for 6500 volts at 1500 K.C. It is adequate for most all low power transmission service since it is produced in the finest ceramic of its type obtainable, and at a low price.

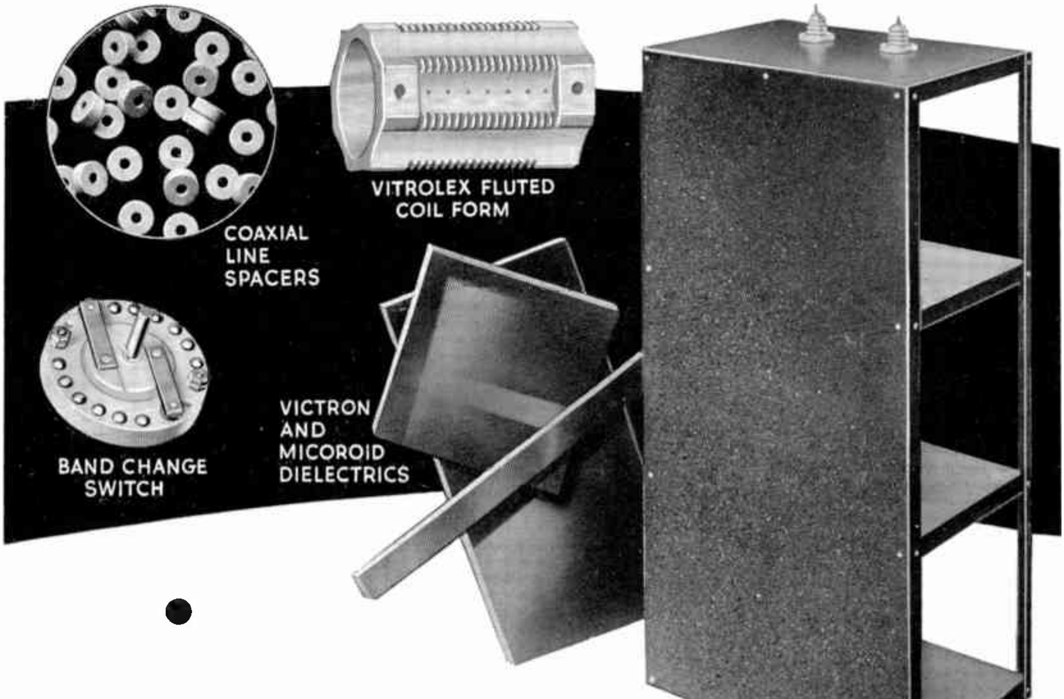
Switching of coils with the turret coil assembly is more desirable than with a construction in which fixed coils and rotary switches are used. It insures short leads, fewer contacts and more efficient placement of circuit components and reduced circuit loss. We offer a complete assembly with steatite or bakelite coil forms. The new horizontal type small plug-in coil form is offered for a variety of applications in the low powered transmitter, frequency meter, laboratory set-up, etc. It is constructed of absolutely stable Vitrolex which will not alter electrically under a wide range of climatic conditions, thus promoting circuit stability. Add G.R. plugs and jacks as needed.

Then there's a real band change switch, Ultra-Steatite coaxial transmission line spacers, Q-Max Lacquer in small containers and many more items to be included in this advanced line of equipment described in part on these pages.

SPECIFICATIONS

Transmitter Frame and Panel: Dimensions 36" x 19" x 12" deep with four shelves complete with panel, screws, two beehive Vitrolex lead-in insulators, terminal studs, etc. Q-Max baked finish. Constructed of heavy gauge steel, sturdy and unsurpassed in appearance. Openings easily made with circle cutter. Shipped knocked down in heavy cardboard container. Price $8.50 net F.O.B. Jersey City, N. J.

Universal Coil Form: Diameter 4", length 6¼". Grooved for 10, 20 and 33 turns. One bar face for any turn spacing you wish. Price $1.50 net. Bars separately — 25c each net.



Fifty Watt Socket: Mounts above or below surface on spacers provided. Special phosphor bronze contacts, glazed Vitrolex insulation. Fine appearance and excellent construction. 95c each net.

Turret Coil Assembly: Consists of low phase angle phenol plastic dielectric support for Vitrolex or phenol coil forms ⅞" O.D. x 2½" long, three pair of contacts per coil, blades, blade support, etc. Single hole mounting, complete with coils ready to wind to your requirements, mount and put to work, $3.00 each net complete.

Beehive Lead-In Assembly: Finest glazed Vitrolex insulation, much superior to porcelain electrically and mechanically, stronger than glass. Will not affect circuit balance in wet weather like porcelain. With 6" rod, 50c each complete net; 13" rod, 60c each complete net.

Plug-In Coil Form: Consists of Vitrolex tube 1" O.D. x 3½" long with six holes for General Radio plugs. Supplied with Vitrolex mounting strip with six correspondingly located holes for G.R. jacks and two additional holes for securing to mounting surface. Assembly includes two G.R. plugs and jacks. Price complete 65c each net.

"Butt-Ins" (Button Lead-In's): Fit 7/16" hole, pass 6–32 screws, ¼" high. Long creepage path. Flash-over between screw and panel 5800 volts at 60 cycles. Price 25c per dozen net.

Coaxial Transmission Line Spacers: Made in Ultra-Steatite, a remarkable new dielectric of extremely low dielectric absorption. Are ⅛" thick, fit standard 5/16" copper tubing and No. 14 wire. Price 15c per dozen net.

Victron Supported Coil Forms: Greatly superior to celluloid supported coils but no higher in price. A complete line in various diameters, and wire size. Send for data sheet and prices.

Vitrolex Fluted Coil Forms: Dimensions — 3" diameter, 5" long, threaded for 30 turns. Vitrolex ceramic ware, unlike porcelain, is non-hygroscopic and low in loss. Price 50c.

Band Change Switch: Double pole, six point, insulated shaft. Positive contact, high voltage spacing throughout, flexible copper leads from blade to terminal. Vitrolex insulation. May be ganged. Supplied with ¼" shaft. Price $1.95 net.

Victron G: A greatly improved product, practically loss free, extremely stable in the presence of water — radio's supreme dielectric.

NET PRICES

	6" x 12"	6" x 6"	1" x 12"
3/16"	$3.60	$2.00	$.75
⅛"	2.50	1.35	.45
1/16"	1.40	.75	.25

Micoroid: A new and superior organic insulator available in sheets. As near an approach to the properties of Victron as it is possible to achieve in an organic insulator. Characteristics, sheet sizes and prices appear in data sheets.

Q-Max No. 3 Lacquer

Ordinary lacquers are harmful in R.F. circuits. Buy Q-Max No. 3 from your dealers — 25c.

Data sheets on above products are ready. Write for them.

Dealers and mail order distributors everywhere have been invited to stock these items for your convenience. If they are not prepared to serve you, order direct. We will ship postpaid anywhere in U. S. A. on orders of $2.00 or more, when accompanied by check or money order. Shipment same day.

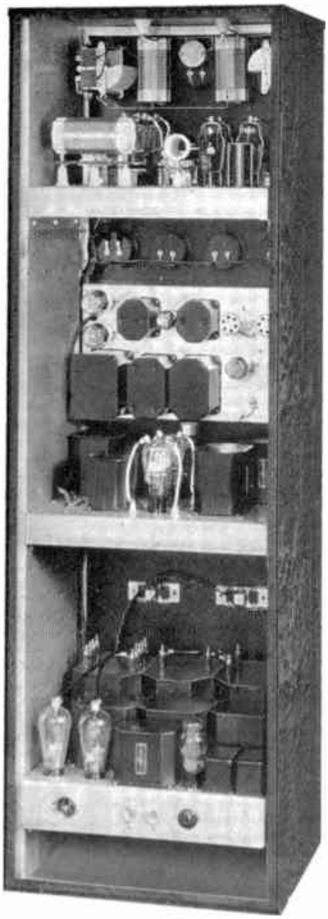
COMMUNICATION PRODUCTS, INC.

245 CUSTER AVENUE, JERSEY CITY, N. J.

Producers of Victron — Vitrolex — Micoroid and Q-Max Compositions

"LOOK INSIDE BEFORE YOU BUY"

HARVEY TRANSMITTERS ARE ENGINEERED FROM THE INSIDE OUT, AND ARE CORRECTLY DESIGNED, PROPERLY RATED AND UNCONDITIONALLY GUARANTEED



REAR VIEW FT-100
Description below

60-T A modern telephone-telegraph transmitter of medium power for three band operation

Power Output: 50 watts CW, 15 watts phone on the crystal fundamental.

Frequency Range: 1600–15,000 kilocycles. Special frequencies on order.

Band Switching: Plate and cathode circuits are switched from front panel permitting operation in any three consecutive bands. Model A: 160–80–40 meters. Model B: 80–40–20 meters. Phone operation on 20 meters requires a 20 meter crystal.

Crystal Switching: Three crystals are switched simultaneously with the cathode circuit. **Radio Frequency Tube:** Single RK-20.

Audio Tubes: One 41 suppressor grid modulator, one 6C6 speech amplifier.

Rectifier Tubes: Three 83-Vs in the bridge circuit with double section filter, pyranol condensers and choke input. One 80 for modulator supply.

Keying: Center tap of RK-20. **Instruments:** One plate milliammeter supplied. Antenna meter available at additional cost.

Antenna Tuning: The 60-T is designed for use with single wire feed permitting operation of one antenna on three bands.

Dimensions: Cabinet measures 23″ high by 19″ wide by 10″ deep.

200-R A versatile transmitter with controlled carrier employing the new high-powered pentode

Power Output: 200 watts CW, 60 watts phone.

Frequency Range: 1500–15,000 kilocycles. Special frequencies on order.

Band Switching: Six circuits, including antenna, are switched from front panel to permit three band operation at will. The fourth, or 160 meter band, employs plug-in coils.

Crystal Switching: Four crystals are switched from front panel covering 20–40–80 CW and phone bands. For 160 meter operation an additional crystal is used.

Radio Frequency Tubes: 6A6 crystal oscillator, 42 Doubler and RK-28 power amplifier.

Audio Tubes: 6J7 speech amplifier, 6C5 speech amplifier, 6F6 suppressor grid modulator, and 84 controlled carrier rectifier.

Rectifier Tubes: One 83V in oscillator power supply, one 80 in suppressor bias supply, one 5Z4 in modulator power supply. Two 866A tubes are used in the main power unit which employs a double section filter with pyranol condensers and choke input. **Keying:** Grid block in the final amplifier.

Instruments: Two Westinghouse meters reading grid and plate current are furnished. Antenna meter available at additional cost.

Antenna Tuning: The 200-R is designed for use with single wire feed. No controls necessary. **Dimensions:** 32″ high by 19″ wide by 16″ deep.

FT-100 A 100 watt transmitter of excellent design

Radio Frequency Section: 802 crystal oscillator, parallel 802s as buffers and two 800s as final amplifier.

Audio Section: Two 800s are employed as class B modulators delivering 100 watts of audio power.

Power Supplies: The high voltage section employs two 866As in double section filter with pyranol condensers and choke input. A 5Z3 supplies the oscillator and buffer stages and there is also a bias supply so that the entire transmitter requires no batteries.

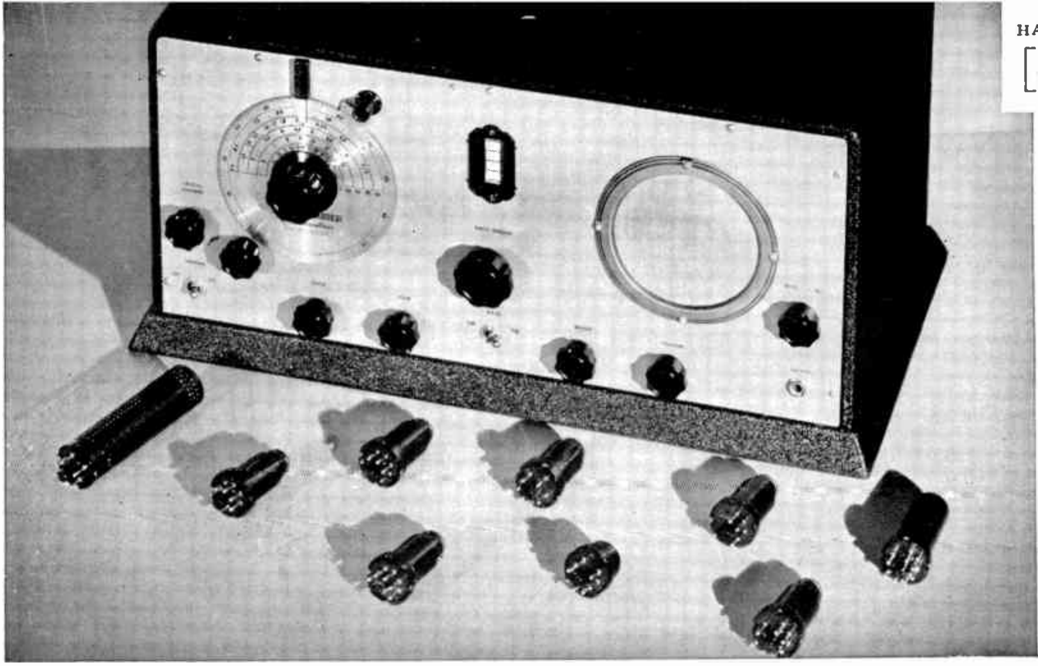
Construction: The FT-100 is enclosed in a steel cabinet 60″ high by 19″ wide by 16″ deep. Six meters and network are furnished. All transformers and chokes are fully cased and impregnated against dust and moisture. The transmitter is also furnished with remote control box for controlling filament and plate voltages.

SPECIAL Our research department is regularly designing and building special electronic and radio apparatus for Colleges, Expeditions and Institutions. Your inquiry will receive our most prompt and careful consideration.

Write for free data and prices on our line

HARVEY RADIO LABORATORIES

12 Boylston Street, Brookline, Mass., U. S. A.



EXPERTS ACCLAIM *the* SUPER SKYRIDER

IT IS outstanding in performance — gratifying in convenience — the short-wave receiver you've dreamt about but never before saw realized.

Nowhere can you get a short-wave receiver with the exclusive features and high grade engineering that you will find in the Super SKYRIDER. You get complete coverage of the short-wave and broadcast spectrum without inconvenient plug-in coils.

It's all in one compact cabinet, speaker, power pack, everything — no loose units or wiring. Look at the list of features you get with the Super SKYRIDER — but they don't cost you a fortune in this superb receiver. Find out all about it today.

- **Metal Tubes** — Elimination of noisy, unsatisfactory tube shields, reduced interelectrode capacities and shorter leads making possible greater gain and fewer circuit complications.
- **Iron-Core I.F. System** — Especially designed for the 1936 Super SKYRIDER — used for the first time commercially in any amateur receiver — having greater sensitivity and a signal-to-noise ratio unattainable with an air core system.
- **Duo-Micro-Vernier Band Spread** — Providing improved accuracy of logging — combines electrical band spreading and micro vernier tuning in an exclusive and distinctive dial with novel illumination.
- **More efficient Antenna Circuit** — Better 5-band coverage of all-wave bands from 7.4 to 550 meters (41000 to 540 K.C.) made possible by tuning to the low frequency end of each band.
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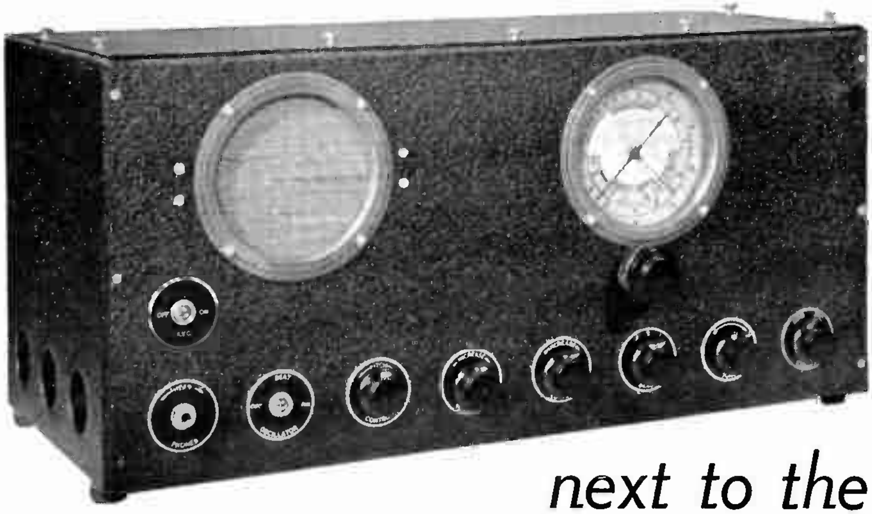

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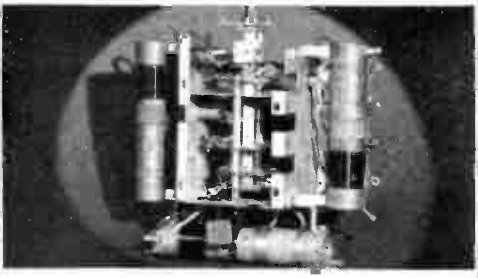

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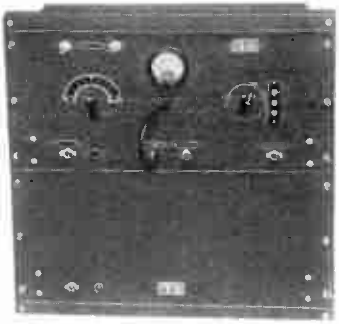

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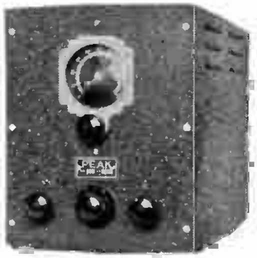

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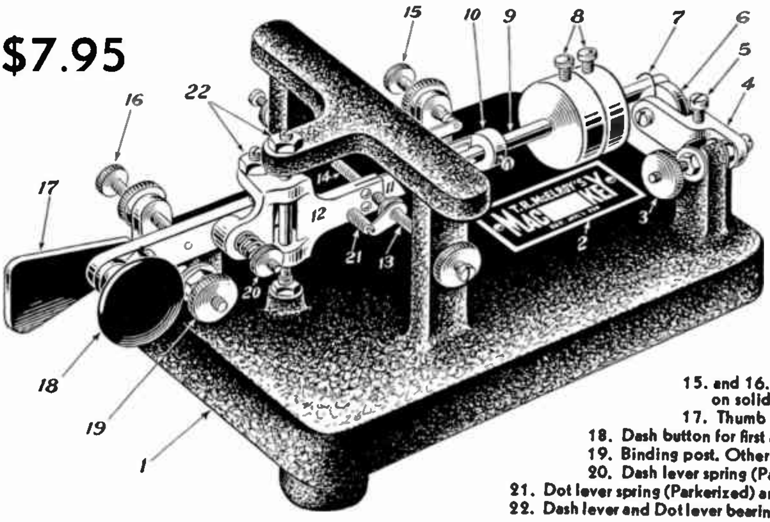

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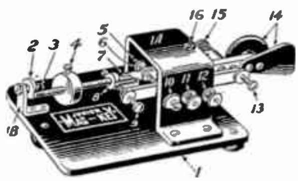

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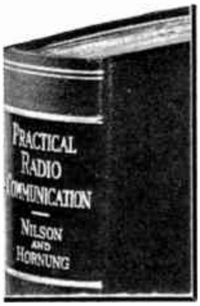

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City and State .... *Company* QSH-36

(Books sent on approval in U. S. and Canada only)

The Mueller Line

TEST *and* BATTERY CLIPS

ALL SIZES FOR ALL PURPOSES

Stocked by Jobbers Everywhere

No. 45-OS

SOLID COPPER RADIO FREQUENCY TEST CLIP

Equipped with phosphor bronze spring and brass screw. ENTIRELY NON-FERROUS and ideal for use on transmitters. Will not heat up on high frequency circuits. Jaw spread ⅜".

No. 85 Clip with No. 87 Insulator

ALLIGATOR CLIP and RUBBER INSULATOR

Long, slender jaws will make contact in cramped quarters. Teeth really mesh on both sides and front end. Both screw and barrel connection. 2⅜" long. Jaw spread ½".

Insulators furnished separately — one half red and one half black.

No. 45 Pee Wee

A very small test clip for radio and electrical work. For making connection to dry cells, meters and helices. Teeth on both jaws which mesh. 5 Amperes. 1½" long. Jaw spread ½".

No. 48-B

A small test and battery clip for connections to B batteries and for general test purposes. Teeth mesh. 5 Amperes. 2" long. Jaw spread 5/16".

No. 27

A high grade test clip for use on meters, in laboratories, testing devices, etc. Teeth mesh on three sides of jaws. 10 Amperes. 2¼" long. Jaw spread 5/16".

No. 24-A

A medium sized clip for connections to storage batteries. Heavy, flanged construction. Lead Plated. Copper shunt protects spring. 25 Amperes. 2⅞" long. Jaw spread 1".

No. 21-A
3⅛" long. Jaw Spread 1⅛".

A heavy duty, lead coated battery clip. Also used for ground connections. 50 Amperes.

No. 11-A — 100 Ampere, Lead Coated Clip.

No. 83

SNAPPER

An insulated, elongated test clip. Spring jaws are operated by a push of the thumb on the opposite end. 7" long. Will reach into inaccessible spots. May also be used as a prod or a retriever. Packed two in a box, 1 red and 1 black.

CLAMPIPE GROUND CLAMP

CLAMPIPE

Patented, channelled construction gives 5-point contact with great strength and rigidity. Screw is hardened. All cadmium plated. The best ground clamp made. Takes pipe up to 1⅜" outside diameter.

RUBBER INSULATORS FOR CLIPS

Rubber insulators, one half red and one half black are made to fit each size of Mueller Clip.

They are constructed so that clips cannot slip forward or back and the long tail forces the wire to bend in an arc thus preventing breakage. A convenient protection against short circuit and shock.

Just give the number of the clip you want the insulator to fit.

SOLID COPPER CLIPS

All sizes of Mueller Clips are also offered made of copper with steel screws and steel springs.

Specify ampere capacity wanted.

Ask for Catalog 680 for Further Details

NET PRICES

Assort Any Products to Obtain Quantity Prices

CODE NO.	*Retail Price*	*Lots of 10*
11-A steel clip	$.50	$.35
21-A steel clip	.20	.14
24-A steel clip	.10	.07
26 Insulator for 24-A	.20	.14
27 Steel clip	.12½	.08¾
29 Insulator for 27	.11	.07¾
45 Steel clip	.05	.03
45-OS Copper clip	.10	.07
47 Insulator for 45	.07½	.05¼
48-B steel clip	.05	.03½
58 Ground clamp	.07	.05
83 Snapper	75c each less 33⅓%	
85 Steel clip	.06	.04
87 Insulator for 85	.05	.03

Mueller Electric Co.
ESTABLISHED 1908
1583 E. 31st St., Cleveland, Ohio

IMPORTANT CHARACTERISTICS...RAYTHEON AMATEUR TUBES

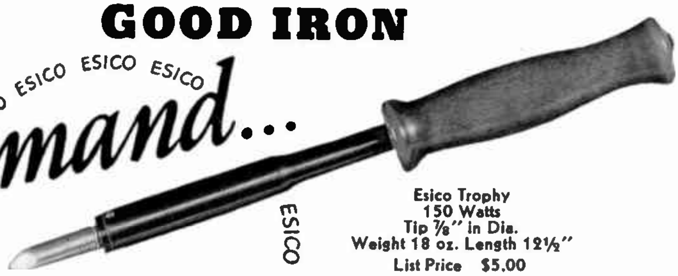
TYPE		FILAMENT			CAPACITIES			PURPOSE	RATED VOLTAGES				RATED MILLIAMPS.			POWER		Driving	Over All	
		Volts	Amps		Cgp	Cgf	Cpf		Plate	Grid	Scr. G	Supp. G	Plate	Grid	Scr. G	Pl. Diss	Output	Power	Height	
RK-10	Triode	7.5	1.25	Thor.	7uuf	4uuf	3uuf	Osc-Rf. Amp.	450	−120			60	10–15		12W	15W	3W	5⅜"	RK-10
								Class B Mod.	425	−50			8*			12W	25W*			
RK-15	Triode	2.5	1.75	Oxide	7.5	2.7	5.0	Rf. Amp.-Doubler	400	−50			50	3-5		10W	12W	2W	6"	RK-15
								Class B Mod.	400	−0			12*			10W	20W*			
RK-16	Triode	2.5	2.0	K	7.5	3.8	6.0	Audio Amp.	250	−28	250		26		6.5	10W	3W		5½"	RK-16
RK-17	Rf. Pentode	2.5	2.0	K	1.0	7.5	16.0	Osc.-Rf. Amp.	300	−50	125		40	3-5	20	10W	7W	2W	6"	RK-17
RK-18	Triode	7.5	3.0	Thor.	4.8	4.6	2.9	Osc.-Rf. Amp.	1000	−150			85	12–15		35W	40W	3W	8½"	RK-18
								Class B Mod.	1000	−50			28*			35W	100W*			
RK-19	Full W. Rect.	7.5	2.5	K				HIGH VACUUM—LOW DROP 1250V. R.M.S. PER ANODE 600 MA Peak CURR.											6⅝"	RK-19
RK-20	Rf. Pentode	7.5	3.0	Thor.	.012	11.0	10.0	Osc.-Rf. Amp.	1250	−100	300	O	80	7–10	37	40W	64W	1.0W	8¾"	RK-20
								Osc.-Rf. Amp.	1250	−100	300	+45	92	7–10	32	40W	80W	1.0W		
								Supp. Mod. Phone	1250	−100	300	−45	43	7–10	36	40W	18W	1.0W		
RK-21	Half W. Rect.	2.5	4.0	K				HIGH VACUUM—LOW DROP 1250V. R.M.S. PER ANODE 600 MA PEAK CURR.											6⅝"	RK-21
RK-22	Full W. Rect.	2.5	8.0	K															6⅝"	RK-22
RK-23	Rf. Pentode	2.5	2.0	K	.02	10.0	10.0	Osc.-Rf. Amp.	500	−90	200	O	50	6-8	40	10W	18W	.8W	6"	RK-23
								Osc.-Rf. Amp.	500	−90	200	+45	55	6-8	35	10W	24W	.8W		
								Supp. Mod. Phone	500	−90	200	−45	32	6-8	40	10W	5.5W	.8W		
RK-24	Triode	2.0	0.12	Oxide	5.5	3.5	3.0	5 Meter Osc.	180	−45			20			1.5W	1.2W		4¼"	RK-24
RK-25	Rf. Pentode	6.3	0.8	K	.02	10.0	10.0	CHARACTERISTICS SAME AS RK-23 SHOWN ABOVE											6"	RK-25
RK-28	Rf. Pentode	10.0	5.0	Thor.	.02	15.5	5.5	Osc.-Rf. Amp.	2000	−100	400	O	120	10–12	75	100W	160W	1.8W	9½"	RK-28
								Osc.-Rf. Amp.	2000	−100	400	+45	140	10–12	60	100W	200W	1.8W		
								Supp. Mod. Phone	2000	−100	400	−50	80	10–12	85	100W	60W	2.7W		
RK-30	Triode	7.5	3.25	Thor.	2.5	2.75	2.75	Osc.-Rf. Amp.	1250	−175			70	12-15		35W	65W	4.0W	6⅞"	RK-30
								Class B Mod.	1250	−70			30*			35W	106W*			
RK-31	Triode	7.5	3.0	Thor.				Class B Mod.	1250	O			30*			40W	140W*		8½"	RK-31
RK-32	Triode	7.5	3.25	Thor.	3.0	2.0	1.0	Ultra H. F. Oscill-Amp.	1250	−250			100	18–20		50W	65W	7.5W	6⅞"	RK-32
RK-34	Dual Triode	6.3	0.8	K	2.7	4.2	2.1	Osc.-Rf. Amp	300	−36			80	16–18		10W	14W	2.5W	5 1/16"	RK-34
								Class B Mod.	300	−15			30*			10W	12W*			
RK-100	Gas Triode	6.3	0.9	K	19.0	23.0	3.0	Rf. Oscillator	110	−25			80	50	150**	10W	3.5W		6¼"	RK-100
								Rf. Amplifier	110	−25			250	50	250**	10W	12W	3.0W		
841	Triode	7.5	1.25	Thor.	7.0	4.0	3.0	Rf. Amplifier	450	−32			50	10–12		12W	14W	1.5W	5⅜"	841
842	Triode	7.5	1.25	Thor.	7.0	4.0	3.0	Aud. Modulator	425	−100			28			12W	3W		5⅜"	842
866A	Half W. Rect.	2.5	5.0	Oxide				MERCURY VAPOR MAX INVERSE PEAK 10000 V. PEAK CURRENT—600 MA.											6⅝"	866A
872A	Half W. Rect.	5.0	10.0	Oxide				" " " " " 10000 V. " " 5.0 A.											8½"	872A

* Indicates Value for Two Tubes. ** Indicates Cathanode Current.

RAYTHEON PRODUCTION CORP., 30 East 42nd St., New York, N. Y.

• WHEN YOU NEED A GOOD IRON

Demand... ESICO!



Esico Trophy
150 Watts
Tip ⅞" in Dia.
Weight 18 oz. Length 12½"
List Price $5.00

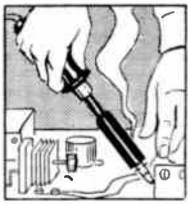
Esico Midget
65 Watts
Tip 7/16" in Dia.
Weight 7 oz.
Length 11¼"
List Price $1.75

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 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

All Esico electric soldering irons are unconditionally guaranteed. A "good" quality iron plus absolute protection assures you of complete satisfaction.

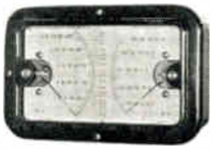
Many thousands of hams the country over admit the superiority of ESICO. Why not join this increasing army of loyal and well satisfied Esico users?

Electric Soldering Iron Co., Inc.
342 West 14th St., New York City

ESICO
REG. U.S. PAT. OFF.

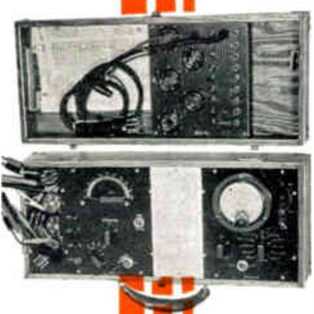

IRC RESISTORS
REG. U.S. PAT. OFF.
"Their Performance Proves Their Quality"
For every resistance need . . . whether you are an amateur, serviceman or manufacturer . . . there's an IRC resistor that will do the job to perfection — one backed with a record of successful performance which means far more than anything we might say in its behalf. Standardize on IRC's! They cost no more — and they excel by actual test.
● TYPE "R" INSULATED METALLIZED
● POWER WIRE WOUND
● RESISTANCE INDICATOR
● TYPE "F" METALLIZED
● PRECISION
● SUPPRESSORS
● RESIST-O-CHEST
Available Through Radio Parts Distributors Everywhere
INTERNATIONAL RESISTANCE CO.
Philadelphia, Pa. — Toronto, Canada
IRC
PRECISION WIRE WOUND
1 WATT 50,000 OHMS
Metallized RESISTOR

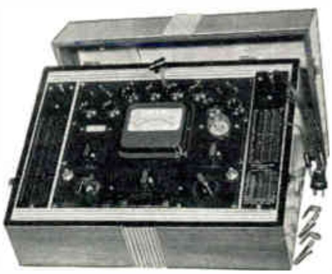
INSTRUMENTS of DISTINCTION by TRIPLETT



ELECTRICAL MEASURING

RADIO SERVICING





SEE THEM AT YOUR JOBBERS

WRITE FOR DETAILS

THE TRIPLETT ELECTRICAL INSTRUMENT CO.

BLUFFTON, OHIO

MIDGET CONDENSERS — For Better Radio Hammarlund PRECISION PRODUCTS — FOR EVERY PURPOSE

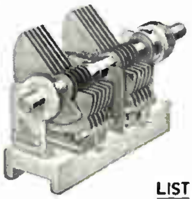
MIDGET VARIABLES

Ideal variable condensers for ultra-short wave and short wave tuning; laboratory, and test equipment. Isolantite insulation. Dielectric losses minimized. All contacts riveted or soldered. Vibration proof. Rotor and stator plates non-corrosive brass — .0225″. Shaft — ¼″ extending 5/16″ beyond rear frame for ganging. End mounting plates — heavy aluminum. Single hole panel or base mounting. Tested for breakdown on 500 V — A.C.

CODE	CAPACITY	LIST
MC-325-M	325 mmf.	$3.50
MC-250-M	260 mmf.	3.00
MC-200-M	200 mmf.	2.75
MC-140-M	140 mmf.	2.50
MC-140-S	140 mmf.	2.50
MC-100-M	100 mmf.	2.25
MC-100-S	100 mmf.	2.25
MC-75-M	80 mmf.	2.00
MC-75-S	80 mmf.	2.00
MC-50-S	50 mmf.	1.60
MC-35-S	35 mmf.	1.50
MC-20-S	20 mmf.	1.40

"M" — Midline Plates "S" — Straight Line Cap. Plates

SPLIT-STATOR TYPES

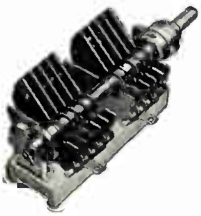


Like the Hammarlund single Midgets, these incorporate every requirement imperative to highest quality. Specifications identical to single types, except that shield plate is located between stator sections. Overall length behind panel — 3¼″. Entire condenser is built on a strong Isolantite base. Made for single hole panel mounting.

CODE	CAPACITY	LIST
MCD-140-S	140 mmf. per. sect.	$4.00
MCD-140-M	140 mmf. per. sect.	4.00
MCD-100-M	100 mmf. per. sect.	3.50
MCD-100-S	100 mmf. per. sect.	3.50

"M" — Midline Plates "S" — Straight Line Cap. Plates

DOUBLE SPACED SPLIT-STATOR TYPES



Identical to split stator condensers except that plates are widely spaced — actual air gap between adjacent rotor and stator plates — .0715″. There is no shield between the stators. This condenser is ideal for ultra-high frequency transmitters using up to 245's or 210's in push pull.

CODE	CAPACITY	LIST
MCD-35-MX	33 mmf. per. sect.	$3.50
MCD-35-SX	33 mmf. per. sect.	3.50

"MX" — Midline Plates "SX" — Straight Line Cap. Plates

DOUBLE SPACED TYPES

Exceptional unit for ultra-short wave receivers and transmitters, particularly compact transmitters. Spacing between rotor and stator plates — .0715″. Great for tuning amplifier stages in crystal controlled transmitters or for neutralizers up to 210's and 50 watters — also as tuners for 5 meter master oscillator power amplifiers. In Midline (MX) and straight line cap. types (SX).

CODE	CAPACITY	LIST
MC-20-SX	25 mmf.	$2.00
MC-35-MX	33 mmf.	2.25
MC-35-SX	33 mmf.	2.25
MC-50-MX	50 mmf.	2.75
MC-50-SX	50 mmf.	2.75

STAR MIDGET TYPES

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 for 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 1½″ depending on capacity. Exceptionally light in weight and strong and compact in construction. Tinned soldering lugs on the front end are supplied to simplify wiring. Plates of straight line capacity type.

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

*Double Spaced Transmitting Type

AIR PADDING TYPES

For short waves and ultra-short waves. As tuning condensers for I.F.'s. Trimmers for R.F. coils and gang condensers. Antenna tuning, fixed tuning of R.F. circuits or plug-in coils and for general padding purposes. Guaranteed to afford constant capacity under any conditions of temperature, humidity, or vibration. Overall dimensions of 100 mmf. size only 1 7/32″ x 15/16″ x 1½″. Isolantite base. Soldered brass rotor and stator plates.

CODE	CAPACITY	LIST
APC-100	100 mmf.	$1.90
APC-75	75 mmf.	1.70
APC-50	50 mmf.	1.50
APC-25	25 mmf.	1.30

BAND SPREAD TYPES

For perfect band spreading or for amateur band frequency meters. Tank section may be set and locked to any desired capacity. Tuning section spreads narrow frequency ranges over entire dial regardless of range of band or coils used. Tank cap. — 100 mmf. Tuning cap. type "120-B" — 20 mmf.; type "150-B" — 50 mmf.; type "175-B" — 80 mmf. Isolantite insulation at front and rear. Plates rigidly held in place.

CODE	LIST
MC-120-B	$3.00
MC-150-B	3.25
MC-175-B	3.50

MIDLINE TYPES

Here is the popular "Midline" condenser which has become a by-word in radio. It has specially shaped brass plates, full floating rotor, removable shaft, perfect bearings, and contact, with a rib-reinforced aluminum alloy frame. "Parmica" low loss insulation is used exclusively. These condensers can be supplied in dual type, too, upon special order. Straight frequency line types also available on special order.

CODE	CAPACITY	LIST
ML-23	500 mmf.	$4.50
ML-17	350 mmf.	4.25
ML-11	250 mmf.	4.00

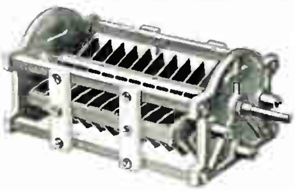
Manufactured by HAMMARLUND MANUFACTURING CO., Inc., 424–438 West 33rd Street, New York

TRANSMITTING CONDENSERS, EQUALIZERS, AND PADDING CONDENSERS

For Better Radio
Hammarlund
PRECISION
PRODUCTS

R.F. CHOKES FOR RECEIVING AND TRANSMITTING

TRANSMITTING TYPES

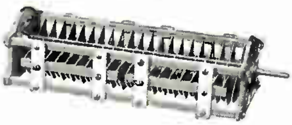


End plates of heavy cast aluminum. Isolantite cross bars. Non-inductive, self-cleaning brush contact. Polished heavy aluminum plates accurately spaced. Round edged for extremely high voltage work. "A" types — 6500 V — .192" plate spacing; "B" types — 3000 V — .080" spacing; "BX" type — 3500 V — .100" spacing; "X" types — 2000 V — .080" spacing, and "C" types — 1000 V — .038" spacing. Overall width — 4 11/16". Height — 3 3/16". Shafts — ¼" — extend 1⅛" beyond the panel bushings. Steel parts cadmium plated. Lock washers under all screws. End frames drilled and tapped for table or shelf mounting. Fully guaranteed.

CODE	CAPACITY	LIST
TC-30-A	30 mmf.	$5.00
TC-50-A	50 mmf.	6.50
TC-100-A	100 mmf.	9.50
TC-150-A	150 mmf.	12.50
TC-225-A	225 mmf.	16.00
TC-100-B	100 mmf.	5.50
TC-150-B	150 mmf.	6.50
TC-225-B	225 mmf.	8.00
TC-335-BX	335 mmf.	12.00
TC-450-B	450 mmf.	12.00
TC-225-X	225 mmf.	6.00
TC-350-C	350 mmf.	5.00
TC-500-C	500 mmf.	5.50

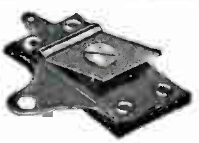
SPLIT-STATOR TRANSMITTING TYPES

Identical to single types except that stator sections are individual. Possibilities of R.F. burns through condenser handle eliminated. "C" types use .038" plate spacing; "X" types — .080" plate spacing and "A" types — .192" spacing.



CODE	CAPACITY	LIST
TCD-500-C	500 mmf. per. sect.	$9.00
TCD-100-X	100 mmf. per. sect.	9.00
TCD-225-X	225 mmf. per. sect.	11.00
TCD-50-A	50 mmf. per. sect.	12.00
TCD-100-A	100 mmf. per. sect.	18.00

STANDARD AND MIDGET EQUALIZERS



Standard type, illustrated at left, is popular 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, illustrated 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 mmf.	$.30

PADDING CONDENSERS

New improved type. Conditioned Isolantite base. Most expensive imported mica used. Tested for capacity, power factor and breakdown at 500 V D.C. 1" x 1⅝".

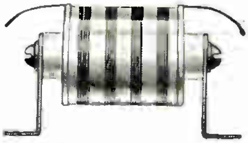
CODE	CAPACITY	LIST
MICS-70	10– 70 mmf.	$ .50
MICS-140	70– 140 mmf.	.60
MICS-220	140– 220 mmf.	.70
MICS-1000	600–1000 mmf.	1.00

TRIMMING CONDENSERS

New double Isolantite type with all the outstanding features of the single type. Phosphor bronze flexible plates shaped to provide substantially straight line capacity increase. Constant capacity and power factor maintained under all varying conditions of temperature, humidity, and vibration. Base 1 15/16". Mounting centers 1½".

CODE	CAPACITY	LIST
MICD-70	10– 70 mmf.	$ .80
MICD-140	70–140 mmf.	.90
MICD-220	140–220 mmf.	1.00

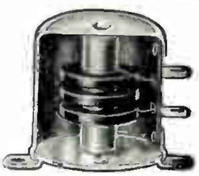
ISOLANTITE R.F. CHOKES



For S.W. and ultra-S.W. receivers, and transmitters. Effective over broadcast band too. Recommended as grid choke for multi-stage 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

R.F. SHIELDED CHOKES



For use in high gain circuits. Universal impregnated wound pies inclosed 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 capacity — 100 ma.

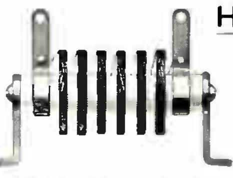
CODE	LIST
CH-10-S	$1.00

R.F. HIGH IMPEDANCE CHOKES

Helical winding choke in bakelite base — 1 13/16" x 1 5/16" in diameter. Ideal for detector plate circuit; R.F. filtering systems in general. Two types — 85 mh. and 250 mh. Current carrying cap. both 60 ma.

CODE	LIST
RFC-85	$2.00
RFC-250	2.25

HEAVY DUTY CHOKES FOR TRANSMITTING



For parallel feed in high powered transmitters — 20- 40- 80- and 160-meter amateur bands. High equivalent impedance more than 500,000 ohms. Effective from 1500 to 15,000 K.C. Six thin universal pies — Isolantite core. 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 2⅜".

CODE	LIST
CH-500	$1.75

R.F. MIDGET CHOKES

So small and so light that they can be supported by own leads. Five impregnated universal wound pies on ¼" Isolantite core. Ind. — 2.1 mh. D.C. res. — 35 ohms. Dist. cap. — 1 mmf. Current carrying cap. 125 ma. Length across caps — 1½". Diameter ½".

CODE	LIST
CHX	$.75

Manufactured by HAMMARLUND MANUFACTURING CO., Inc., 424–438 West 33rd Street, New York

COIL FORMS, COIL KITS, SOCKETS, AND SHORT WAVE MANUAL

For Better Radio
Hammarlund
PRECISION
PRODUCTS

I.F. TRANSFORMERS, FLEXIBLE COUPLINGS AND TUBE SHIELDS

ISOLANTITE SHORT WAVE COIL FORMS

Popular coil form so many fans are using today. Black enameled wooden knob with flat top. With removable paper disc protected by celluloid. Surface "non-skid." Plenty of holes. Eliminates drilling. Slotted bottom for primary or tickler. 4, 5, and 6 prong types. 1½" diameter. 2½" long exclusive, of course, of knobs and prongs.

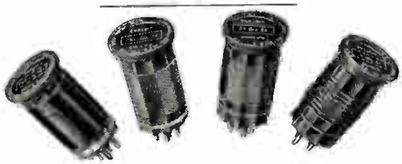
CODE	LIST
CF-4 (4 prongs)	$1.00
CF-5 (5 prongs)	1.00
CF-6 (6 prongs)	1.00

XP-53 COIL FORMS

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" in diameter x 2⅞" long exclusive of prongs. Kits with wound coils also available. Set of 4 coils tuned with MC-140-M condenser covers 17–270 meters. Additional coils for broadcast band too. Secondary of 17–47 and 33–75 meter coils, heavy silver plated wire; enameled copper wire for other secondaries. Kits described below.

CODE	LIST
SWF-4 (4 prongs)	$.35
SWF-5 (5 prongs)	.35
SWF-6 (6 prongs)	.40

SWK COIL KITS



CODE	LIST
SWK-4 (four 4 prong, 2 winding coils, 17–270 meters)	$3.00
SWK-6 (four 6 prong, 3 winding coils, 17–270 meters)	3.75
BCC-4 (one 4 prong, 2 winding coil, 250–560 meters)	1.25
BCC-6 (one 6 prong, 3 winding coil, 250–560 meters)	1.50

STANDARD AND ACORN ISOLANTITE SOCKETS

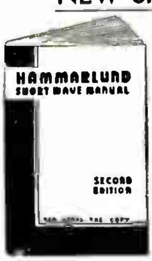
Standard socket at left. Lowest losses. Constant resistivity. Gripped prongs — cannot shift. Guide groove. Rust proof side gripping contacts. Glazed top and sides. Sub-panel or base mounting. 2¼" x 1⅝".

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

Acorn socket at right. Isolantite. For new high frequency acorn tubes—types 954 or 955. 1⅞" in diameter. Five double grip, silver-plated phosphor bronze prongs — eyeletted and lipped to base. Guaranteed perfect contact. Prongs cannot shift or move—a Hammarlund feature. Has alignment plug. Top sides and plug glazed.

CODE	LIST
S-900	$1.50

NEW SHORT WAVE MANUAL



A most valuable short wave guide. Thirty-two pages of important news about short waves and constructional details on the 13 most popular short wave receivers and power supplies, selected from such leading magazines as QST, Radio News, Radio, Short Wave Craft, and the New York Sun. Each unit has been both tested and further improved in the Hammarlund laboratories.

CODE	LIST
SWM-35	$.10

AIR TUNED I.F. TRANSFORMERS

Air tuned primary and secondary units with plate and grid coils of Litz wire. Exception "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 K.C.	$4.50
ATT-465	465 K.C.	4.50
*ATT-175-CT	175 K.C.	4.50
*ATT-465-CT	465 K.C.	4.50
**ATO	465 K.C.	4.50

*Center Tapped Type **Beat Oscillator Type

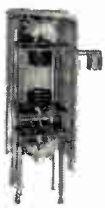
"T" AND "ST" I.F. TRANSFORMERS

For experimental and replacement in superheterodyne midgets, automobile sets, etc. "T" and "ST" type have tuned grid, tuned plate, lattice wound impregnated coils. "ST" type — 2¾" high x 1 7/16" square. Type "T" model — 2⅛" diameter x 3⅛" high. Litz wire used in 465 K.C. types. Standard and center tapped types for split input tube circuits (type "ST" illustrated at right).

CODE	FREQUENCY	LIST
ST or T-465	465 K.C.	$1.65
ST or T-175	175 K.C.	1.65
*ST or T-465-CT	465 K.C.	1.65
*ST or T-175-CT	175 K.C.	1.65
**TBO-465	465 K.C.	2.00

*Center Tapped Type **Beat Oscillator Type

VARIABLE COUPLING AIR-TUNED I.F. TRANSFORMERS



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 with coupling mechanism. Thumb screw adjustment where continuous variation is not required. Impregnated three pie Litz windings. Exceptionally high "Q" of 130. 2" x 2" x 5".

CODE	FREQUENCY	LIST
VT-465	465 K.C.	$5.50
VT-175	175 K.C.	5.50
VTC (variable coupling mechanism for panel control of up to four transformers)		2.00

ALUMINUM TUBE SHIELDS

The complete isolation afforded by this shield permits full use of the enormous amplification possibilities of the new high gain R.F. pentodes of the 2.5 volt and 6.3 volt series. A special drawn-in neck completes the shielding between control grid and plate and a removable top is used to entirely shield the control grid cap. Body, cap, and base are all made of heavy aluminum and designed for maximum cooling. Measures 4⅝" high x 1⅝" diameter. Mounting center — 1 27/32".

CODE	LIST
TS-50	$.40

FLEXIBLE COUPLINGS

A convenience and time saver where tandem operation of independent units is required. Bakelized canvas with brass bushings for ¼" shafts. The over-all diameter is 1½". Four rust-proofed and hardened steel set screws guarantee and assure against any slipping of the shafts.

CODE	LIST
FC	$.60

Manufactured by HAMMARLUND MANUFACTURING CO., Inc., 424–438 West 33rd Street, New York

THE NEW HAMMARLUND "SUPER-PRO"

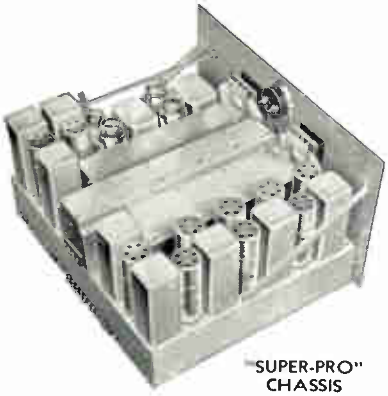
OUTSTANDING FEATURES

- Electrostatically shielded input
- Automatic or manual gain control
- "Send-receive" switch to "kill" receiver during transmission
- Panel control of beat frequency oscillator
- Selectivity continuously variable from front panel
- Band spread tuning
- Separate R.F. and I.F. Gain control
- Speaker-phone switch
- Audio Volume control
- Tone control
- Illuminated main and band spread dials
- Main dial calibrated in mega-cycles and kilocycles

"SUPER-PRO" IN METAL CABINET

The new Hammarlund "Super-Pro" is the outstanding achievement of the Hammarlund laboratories — a 16-tube superheterodyne model with over 100 new major features.

Two 6D6 tubes are used in two tuned radio frequency amplifying stages. One 6C6 is used as a high frequency oscillator electron coupled to the first detector. The first detector is a 6A7. Three 6D6 tubes are used in the three stages of 465 K.C. intermediate frequency amplification. Coupling of these stages is variable and controlled by means of a single front panel knob. One 6B7 is used in a combination fourth I.F. stage and diode second detector. A 6C6 is used as a low frequency beat oscillator. A 6B7 is used for amplified automatic volume control. A 76 is used in the first audio stage resistance coupled. Then comes a 42 used as a Class "A" driver stage. This is followed by two 42's as Class "AB" or "A Prime" push-pull audio output. Two rectifiers are used — a 5Z3 for plate voltage and a 1-V for grid voltage.



"SUPER-PRO" CHASSIS

Complete coverage from 20 megacycles to 540 K.C. (15 to 560 meters) is provided in a most effective manner. This range is covered in 5 bands which are changed by means of a specially designed switch with silver plated multiple contacts, which automatically short circuit all coils not in actual use. The switch presents a radical departure from switches now commonly used for this purpose and embodies the well-known knife principle. The main dial is accurately calibrated in megacycles from 2.5 M.C. to 20 M.C. and in kilocycles from 540 to 2500. Only the scale in actual use is visible. This is accomplished automatically when the band switch is set. The "Super-Pro" receiver consists of two major units — the receiver proper and the power unit.

Standard table model "Super-Pro" in wrinkle finished metal cabinet; power supply also in wrinkle finished cabinet; 16 tubes, and matched electro-dynamic speaker.......................................list $330.00
Quartz Crystal Filter model complete in metal cabinets as described above, 16 tubes and speaker..list $360.00
Rack type, Standard model complete with dust shields with 16 tubes and speaker ....list $367.50
Rack type, Quartz Crystal Filter model, complete with dust shields with 16 tubes and speaker....list $397.50

PRICES COVER 110 VOLT, 60 CYCLE MODELS

Manufactured by HAMMARLUND MANUFACTURING CO., Inc., 424–438 West 33rd Street, New York

RADIO TRANSCEIVER LABORATORIES

DUPLEX TRANSMITTER-RECEIVER UNIT

TYPE TR-53-6A6

For Fixed or Mobile Radiophone Communication

GENERAL: Type TR-53-6A6 Duplex Unit is a medium power Transmitter employing the latest type twin-triodes, unity coupling and Class B modulation; and a four tube super regenerative receiver with tuned r.f. and integral dynamic speaker. It is designed for phone or i.c.w. without the use of external microphone battery or tone. Our laboratory developed the first transceiver using twin-triodes and now offers these compact tubes in an efficient modern duplex unit.

SPECIFICATIONS

Frequency Range: 56 Mc to 60 Mc tuned by a Cardwell isolantite insulated condenser and vernier dial. Also supplied for 30 to 41 Mc experimental frequencies or 28 to 30 Mc amateur band.

Duplex Operation: Duplex or break-in operation is two way transmission and reception similar to that of a land telephone circuit. The operator talks and listens without throwing a switch and he may interrupt the conversation at will, or "break-in." A panel switch knob is provided for turning off the transmitter when listening on the transmitting frequency. Provision for headphones is incorporated.

Carrier Power: 7 watts; completely modulated 28 watts.

Microphone: A single button microphone of the highly damped type should be used in order to avoid acoustic feedback between speaker and microphone. No microphone battery is required.

Power Supply: Transmitter and receiver are separate units completely shielded from each other, and each has its own power supply socket. The unit may be installed with individual power supplies for transmitter and receiver, or both may be connected to the same power source. Supply cables should be shielded to prevent receiver radiation.

Receiver: The receiver employs a super-regenerative detector of the indirectly heated cathode type. No better type of receiver has been developed for ultra-high frequencies to date. The enormous sensitivity of this type of receiver creates a background noise when no signals are received, but this noise is completely eliminated when a strong station carrier is tuned in. A super-heterodyne of equal sensitivity would have as great a noise level and an automatic volume control would be necessary. The super-regenerative receiver has a perfect automatic volume control inherent with the detecting action. Automobile ignition interference is completely eliminated without the use of suppressors.

Radiation Elimination: Radiation from the detector and its attendant interference to other receivers is eliminated by the use of a screen grid *tuned r.f. stage* and careful shielding. The receiving antenna and receiver proper are shielded from detector radiation. The r.f. stage is instrumental in appreciably increasing the signal to noise ratio and overall sensitivity.

3.5 Watt Audio Output: The super-regenerative detector is followed by a stage of a.f. amplification. A volume control is introduced in this circuit as are tip jacks for headphone insertion. The final or output stage employs a power pentode capable of delivering 3.5 watts to the five inch dynamic speaker, which is mounted behind the grill shown in the photograph.

I.C.W.: A jack for the insertion of key leads for code transmission is incorporated. No external tone is required.

Mounting: The entire duplex unit is mounted on a removable panel, is housed in a black crackle finished steel case, and is provided with ventilating louvres and two handles. The latter may be used for securing a strap for carrying or for fastenings in mobile use.

Dimensions: (Width) 15 x (Height) 7½ x (Depth) 7½ inches.

Net Weight: 16½ pounds.

Tubes: Transmitter: 3 — 53 Twin triodes for 2.5 volts.
3 — 6A6 Twin triodes for 6.3 volts.
Receiver: 58, 56, 56, 2A5 for 2.5 volts.
78, 76, 76, 42 for 6.3 volts.

AMATEUR NET PRICE: $39.75. Tubes for above **$4.27**

POWER SUPPLY: 110 volt 60 cycle supply — class B swinging and output chokes, 300V at 200 m.a.; 6.3V at 3.4 amps. and 2.5 volts at 10.75 amps. Complete with cables, plugs, pilot lamp and 5Z3 rectifier tubes **$25.53.**

TYPE PTR-19

For the Broadcasting of Field Events

General: Type PTR-19 is the result of exhaustive experiments with low and medium power transmitters and receivers, and is designed to give maximum power output from self-contained batteries. Previous pack units employing type 30 and 33 tubes were limited to a power output of approximately 0.2 watt. By the use of three twin-triodes type PTR-19 develops ten times the power of the 30–33 combination.

DESCRIPTIVE BULLETIN ON REQUEST

8627—115th STREET, RICHMOND HILL, N. Y.

THIS CATALOG

covers practically the complete Johnson line for 1935–36. An exception is a large variety of commercial-type Inductors, and Fixed and Variable Air Condensers, on which we will be glad to send details. Technical bulletins are available where noted and will be sent on request.

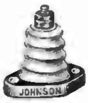
STAND-OFF INSULATORS

The original Johnson Stand-Off Insulators are characterized by perfection of ceramic design, logical proportions and range of sizes, accuracy, and, most important, a very superior quality of porcelain and hardware. The new "Bee-hive" and straight side insulators (styles B and C) have unbreakable cadmium plated drawn steel bases and as usual mount in very little space. Jack types are available in many sizes. Specify white or brown glaze.

A

Cat. No.	Body Height	Hard-ware	Style	List Price
20	1 9/16"	10-32	D	12¢
20J	1 9/16"	74 Jack	D	15¢
22	1"	8-32	D	8¢
24	5/8"	6-32	D	7¢
60	4 1/2"	1/4-20	A	65¢
62	2 3/4"	1/4-20	A	30¢
65	1 3/8"	10-32	C	25¢
65J	1 3/8"	74 Jack	C	30¢
66	2 3/4"	1/4-20	B	40¢
66J	2 3/4"	76 Jack	B	65¢
67	4 1/2"	1/4-20	B	60¢
67J	4 1/2"	76 Jack	B	85¢


B



C

THRU-PANEL INSULATORS

The carefully worked out line of Johnson Thru-Panel Insulators reflect the same qualities possessed by the Stand-Off types. Low absorption porcelain (highly important in R.F. circuits); smooth glazing; solid brass nickel plated hardware with milled nuts; cushion washers; flat, large area mounting surfaces; longer bottom sections with extended leakage path; soldering terminals on jack types—are features of Johnson design. Specify white or brown glaze.


D

Cat. No.	Body Height Top	Bottom	Panel Hole	Hard-ware	List Price
40	1 1/4"	1/2"	1/2"	10-32	25¢
40J	1 1/4"	1/2"	1/2"	74 Jack	30¢
42	7/8"	3/8"	7/16"	10-32	20¢
42J	7/8"	3/8"	7/16"	74 Jack	25¢
44	5/8"	5/16"	5/16"	6-32	14¢
45	1 3/8"	11/16"	9/16"	10-32	30¢
45J	1 3/8"	11/16"	9/16"	74 Jack	35¢
46	2 3/4"	1"	3/4"	1/4-20	55¢
46J	2 3/4"	1"	3/4"	76 Jack	80¢
47	4 1/2"	1 1/2"	1 1/16"	1/4-20	80¢
47J	4 1/2"	1 1/2"	1 1/16"	76 Jack	$1.05

45 and 45J are Style E, all others Style F.

E


F

HANDLE INDICATORS

Highly attractive solid molded bakelite controls which enhance the appearance of any equipment. "Window" design makes possible three separate scales if desired. No. 204 has 4" diameter etched scale with polished figures on black background, and fits ¼" shaft. No. 206 is similar, with 6" scale, fits ¼" shaft, and has removable bushing for ⅜" shaft.

No. 204. Handle Indicator. List Price . **$1.25**

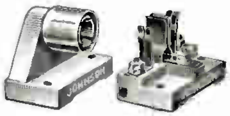
No. 206. Handle Indicator. List Price . **1.80**

TRANSMITTING TUBE SOCKETS

For many years the accepted "best" for mounting "UX" and "50 Watt" tubes, now also made for 5 prong tubes such as the RK28 and RCA803. All have a heavy polished nickel plated brass shell — a necessity for properly supporting transmitting tubes. Contacts are one piece, of heavy cadmium plated phosphor bronze, and make firm wiping side contact with the tube prongs. Connections may be soldered directly to contact springs. "FB" types are for vertical panel mounting and are enclosed in black finished cast aluminum cases. Bases are of fine quality low absorption porcelain — specify whether white or brown glaze.

Cat. No.	Type of Tube	List Price
210	"UX" base	$1.25
210FB	"UX" base	2.50
211	"50 watt"	1.75
211FB	"50 watt"	3.50
216	5 prong	2.50

"250 WATT" SOCKET SET



A new improved mounting for 204A, 849, and similarly based tubes. Plate terminal has "safety cup," preventing accidental displacement of the tube. White glazed low absorption porcelain bases.

No. 215. "250 Watt" Socket Set. List Price **$3.50**

PLUGS AND JACKS

"Banana Spring" Type


74 75

Johnson perfected design, nickel-silver springs, and high grade nickeled brass screw machine parts with accurate threads and milled nuts, result in superior plugs and jacks of this popular type. Studs extend full length of springs. 77A Plug is like 77 but has 10-32 screw for mounting on ceramic coil forms, etc.


76 77

Cat. No.	Thread	List Price
74 Jack	¼-28	6¢
75 Plug	6-32	7¢
76 Jack	⅜-24	30¢
77 Plug	¼-28	25¢
77A Plug	10-32	30¢

"Spring Sleeve" Type

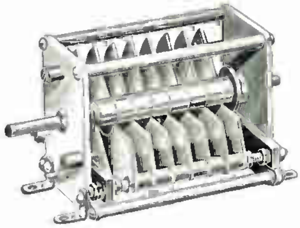

70 71

A Johnson development, to solve the need for mechanically strong, low resistance plugs and jacks, having no "wobble." Made of brass, brightly nickeled, with phosphor bronze spring giving permanent tension and smooth action. Plugs will fit into copper tubing of same size as body, and have holes in threaded ends for soldering leads.


72 73

Cat. No.	Thread	List Price
70 Jack	¼-20	35¢
71 Plug	¼-28	12¢
72 Jack	10-32	20¢
73 Plug	10-32	6¢

TYPE "D" CONDENSERS



Johnson Type "D" Condensers have been specially designed for high frequency transmitting — not merely adapted from receiving condenser parts. Careful engineering has made possible extreme values of capacity and plate spacing in comparatively small bulk. Heavy construction is apparent throughout — in the end plates, tie-rods, rotor and stator plates, spacers, insulation, bearings, contacts. A special feature is the use of MYCALEX insulation on all models without extra cost, with very long path from stator to frame. With all these expensive features, Type "D" Condensers are still among the lowest in price!

The wider plate spacings are invaluable for use with the newer, higher power, more efficient tubes, on which other condensers break down.

Special capacities can be supplied promptly. "D" Condensers are further described in Bulletin 200AH.

Catalog Number		Volts Spacing	Capacity μμf Max. *	Min.	List Price
50D35	Single Section	3500 .080"	46	20	$6.50
100D35			100	23	7.25
150D35			145	27	8.00
250D35			250	34	9.50
350D35			350	40	11.00
500D35			500	53	13.25
50D70		7000 .175"	50	25	7.50
100D70			100	31	9.50
150D70			150	40	11.50
250D70			250	55	15.50
350D70			350	70	19.75
50D90		9000 .250"	50	27	9.00
100D90			100	39	11.00
150D90			150	50	13.00
250D90			250	76	17.00
100DD35	Dual Section	3500 .080"	100	23	$11.00
150DD35			150	27	12.50
200DD35			200	32	14.00
300DD35			300	42	17.00
70DD70		7000 .175"	70	27	12.50
100DD70			100	30	14.75
150DD70			150	38	18.25
200DD70			200	45	22.00
50DD90		9000 .250"	50	27	13.25
100DD90			100	39	17.25

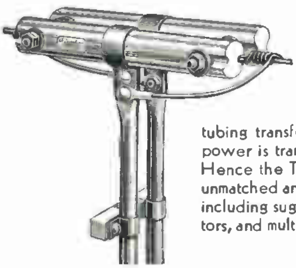
Note These Exclusive Type "D" Features!

Heaviest plates of any similar condensers . . . **MYCALEX Insulation** . . . **Only 4 long insulation paths** compared to 8 or 12 short paths in other condensers . . . **Laminated rotor brushes** front and rear — the best contacts ever used on small condensers . . . **Adjustable Bi-metallic cone bearings** . . . **Heavy tie-rods** provide rigid frame and ample protection . . . **Large diameter spacers** and proper location give exceptional rigidity to both rotor and stator plates . . . **Shafts extended front and rear** for ganging or rear drive . . . **Insulated tie-rods** eliminate "short-circuit loops," reducing tank losses . . . **Higher capacities and greater plate spacings** than are possible in other small condensers.

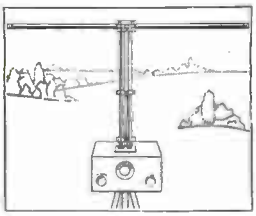
General Specifications

Plates. .051" Aluminum, edges rounded and polished.
End Plates. 1/8" Aluminum.
Insulation. Mycalex.
Shaft. Steel, cadmium plated, 1/4" diameter, extended 1½" front, ¾" rear.
Finish. Frame and spacers etched, plates polished.
Voltage Ratings. Peak breakdown voltages, 'D35 models (.080" spacing) 3500 volts; 'D70 models (.175" spacing) 7000 volts; '90 models (.250" spacing) 9000 volts.

* Capacities given in table are PER SECTION.



TYPE "Q" ANTENNA



The Johnson Type "Q" Antenna has achieved outstanding success in high frequency transmitters throughout the world because of its high efficiency. The special quarter-wave tubing transformer accurately matches line and antenna impedances, and power is transferred with practically no losses even with very long lines. Hence the Type "Q" will radiate TWICE as much power as the common unmatched antenna-feeder system. Bulletin 100H gives further information, including suggestions for coupling to the transmitter, use on harmonic radiators, and multiple band operation.

Cat. No.	Amateur Band	List Price
5Q	5 meters	$6.50
5QM	5 meters	9.50
10Q	10 meters	6.25
20Q	20 meters	9.90
40Q	40 meters	17.50
80Q	80 meters	32.75

SPECIAL 5 METER "Q" ANTENNA

This special form of "Q" antenna for 5 meters is designed for convenient installation with fixed or portable transmitters. May be mounted directly on the transmitter case, or suspended in the air with a transmission line back to the equipment. Impedances remain accurately matched in both cases. Suitable Mycalex insulated fittings are made for convenient line construction, and are described in Bulletin 100H. The 5QM is a special model, Mycalex insulated in place of porcelain.

ENAMELED COPPERWELD ANTENNA WIRE

Developed for use with the "Q" Antenna, Johnson Enameled Copperweld Antenna Wire is the ideal material for transmitting doublets, directional antenna systems, and other applications where the wire must not stretch nor sag. It has a steel core, welded to a heavy copper exterior and enameled, combining high R.F. conductivity, freedom from corrosion, and almost three times the strength of ordinary enameled copper antenna wire.

No. 350 Antenna Wire. 12 ga. List, per ft. . . . . 1½¢
No. 352 Antenna Wire. 14 ga. List, per ft. . . . . 1¢

E·F·JOHNSON·COMPANY
MANUFACTURERS OF *Radio Transmitting Equipment*
WASECA·MINNESOTA·U·S·A

Johnson equipment is sold at usual discounts by nearly all good suppliers. If necessary, orders may be sent to us, stating the name of your usual jobber.

"HI-Q" INDUCTORS

Johnson "Hi-Q" Transmitting Inductors are ideal for modern amateur transmitters. High electrical efficiency is secured by proper proportions, generous conductor size, and the use of excellent hard rubber insulation correctly applied. Johnson edgewise wound copper (nickel plated) produces inductors unequalled for compactness, rigidity, and ease of adjustment. The flat surface offers excellent contact to our LC4 Clips, which can be accurately placed and readily moved to any spot on the coil. This greatly facilitates coupling adjustments, use of band change switches, retuning, etc.

For Impedance Matching Networks, two special "Hi-Q" Inductors are provided, for balanced and unbalanced circuits. Johnson 350D35 or 350D70 condensers are suitable for these networks on all amateur frequencies.

Cat. No.	μh	List Price
620	88	$9.25
622	44	6.95
624	21	6.05
626	10	4.90
628	4.4	4.40
†619	2.0	4.90
†623	0.8	4.10
†627	.26	3.55

†Generally used as coupling coils with tank coils bearing adjacent numbers.

For further information, get Bulletins 350H on "Hi-Q" Inductors, and 130H on Impedance Matching Networks.

LC4 Inductor Clip. A nickel plated phosphor bronze clip with tinned copper soldering terminal. Not included with inductors and should be ordered separately. List Price . . . . **20¢**

* If dual-section condensers are used, each section must be double the indicated capacity.

** "Two Units" refers to two coaxial inductors in series, usually with a coupling coil between them, as in balanced tank circuits.

Commercial types of inductors are described in Bulletin 300H, free on request.

RECOMMENDED TANK CIRCUIT COMBINATIONS

Amateur Band Meters	Tuning* Capacity μμf	Inductor** Single Unit	Two Units
160	100 200	620 622	622
80	50 100 200	622 624 626	624 626
40	25 50 120	624 626 628	626 628
20	15 30	626 628	628

Slotted Hard Rubber Mounting Strips

Three required for each coil. Easily sawed. First two figures in catalog number give number of slots.

Cat. No.	Coil Dia.	μh Max.	Turn Spacing	List Each
19256	2½"	7.2	3/8"	45¢
17254	2½"	8.5	1/4"	40¢
25254	2½"	14	1/4"	55¢
26304	3"	20	1/4"	55¢
36304	3"	30	1/4"	60¢
31403	4"	52	3/16"	45¢
46403	4"	86	3/16"	65¢

INDUCTOR PARTS

Inductors similar to our "Hi-Q" types may be constructed in any size desired by the use of the Edgewise Wound Copper Strip (not plated), Hard Rubber Mounting Strips, and Cast Aluminum Bases here listed. Copper is 1/16" x 1/4", and can be furnished in many additional sizes as well as heavier material. Bulletin I-352H contains full instructions.

Edgewise Wound Copper

Inside Diameter	List Price Per Turn
2½"	6¢
3"	7¢
4"	8¢

Cast Aluminum Mounting Bases
Two required for each coil

Cat. No.	For Coil Diameters	List Price Each
403	2½"–3"	20¢
404	4"	20¢

ANTENNA INSULATORS

107
112
120

151
152
153

These insulators are of genuine WET PROCESS porcelain with smooth white glazing. The all-porcelain types are 1" in diameter and will stand 1500 pounds pull. Their long leakage path, low capacity, and freedom from moisture absorption result in exceptional efficiency. The new Commercial Type is 1½" in diameter for uses where much greater strength is necessary. The aluminum alloy fittings are non-corrosive. Overall lengths 7½" greater than leakage paths listed.

Cat. No.	Length	List	Cat. No.	Length	List
107	7"	$0.70	151	8"	$7.00
112	12"	.90	152	12"	8.50
120	20"	1.50	153	18"	12.00

STRAIN INSULATORS

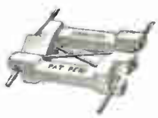
The No. 32 Airplane Strain Insulator is also very useful for light guys and receiving antennas. The new No. 38 "Cruciform" Strain Insulator is specially designed for R.F. applications, having low capacity, long leakage path, light weight. Both are 1½" long, of white glazed low absorption porcelain.

No. 32 Airplane Insulator. List . . . . **7¢**

No. 38. Strain Insulator. List . . . . **15¢**

TRANSPOSITION INSULATORS

Much used for both receiving and transmitting feed lines. This original Johnson Insulator simplifies installation, weighs very little, does not twist the line, and has high insulating value. White glazed low absorption porcelain.



No. 31. Transposition Insulator. List Price **12¢**

FEEDER SPREADERS

A new Commercial Feeder Spreader of best WET PROCESS white glazed porcelain. Heavy duty type, 7/16" x 5/8" x 6".

No. 146. Commercial Type Spreader. List Price . . . . **40¢**

No. 132 2" long. List Price . . . . **12¢**
No. 134 4" long. List Price . . . . **15¢**
No. 136 6" long. List Price . . . . **20¢**

Every amateur transmitting and receiving need is supplied by these new 2", 4", and 6" feeder spreaders. ⅜" x ½" cross section, of white glazed low absorption porcelain.

An Engineering and Construction Service, devoted wholly to Amateur Transmitters, offers these facilities—

High-Power C.W. Transmitter

Medium-Power Phone Transmitter

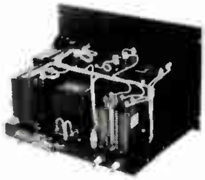
» Many years experience in building hundreds of amateur transmitters, from five watts to one thousand watts.

» What we believe to be the best engineering talent in the country.

» Excellent laboratory facilities for development and testing.

» A well equipped shop where proper tools and machinery keep down construction costs.

1200-600V-Bridge Rectifier



Power Unit 2,000V-500MA

» An able and experienced group of workers who are themselves radio amateurs and therefore appreciate and understand amateur problems.

» A location in the center of the parts-manufacturing industry, where components can be bought economically and promptly.

Liner Sweep Cathode Ray Oscilloscope

» The determination to hold our reputation for building, at moderate cost, the very best in amateur transmitters.

Reconstruction of 160M. Phone W2HVY

Before modernizing your present equipment or buying a new transmitter, phone or c.w., let us tell you what we can do in a transmitter built to fill exactly your individual needs; and to fit your pocketbook as well. It is altogether probable that we can save you quite a tidy sum. A few of our recent jobs are illustrated on this page—we shall be happy to give as references the names of their thoroughly satisfied owners.

RADIO APPARATUS CORPORATION

240 Central Avenue, Newark, New Jersey

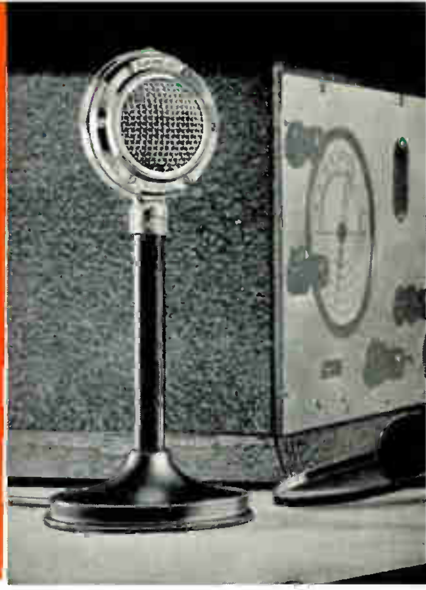
Telephone: Market 3-2020

F. L. KALTMAN—SALES
W2AFQ

HUGO ROMANDER—ENGINEERING
W2NB

• USE SHURE MICROPHONES

for Amateur Communications Applications



73A Crystal Lapel Microphone. Only 2 inches in diameter — weighs less than 2 ounces — permits the speaker to move freely, yet assures correct pickup at all times. Exceptionally faithful response. Furnished with 25 feet of shielded cordage and lapel clip. List Price **$25**

70H Crystal Microphone. A general purpose, diaphragm-type microphone, adopted by 35 leading amplifier and transmitter makers because of superior quality "Wide-Range" reproduction. Special Curvilinear Diaphragm and exclusive "Cantilever" crystal actuation. Mounts on stand or in carbon ring. Complete with 7 feet of cable, mounting ring and 4 "Quickway" hooks. List Price **$22.50**

70S "Communications Type" Crystal Microphone. Specially designed for high-efficiency 'phone work. Doubles sideband power on "intelligibility" speech frequencies for clear, crisp signals that cut through noise and static. Connect as you would an ordinary crystal microphone. Complete with integral rubber-black Desk Mount and 7 feet of shielded rubber-jacketed cable. Chromium plated head. List Price **$25**

Guarantee

Every Shure Microphone is guaranteed to be free from mechanical and electrical defects for a period of one year from date of shipment from the factory provided all instructions are complied with fully.

Shure Crystal Microphones are licensed under patents of the Brush Development Company.

● The 6 models listed on this page have been selected because of their particular suitability for most amateur radiophone stations. The complete SHURE line contains **more than 100 Microphones, Stands and Unit Accessories** . . . . Complete Microphone Equipment for every Microphone Application! There are general-purpose Crystal, Carbon and Condenser microphones, "Wave-Equalized" High-Fidelity Crystal and Condenser microphones and the new "Spheroid" Non-Directional Crystal Microphone for High-Fidelity service. SHURE Microphones are stocked by Authorized Distributors throughout the world. For complete information on any item, ask your Jobber or write.

MICROPHONE REPAIR SERVICE

All microphones require occasional repairs. All carbon microphones need reconditioning at least once every year to maintain sensitivity and quality.

"Microphone Headquarters" long experience in building Shure Microphones and repairing microphones of all types and manufacture, together with precision testing equipment and comprehensive stocks of replacement parts, makes possible an economical, prompt, reliable repair service — a service used by many leading broadcast stations. Ask your Jobber or write for quotations.

71A Crystal Hand Microphone. A crystal microphone, in convenient form, specially designed for "close-talking" and minimum background noise. Furnished with 7 feet of shielded rubber-jacketed cable. List Price . . . . **$25** (Models with switches, as well as "non close-talking" models, are available in both crystal and carbon types.)

3A Two-Button Microphone. Where economy is most important, this Two-Button carbon microphone is the solution. Standard Shure features, including screen-protected diaphragm and "Quickway" hooks. Overall diameter 3⅛". Thickness ½". Net weight 5½ ounces. Brightly nickel plated. List Price **$6.50**

5B Two-Button Microphone. A full size Two-Button carbon microphone with precision adjustable buttons. Screen-protected diaphragm and convenient "Quickway" hooks. Chromium plated. Overall diameter 3¾". Thickness 1 1/16". Weight 5 ½ ounces. Truly outstanding for 'phone or general-purpose use. List Price **$10**

SHURE BROTHERS COMPANY

Manufacturers Engineers — *Microphone Headquarters* — *Cable Address SHUREMICRO*

215 WEST HURON ST. CHICAGO, U. S. A.

Greater BAND SPREAD

Less NOISE

INCLUDES THE PRE-ADJUSTED, PRE-ALIGNED TOBE TUNER

EXCLUSIVELY FOR 160-80-40 & 20 METER AMATEUR BANDS

TOBE AMATEUR Communication RECEIVER

We Ask You to Compare It

on merit alone

with your favorite communication job

REGARDLESS OF PRICE!

What Do You Demand of Your IDEAL COMMUNICATION RECEIVER?

Is it SENSITIVITY You Want?—

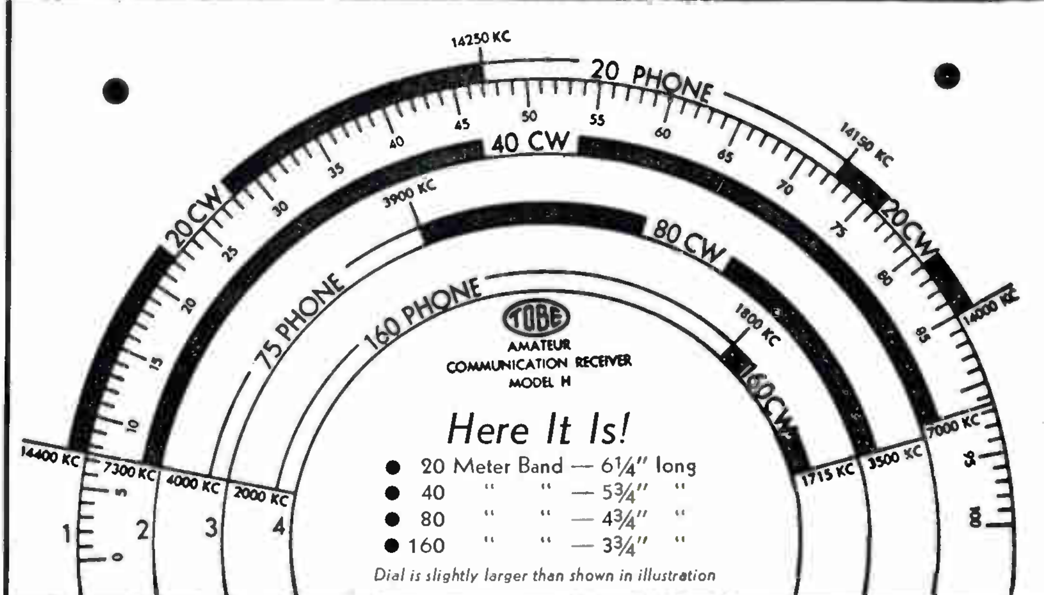
The TOBE receiver has more than you need. Better than 1 microvolt on all bands.

SELECTIVITY?—

In addition to the sharply tuned preamplifier the I.F. band pass amplifier, incorporating six tuned circuits, may be adjusted for regenerative S.S. reception with perfect manual control on panel front.

AND—

IF *You're looking for* BAND SPREAD



True Electrical Band Spread

Low maximum capacity tuning condensers giving high L/C ratio

NO TANK CONDENSERS ARE USED

Even the two-inch 360° vernier dial logs absolutely with NO backlash

---

THE TOBE COMMUNICATION RECEIVER

R.C.A. LICENSED

is supplied in kit form only, in two models:—

STANDARD (highest quality mica trimmers) . . . . Net $46.40

TOBE SPECIAL (for particular Hams, all critical circuits air trimmed) $52.40

These prices cover complete chassis kit and Wright-DeCoster 1000-B, 8″ dynamic speaker in metal cabinet.

TOBE AMATEUR TUNERS, as used in above sets, completely wired, with dial, fittings, etc:

Standard (mica trimmed) $19.95

Special (air trimmed) $25.95

Catalog sheet on metal cabinet, speaker, special escutcheon, etc., for these receivers will be gladly forwarded on request

TOBE DEUTSCHMANN CORP.
Canton, Massachusetts
Export Dept: 105 Hudson St., New York, N.Y.

Write FOR YOUR COPY OF NEW JEFFERSON CATALOG

Complete

LISTINGS
OF CHOKES —
AUDIO,
POWER,
PUSH-PULL,
MICROPHONE,
CLASS "B" DRIVER,
MODULATION,
LINE & MIXING,
TRANSFORMERS

Your WHOLESALER
CAN SUPPLY YOU AT THE
USUAL AMATEUR DISCOUNT

JEFFERSON ELECTRIC COMPANY

BELLWOOD (Suburb of Chicago) ILLINOIS

CANADIAN FACTORY: 535 COLLEGE STREET, TORONTO

JEFFERSON *Radio* Transformers

SPRAGUE CONDENSERS

Short Wave HIGH FREQUENCY BY-PASS TYPE

The Ideal Mica Replacements

If you haven't tried these popular Sprague units, you're missing a real treat! Guaranteed as excellent mica substitutes for Short-Wave By-Passing and many other uses except R.F. Much smaller than mica — cost far less — and you can't break them down. Metal encased, non-inductive, low power factor, oil impregnated, 1500 V. and 1000 V. continuous D.C. rating.

Cat. No.	Capacity	Working Voltage	Dimensions Diam. Lgth.	List Price	Your Price
SW–22	.002	1500	9/16" by 1 9/16"	$.45	$.27
SW–25	.005	1500	5/8" by 1 11/16"	.45	.27
SW–11	.01	1500	11/16" by 1 11/16"	.70	.42
SW–12	.02	1500	11/16" by 1 11/16"	.75	.45
SW–15	.05	1000	7/8" by 2 1/4"	.80	.48
SW–1	0.1	1000	7/8" by 2 1/4"	.90	.54

FAMOUS "EC" DRY ELECTROLYTICS

IMPROVED TYPE—DOUBLE TESTED

Exclusive new improvements make these famous Sprague "600" Line "EC's" far and away the best Dry Electrolytics you've ever used *AT ANY PRICE*. Each unit is DOUBLY TESTED — then backed with our ABSOLUTE GUARANTEE which doubly assures your satisfaction. They have extremely good humidity characteristics, low leakage, low power factor (averaging 5%) and will stand high surges. The original 600 volt condensers in one standard voltage for all jobs — and the best! Sold singly or in Emergency Kits containing complete handy assortments.

Cat. No.	Capacity Mfd.	Dimensions	List Price	Your Price
EC–50	.5	2 1/8 x 1 x 7/16	$.80	$.48
EC–75	.75	2 1/8 x 1 x 7/16	.85	.51
EC–1	1	2 7/16 x 1 1/8 x 9/16	.85	.51
EC–2	2	2 7/16 x 1 1/8 x 9/16	.95	.57
EC–4	4	2 7/16 x 1 1/8 x 11/16	1.15	.69
EC–6	6	2 7/16 x 1 1/8 x 1 1/8	1.30	.78
EC–8	8	2 7/16 x 1 1/8 x 1 3/8	1.35	.81

SPRAGUE TRANSMITTING CONDENSERS

Oil Impregnated — Oil Immersed—
Full Voltage Information on Every Label

If you're tired of buying transmitting condensers of higher voltage ratings than you actually need in order to play safe . . .

If you're tired *guessing* as to what you can expect of them . . .

. . . Then try Sprague Oil Condensers. They're rated to conform to tube characteristics. The labels give you *complete* voltage information. These condensers are of the smallest size at the highest voltage and of the most popular type ever offered. Oil impregnated and oil filled. Sold by leading jobbers.

Cat. No.	Capacity	D. C. Working Voltage	Surge Voltage	List Price	Your Price
OT–11	1 Mfd.	1000v	1500v	$2.50	$1.50
OT–21	2 Mfd.	1000v	1500v	4.50	2.70
OT–22	2 Mfd.	2000v	3000v	8.00	4.80
OT–41	4 Mfd.	1000v	1500v	7.00	4.20
OT–27	2 Mfd.	700v	1000v	3.50	2.10

SPRAGUE 600 LINE

MIDGETS
•
TUBULAR AND BATHTUB BY-PASS TYPES
•
"500" WET ELECTROLYTICS
•
WET & DRY ELECTROLYTICS
•
MULTIPLE UNITS
•
AUTO RADIO & VIBRATOR CONDENSERS
•
ETC., ETC.
Write for Catalog
•
SPRAGUE PRODUCTS CO.
North Adams Mass.

BARGAINS—ARMY AND

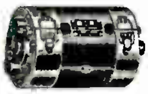
EDISON STORAGE BATTERIES
ALL TYPES
1.2 VOLTS PER CELL

A & B Type

A-4	Amps. 175. Per cell	$3.50
A-6	Amps. 225. Per cell	$4.00
A 8	Amps. 300. Per cell	$5.00
B-4	Amps. 90. Per cell	$3.50
M-8	Amps. 11. Per cell	$1.00
L-40	Amps. 25. Per cell	$1.50
J-3	Amps. 37. Per cell	$3.00
A-12	Amps. 450. Per cell	$10.00

L & M Type

DYNAMOTORS



Dynamotor 32/350 volt, bail bearing, 80 mills. Special $9.00. Per pair . . . $15.00
24–750 volt Gen. Electric 200 mills . . . $27.50
24–1500 Gen. Elec. 2½ kw. output . . . $95.00
12–350 volt 80 mills . . . $18.00
12–750 volt 200 mills . . . $30.00

12–750 volt 1000 mills . . . $50.00
32–350 volt 80 mills . . . $9.00
32–300 volt 60 mills . . . $7.50
Dynamotor armatures, General Electric triple commutators, d.c. 24/1500 volt . . . $12.50

Navy Aircraft Dynamotor, Gen. Elec., new, 24/1000 volts, 1 amp., extended shaft with pulley, can be driven by motor. or propeller, giving 24 volts output for filament and 1000 volts for plate or driven by its own input of 24 volts. Value $250.00. Our special price . . . $50.00

Complete portable telephone outfit. Has heavy bronze breastplate with 25 ft. waterproof wire and plug. Used with dry cells and 100-ohm mike transformer . $3.95

Dubilier Condenser. Type CD-1494 mica transmitting .0006 mfds., 25,000 volts. Price . $10.00

WE Model 1918 Field Telephone Set, Magneto ringing, Battery talking. Also used as buzzer phone. Complete with sending key, microphone and headphones . . . $10.00

H & H Push-button Momentary Contact (make or break) switch, 250 volt, 10 amp., two circuit, one normally open, one normally closed . . . 50c

MOTOR GENERATORS

120 d.c., 110 or 220 a.c., 500 cycle, 250 watt . . . $30.00
120 d.c., 110 or 220 a.c., 500 cycle, 500 watt . . . $40 to $95.00
120 d.c., 110 or 220 a.c., 500 cycle, 1 kw . . . $75 to $100.00
120 d.c., 110 or 220 a.c., 500 cycle, 2 kw . . . $50 to $150.00
120 d.c., 110 or 220 a.c., 500 cycle, 5 kw . . . $95 to $250.00
120 d.c. to 20 d.c. 2 kw . . . $60.00
120 d.c. to 400 d.c. 2 kw . . . $45.00
120 d.c. to 600 d.c. 2 kw . . . $65.00

CONVERTERS

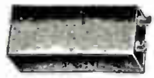
120 d.c., 120 a.c., 60 cycle, 2 kw . . . $85.00
Converters, 32 d.c. — 110 a.c., 400 mills . . . $15.00
Converters, 32 d.c. — 110 a.c., 800 mills . . . $20.00
Converters, "Dayton", input 110 a.c., 60 cycle, output 450 d.c., 80 mills and 7 d.c. 1.75 amps. 1750 r.p.m. also has extended ½" shaft. Complete . . . $40.00
Wappler X-ray Co. 110 or 220 d.c. input — 75 or 150 a.c. output.
1 KVA . . . $35.00 — *1½ KVA* . . . $45.00
3 KVA . . . $60.00 — *5 KVA* . . . $75.00

GENERATORS

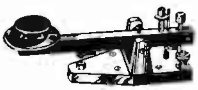
110 volt a.c. 900 cycle, self-excited 200 watts . . . $10.00
120 volt a.c. 600 cycle, self-excited 250 watts . . . $15.00
110 volt a.c. 500 cycle, self-excited 250 watts . . . $25.00
1500 volt d.c. 660 mills, 1 kw. Esco 1750 r.p.m. . . . $45.00
240 volt 500 cycle, self-excited 2500 r.p.m. 250 watt (also hand drive) . . . $25.00
120 volt d.c. 5 kw . . . $60.00
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
12 volt d.c. 60 amp . . . $15.00
12 volt d.c. 33 amp . . . $7.50

(J-3 cells)

NEW — Edison Storage Battery, Army Type BB-1, 10 volt, 37 amp., contains 7 cells. Complete in steel portable case. $15.00



Condensers, W. Elec. type 21AA, 1000 volt A.C. test, 1 mfd . . . $.75



Army Aircraft Type J-3 solid brass transmitting key, large Tungsten contacts, beautiful action. $1.50

U. S. Army Morse Key and Sounder — mounted on panel . . . $1.95

METERS

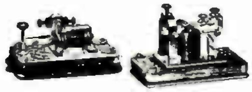
GE Type DO-14, 3 inch flush mounting voltmeters. Single scale 0–25, 0–250, 0–750 (less external resistors on 0–250 and 0–750) . . . $3.50

Roller-Smith 0–10 milliammeter, 3 inch flush mounting . . . $1.95

Webster ¾" spark coil, 110 volt 60 cycle, 30 watts, with vibrator . . . $3.00

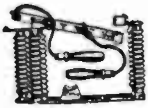
Century and Mesco high frequency navy type buzzers . . . $2.00

Westinghouse oil X-ray transformers, 100,000 volt, 30 milliamps., 3 KVA, 220 volt, 60 cycle, single phase . . . $90.00



Western Electric Relay with Adjustable Platinum Contacts. Capable of controlling a local circuit of comparatively high voltage, with a very low primary consumption. (6 volt battery.) . . . $3.50

Army Signal Corps 20-Ohm Telegraph Sounder. For operation on 6-volt battery or dry cells . . . $1.50



Lightning switch, ceiling type, heavy brass. Can handle 10 K.W. . . . $4.50

MINNEAPOLIS HONEYWELL LOW CURRENT

AC Relay, single pole, double throw, silver contacts, will handle 30 amps. 110 or 220 volt . . . $3.00

ARMY HEADPHONE RECEIVER

100 ohm . . . $.75

U. S. Navy Phones. 80 ohms. Excellent for practice and code instruction purposes. High grade make . . . $.75

Westinghouse Type CX 3" dia. D.C. meters:
0–2 Amperes . . . $4.50
0–50 Amperes . . . $6.50

Ward Leonard Vitrohm Rheostats. Variable 500 ohm, .2 to 1.5 amp., 35 taps, field regulation type . . . $5.00

Ward Leonard Vitrohm Rheostats. Variable 6 ohm., 15 to 5 amp. battery charging type . . . $3.50

Slide Wire var. rheostats 125 ohm 2.5 amp . . . $1.25

Slide Wire var. rheostats 250 ohm 1 amp . . . $1.00

Resistors, Edison base W.L 600–900–2000 ohm . . . $.25

Western Electric type 21AB condensers. 1000 V. a.c. test. Three capacities, .125, .25 and .5 mfd. Each . . . $.75

Wireless Spec. copper gladd leyden jar, 10,000 working voltage, .002 mfd . . . $2.00

Bunnell Resistance Box. 1 to 10,000 ohms. A beautiful piece of laboratory or test apparatus. Complete with plugs. Special price $15.00

Switchboard. 8-line portable Western Electric. Magneto ringing dry cell talking circuits. 8 drops, 26 anti-capacity key switches. Regular price, $175. Special . . . $30.00

Radio Frequency Driver. 6,000 to 30,000 meters. Navy type SE1603. Cost $180. Special . . . $7.50

MOTORS

New ¼ h.p. single-phase 60 cy. double shaft ½" 1750 r.p.m. Diehl 110 v. . . . $8.65
New .6 h.p. 2-phase 60 cy. 220 v. 3450 r.p.m. Westinghouse. $15.00
New 1¼ h.p. 1-phase 60 cy. 110 or 220 v. 3450 r.p.m. Diehl $40.00
New ½ h.p. DC 115 v. 3450 r.p.m. Westinghouse . . . $15.00
New ½ h.p. DC 230 v. 3450 r.p.m. Westinghouse . . . $15.00

NAVY RADIO SURPLUS

Voltmeters, D.C. portable new Weston model 45, 3 scale 0–3–15–150 guaranteed ¼ of 1% accurate.............$40.00

Ammeters, D.C. portable, new Weston model 45, 3 scale 0–1.5–15–150 with 3 scale external shunt and leads ¼ of 1% accurate....................$30.00

Army Portable Radio Transmitter and Receiver, Type BC-9A..........$15.00

Army Radio Tuner, Type BC-115. $5.00

Army Radio Telegraph Tube Transmitter, and Receiver Type BC-32 A..$15.00

Army Amplifier — uses 7 VT-5 (peanut) tubes, Type BC-116-A..........$7.50

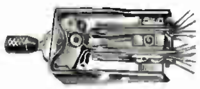
Army Detector and Audio Amplifier, Type BC-101-B...............$7.50

Army Radio Amplifier, Type SCR-72, 2 stage.......................$5.00

GR Type 107-F variable inductor..$10.00

GR Type 101-L variable capacitor.$15.00

Baldwin Head-phones, Genuine Mica Diaphragm 2000 ohm. Regular $15.00 value..$3.50



Anti-Capacity Switches

W.E. 12 and 14 Terminals, all with Platinum Contacts, value $3.50 each. Our price, 95c each.

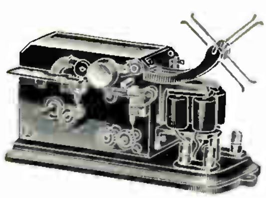
Ampere hour meter, Sangamo, battery charge and discharge. Type MS. 0 to 400 scale, capacity 15 amp. $10.00

Famous Minneapolis Honeywell furnace heat control motors. Will open and close damper automatically and maintain even temperature when used with thermostat. $12.50

With built in switch for operating blower, furnace fan, oil burner, etc........$15.00

We also have Blower with motor...$12.50

Army wavemeter — 150 to 450 meters — with Century high-pitch buzzer and flash-lamp indicator.................$5.00



Telegraphic tape register, 10 ohms. May be used to intercept dial phone calls. Has innumerable uses. Used $15.00. Reconditioned $20.00

Condensers, Mica, op. volts 12,500, cap. .004 Dubilier, new....................$17.50

Dubilier, used....................$15.00

Wireless spec. new...............$15.00

Wireless spec. used...............$12.50

Condenser, Dubilier, mica, volts 40,000, cap. .0012–.001–.0008 or .003..........$10.00

Condenser, Dubilier, mica, op. volts 8,500, cap. .004.......................$5.00

Condenser, Dubilier, mica, op. volts 8,500, capacity .0004 mfd.................$5.00

Condensers, Murdock .002 mfd. 5000 volt. $1.00

Westinghouse Type LD oil condensers — 3.6 mfd. 3500 v. operating..............$30.00

.47 mfd. 10,000 v. operating........$70.00

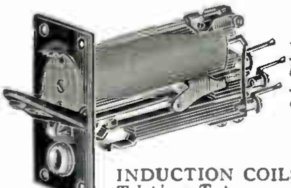
RELAYS

Relay, low voltage line, cap. 2 amp. 60c each, two for $1.00. Silver contacts.

Relay West. Elec. low voltage, 2 upper and 3 lower platinum point screws, 3 contact arms. $5.00

Relays, West. Elec. types, 122-AB, 122-DH, 149-T, 172-B....................$2.50

Transformers, G.E. current type, 125 to 2500, with center tap, 60 cycle, 200 watt......$7.50

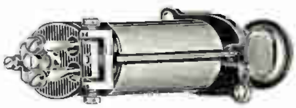


Relay and Jack Combination 350 ohms, 6 volt, $1.00

INDUCTION COILS, *Battery Telephone Type............$.75*

W.E. TELEPHONE TEST SET

No. 175–125 W. has large variety of uses. Price........................$4.50



SPECIAL

Can be used with the new Vacuum Contact when operated on 45 volts. Western Electric Signal "Drops," 1000 ohm, type D-12.............................$1.00

Microfarad meter, Weston portable, model 372, cap. .0002 to .003 volts 220 cycle 500...................$85.00

Transformer D.C., Gisholt, Underwriters approved, auto. relay type. 110 to 10 volts.........................$25.00

Motors, Universal 1/12 H.P. 110 volt, backgeared, R & M, 2 R.P.M.....$7.50

Motors, all voltages and freq. 1/30 H.P. backgeared M. H. ¼ R.P.M.....$10.00

Motors, Synchronous, 110 or 220v 60 cycles 1800 R.P.M. ¼ H.P......$10.00

Motors, Synchronous, 110 or 220v. 60 cycles 1800 R.P.M. ½ H.P.....$17.00

Motors, Vertical 110v 60 cycles R & M ¼ H.P. 1800 R.P.M..............$9.85

Motors, Universal, Dumore 1/12 H.P. 110v.........................$5.00

Motors, G. E., 3 speed, all voltage and freq. Large frame 1/15 H.P. ½" shaft $5.00

Turbo-generator, Westinghouse 4000 R.P.M. 10 KW 120 DC 150 Lb., used $175.00 new................$325.00

Relays, W. E. type "E" high res. multi-contact...................... $.75

Decremeter, Kolster, Bureau Standards type "C". 300 to 10,000 meters....$35.00

Wavemeter, Firth, 1000 to 20,000 meters $20.00

Magnetos, French, army mine type. $1.00

Buzzerphones, model 1914 army, both phone and telegraph, complete, each. $5.00

Microphone cable, No. 18-3, shielded type $ per hundred feet..............$7.00

Transformers, 1.5 KVA 220 to 3500v 60 cycles......................$25.00

Transformers, 3 KVA 220 to 12,000v 60 cycles......................$45.00

Transformers, 5 KVA 220 to 12,000v 60 cycles......................$60.00

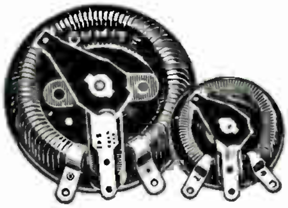
We have on hand thousands of items, too numerous to mention, suitable for laboratory, shop and experimental use. New items are received daily. A visit to our seven story warehouse will be well worth your while. We invite inquiries on the various pieces of equipment listed on these pages, or on your needs which we can probably supply, at bargain prices, from our immense stock.

Dept. H, 105-7 Fulton Street, New York City

OHMITE

Rheostats—Resistors—Chokes

Vitreous Enameled Rheostats



Ohmite all-porcelain, vitreous enameled rheostats are available in six physical sizes as follows: Model H — 25 watt, Model J — 50 watt, Model K — 100 watt, Model L — 150 watt, Model N — 300 watt, and Model R — 500 watt. These rheostats are the only ones having all of the following features — wire wound over a porcelain core — rheostats have many steps of resistance — wound core is fused to porcelain base with vitreous enamel — contacts are of metal-impregnated graphite — shafts and bushings are insulated from electrical circuit — all units approved by Underwriters' Laboratories.

"DIVIDOHM" Semi-Variable Resistors

These vitreous enameled adjustable units have a great many uses in radio work; they make excellent voltage dividers as several adjustable lugs may be used on one unit; the "ball-point" contact shorts out little resistance yet makes a firm connection to the bared space on the winding. Made in six sizes — 25 watt, 50 watt, 75 watt, 100 watt, 160 watt, and 200 watt, in resistance values from 1 ohm through 100,000 ohms. Mounting brackets and one adjustable lug furnished with each unit.

"BROWN DEVIL" Vitreous Resistors

These are companion units to the Red Devils; two sizes are available, 10 watt in resistance values from 1 ohm through 25,000 ohms and 20 watt in resistance values from 5 ohms through 100,000 ohms. Units are wire wound and have coating of vitreous enamel which insulates the winding and protects it against moisture. Because the high resistance units (above 50,000 ohms) will seldom dissipate much wattage, they have been coated with a special low temperature enamel. All Brown Devils have tinned wire leads which make for easy connecting or soldering.

"RED DEVIL" Cement-coated Resistors

These famous wire wound resistors are made in both 10 watt and 20 watt sizes; resistance values run from 1 ohm through 25,000 ohms in the 10 watt size and 30,000 to 100,000 ohms in the 20 watt size. Because of their high temperature cement coating Red Devils will handle extreme overloads without failing; even *red heat* will not cause these units to burn out. They have many uses in amateur work and should be used in applications within their range which require ruggedness and long service. Units have tinned wire leads for connecting.

Vitreous Enameled Fixed Resistors

Now made in five sizes: 25 watt, 50 watt, 100 watt, 160 watt, and 200 watt. Resistance values range from 5 ohms through 250,000 ohms. Wire wound over porcelain core and covered with Ohmite vitreous enamel; connections made to terminal lugs both mechanically and by brazing thus assuring permanent, trouble-free, constant resistance units. All are furnished complete with mounting brackets as shown. These are units you can depend on for receivers or transmitters.

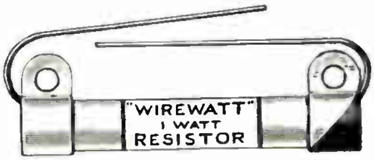
"MULTIVOLT" Tapped Vitreous Resistors

These are vitreous enameled resistors which have ten equal sections. They were especially designed for amateur work as they make ideal voltage dividers and bleeders. Even though the entire winding is covered, adjustments may easily be made by connecting to the lugs with spring clips; thus plate voltages may be adjusted as required. Made in three sizes — 50 watt, 75 watt, and 150 watt. Mounting brackets furnished with units.

OHMITE

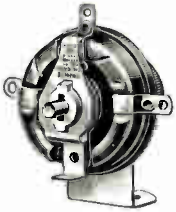
Resistors—Switches—Handbooks

"WIREWATT" One-watt Resistors



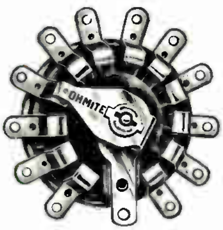
These small one-watt wire wound resistors have many uses, especially in receivers; they are available in resistance values from 100 ohms through 25,000 ohms. Because they are wire wound, they have no voltage or temperature characteristics and are absolutely quiet in operation. Winding is covered with moisture proof material which also insulates against short circuits. Wire leads tinned for quick soldering.

Transmitting Band-Switches



Band-Switching is the modern method of changing transmitter frequency. It substitutes a quick turn of a dial for the cumbersome, messy job of coil changing and retuning. Band-Switching may be used in all stages, thus offering complete front-of-panel control. Ohmite switches are designed to handle xmitters up to 1 KW; their all-porcelain construction and insulated shafts allow them to be used on high voltages with safety. Each switch has three contacts so that three bands may be covered with one set of inductors. Switches are furnished complete with mounting brackets and bakelite knobs.

Vitreous Enameled Tap-Switches

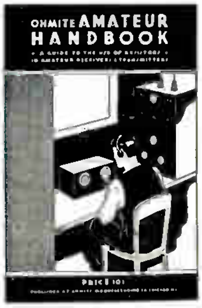


These high-voltage switches are now made and stocked in 4 point to 12 point sizes. They are used with tapped transformers, in high frequency or high voltage circuits, to switch transmitter from key to phone, etc. Because of their all-porcelain construction and insulated shafts and bushings, they will safely handle the voltages found in amateur rigs. Similar to Band-Switches except for larger number of contacts. Furnished complete with bakelite knob.

High Frequency Chokes

These small high frequency chokes are made especially for use in five and ten meter transmitters. The winding is protected against contact with other live parts and against corrosion. Because of their small size these chokes may be used even in the smallest transceivers. Characteristics of chokes are as follows: Maximum current—1,000 mils. Inductance—5.4 mic. henries. Resistance—0.85 ohms. Larger chokes or chokes with other characteristics may be secured upon order.

OHMITE AMATEUR HANDBOOK—SECOND EDITION



Here is a *new edition* of the popular Ohmite Handbook which now has twenty pages of real live dope about resistors, rheostats, voltage dividers, bleeders, modulators, wattage charts, etc. A complete description of basic Band-Switching circuits has been added as well as data on a completely new idea in amateur chokes. Liberal use is made of tables and charts so that practically all tiresome calculations have been eliminated. Price 10 cents postpaid, or from your radio parts dealer.

Write for

COMPLETE CATALOG

The data given here is necessarily brief and merely outlines some of the items in the Ohmite line. For complete details, technical information, wattage and current ratings, write for Ohmite Catalog Number 14, twelve pages of live dope about resistors, rheostats, switches, chokes, etc. A post card will bring your copy at once.

OHMITE

MANUFACTURING COMPANY

4829 Flournoy Street Chicago, Ill.

OHMITE

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Coto

RF CHOKES

CI-11

CI-13

CI-20

TYPE CI-11. Wound on an Isolantite core with four continuous universal pies, TAPERED to provide maximum impedance in the amateur bands. Fitted with nickel plated caps permitting either grid leak mounting or soldered connections. Inductance, 2.5 mh.; current carrying capacity, .125 amp.; D. C. resistance, 40 ohms; size, 1½ in. x ½ in. . . . . . . **LIST PRICE $.60**

TYPE CI-12. Capable of carrying more current than the popular 125 ma. type. Retains all the features of the CI-11. Will pass 250 milliamperes without heating. Inductance, 2.2 mh.; D. C. resistance, 18.5 ohms; size, 1½ in. x ⅝ in. . . . . **LIST PRICE $.75**

TYPE CI-13. A compact unit for transceivers, etc., where space is at a premium. Single layer winding on Isolantite, capped and pigtailed similar to the CI-11 and CI-12. Overall length, 1½ in. . . . . **LIST PRICE $.40**

TYPE CI-20. A compact, efficient choke for the high power stage. Wound with five continuous universal tapered pies on a one-half inch Isolantite core, three inches long. Non-resonant throughout the amateur bands, the effective impedance is high enough to make practical, parallel plate feed. This is also true of the smaller types, CI-11 and 12. Inductance, 4.5 mh.; current carrying capacity, .6-.8 ampere; D. C. resistance, 12.5 ohms; size, 3⅝ in. x 1⅜ in. . . . . **LIST PRICE $1.25**

STAND-OFF INSULATORS

CI-30

CI-33

Made in two sizes, these Isolantite insulators are suitable for mounting apparatus clear of absorbing surfaces. Metal fittings are attached at both ends by 6-32 screws. They may be readily removed for special mounting on the core.

TYPE CI-30. Core Size 3 in. x ½ in.; Overall Lgth. 3⅜ in. . . . . LIST PRICE $.30

TYPE CI-31. Core Size 1¼ in. x ½ in.; Overall Lgth. 1⅞ in. . . . . LIST PRICE $.20

HIGH VOLTAGE SHAFT COUPLING

Useful wherever controls must be isolated from high voltage equipment. Two sizes provide ample insulation against flashover. Insulation is Isolantite. Exact alignment of apparatus is not necessary due to unique semi-rigid construction. Absolutely no blacklash. Made only for ¼-inch shafts.

CI-32. Overall Lgth. 3 5/16 in. . . . . LIST PRICE $.80

CI-33. Overall Lgth. 2 3/16 in. . . . . LIST PRICE $.75

HIGH FIDELITY COUPLING TRANSFORMERS

Type A

Type D

These audio units have an essentially flat frequency response from 50 to 9000 cycles. Distributed capacity is kept oxtremely low resulting in minimum waveform distortion. All output transformers have correctly adjusted air gaps to permit carrying Class "C" plate current through secondary. All driver transformers are arranged so that individual bias may be applied to each Class "B" tube.

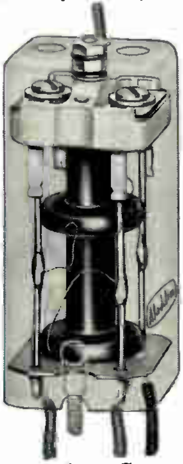
Cat. No.	Type Mtg.	Purpose	Coupling		Wgt. Lbs.	List Price
			From	To		
CI-402	A	Class B Driver	2-6B5's Class A	2-03A's Class B	7	$8.00
CI-403	D	Class B Output	2-03A's, 242A's, 11's Class B	Class C R. F. 2500-10,000 ohms	34	28.00
CI-406	A	Class B Driver	2-6B5's Class A	2-242A's, 211's Class B	7	8.00
CI-408	A	Class B Driver	2-45's Class A	2-801's Class B	6	7.00
CI-411	D	Class B Output	2-RCA 838's	2500-10,000 ohm load	34	28.00
CI-412	D	Class B Output	2-Taylor HD-203A's	3500-6250 ohm load	45	45.00
CI-413	D	Class B Output	2-Eimac 50T's	10,000 ohm load	34	28.00
CI-414	D	Class B Output	2-Eimac 150T's	4000-6250 ohm load	48	50.00

COTO manufacturers, in addition, a full line of FILAMENT HEATING AND PLATE TRANSFORMERS, SWINGING AND SMOOTHING CHOKES. Write for complete catalog describing these products in detail. Prices subject to usual amateur discount.

COTO-COIL COMPANY, PROVIDENCE, R. I.

Aladdin
Polyiron
I.f. Transformers

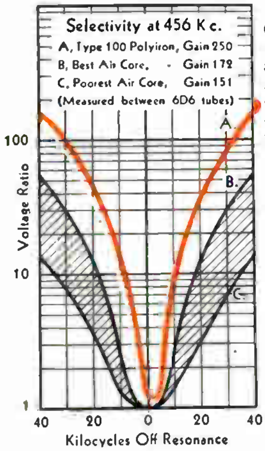
Polyiron Core I.f. Transformers reduce QRM and improve any air-core superheterodyne.



Type C

Polyiron is a patented magnetic core material molded from microscopic insulated particles of iron. The character of this material differs from ordinary iron in that eddy currents and hysteresis losses which occur in solid iron at high frequencies are not present in Polyiron.

The effect of this magnetic material in the core of an I.f. coil is to reduce the amount of wire necessary to secure a given inductance and to concentrate the magnetic field. This results in a high Q ratio of L/R and lower distributed capacity. Thus the resonant peak becomes sharper and the selectivity greater with Polyiron core I.f. transformers than has ever been possible with air-core transformers. The Type *C101M* illustrated above is only 2½" high and 1⅛" square, yet equals the largest air-core transformer used in communication receivers!

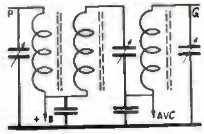


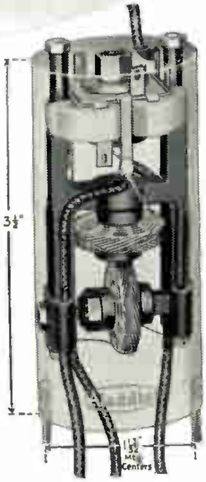
Small size Polyiron core I.f. transformers are particularly suitable for battery-operated mobile receivers which must be built in the smallest space, yet have high gain.

Coupling of the coils may be varied in manufacture to secure flat-topping, sharp peaks, or maximum gain without sacrificing any of the advantages of high Q or the wide tuning range made possible with Polyiron. A typical example of comparative performance of air-core and Polyiron-core transformers is illustrated in the graph.

Curve A is that of a Polyiron transformer compared with the best (B) and poorest (C) types of commercial air-core coils.

Aladdin Polyiron Core Coils are used in the finest commercial receivers. The diagram (Electronics, May, 1934) shows the band-pass I.f. circuit of the All-Wave Stromberg-Carlson Model 68 using Polyiron coils.





Type A

The most popular types of Aladdin Polyiron I.f. transformers are listed below. Where 6-volt tubes are specified, equivalent 2½-volt tubes may be employed. All transformers are supplied with trimmer condensers of mica or air dielectric for both primary and secondary. Type *C* is in the small container. Type *A* is in the larger shield.

Specifications and List Prices

Mica Dielectric Trimmers

Type A100, 456 or 465 Kc. Gain 250 between 6D6 and 6D6 tubes (illustrated above). $3.00
Type A200, 456 or 465 Kc. Gain 149 between 6D6 and 0.5 meg. diode load........ 3.00
Type A101, 456 or 465 Kc. Gain 62 between 6A7 and 6D6 tubes (for sets with R.f. stages)................................ 3.00
Type A201, 456 or 465 Kc. Gain 155 between 6D6 and 6H6 tubes, or other diode... 3.00
Type A175, 175 Kc. Gain 364 between 6D6 and 6D6 tubes (excellent for CW and selectivity) 3.00
Type A275, 175 Kc. Gain 244 between 6D6 and 6H6 tubes, or other diode tube........ 3.00
Type C101M, 456 Kc. Gain 52 between 6A8 and 6K7 tubes, for mobile receivers........ 2.50
Type C200M, 456 Kc. Gain 58½ between 6K7 and 0.5 meg. 6H6 diode load, for mobile receivers 2.50

With Air-Tuned Trimmers, size 4"x1-7/16"x1⅞".

Type G101, 456 or 465 Kc. Gain 75 between 6A7 and 6D6 tubes as first stage I.f......... 5.50
Type G201, 456 or 465 Kc. Gain 175 between 6D6 and 0.5 meg. diode load.............. 5.50

All gain figures are approximate and depend on tube and circuit constants. List prices subject to 40% discount to amateurs.

Amateurs, experimenters, and "Ham" distributors—write for full information!

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Other patents pending

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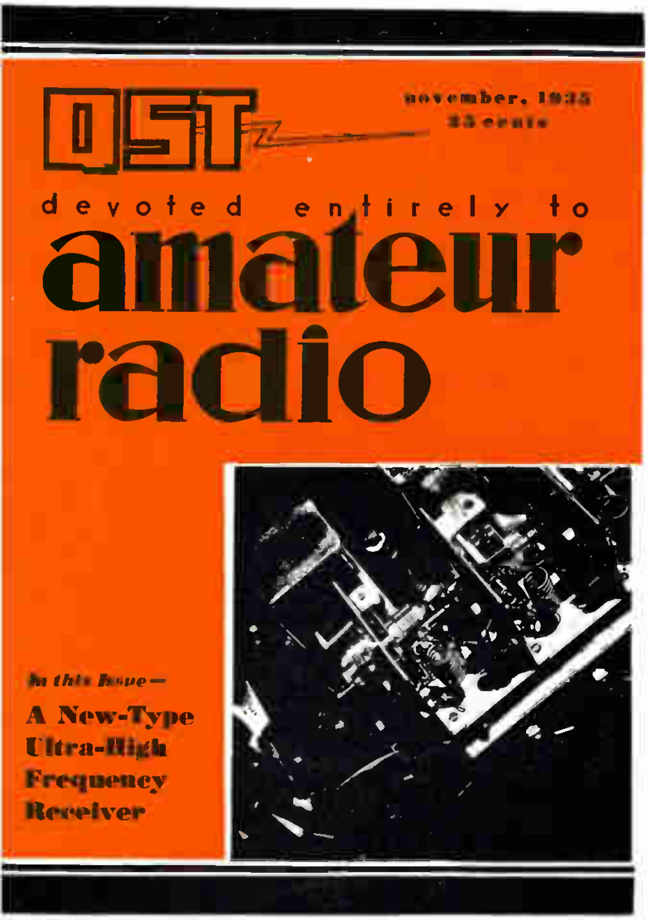
American Radio Relay League
West Hartford, Conn.

IN KEEPING with its policy of providing all services within its power, The American Radio Relay League makes available to amateurs and would-be amateurs literature properly prepared to present in the best form all available information pertaining to amateur radio. The fact that its offices are the national and international headquarters of radio amateurs, makes League publications authoritative, complete, up-to-the-minute; written from a thoroughly practical amateur's point-of-view. These publications are frequently revised to keep abreast of the fast-changing field. All are printed in the familiar *QST* format which permits thorough but economical presentation of the information. Various invaluable printed forms, designed to facilitate compliance with the rules of good amateur practice, are available at moderate cost. We maintain to the best of our ability a stock of back copies of *QST* which are available at the original single-copy price. Many of the publications and supplies described in the following pages are handled by your dealer for your convenience.

The American Radio Relay League, Inc.

West Hartford, Connecticut



The OFFICIAL MAGAZINE of The AMERICAN RADIO RELAY LEAGUE

For twenty years (and thereby the oldest 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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The back copies of *QST* contain the record of development of modern amateur technique. They are invaluable as technical references. Our supply of most issues is already exhausted, but many since 1925 are still available.

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With each Binder is furnished a sheet of gold and black gummed labels for years 1919 through 1938. The proper one can be cut from the sheet and pasted in the space provided for it on the back of the binder.

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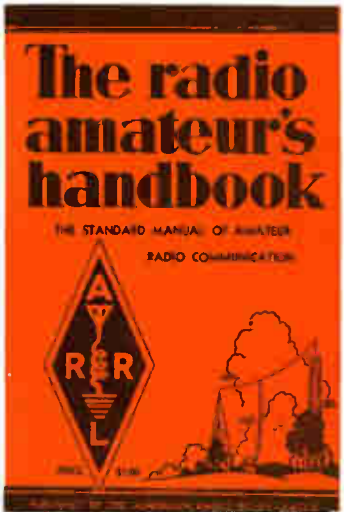

The *Handbook* tells the things which are needed for a comprehensive understanding of Amateur Radio. From the story of how Amateur Radio started through an outline of its wide scope of the present — from suggestions on how to learn the code through explanations of traffic-handling procedure and good operating practices — from electrical and radio fundamentals through the design, construction, and operation of amateur equipment — this book covers the subject thoroughly. It includes the latest and the best information on everything in Amateur Radio.

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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.

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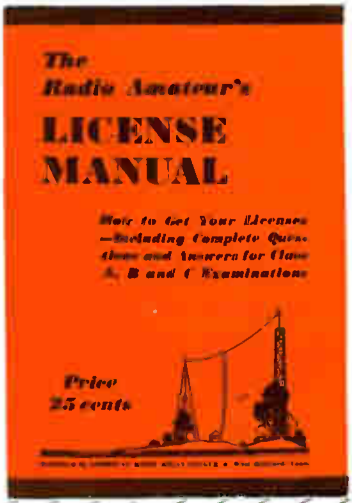

Before you can operate an amateur transmitter, you must have a government license and an officially assigned call. These cost nothing — but you must be able to pass the examination. The License Manual tells how to do that — tells what you must do and how to do it. It makes a simple and comparatively easy task of what otherwise might seem a difficult task. 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.

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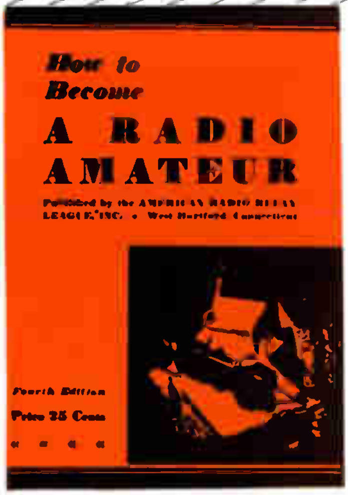

Universally recognized as the standard elementary guide for the prospective amateur, HOW TO BECOME A RADIO AMATEUR describes, in clear understandable language, apparatus incorporating features hitherto confined to more advanced stations. Although completely modernized, the station can still be built 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.

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LIGHTNING

by the

Aware of the practical bent of the average amateur and knowing of his limited time, the 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 the design and construction of radio equipment. The various lightning calculators are ingenious devices for rapid, certain and simple solution of the various mathematical problems which arise in all kinds of radio and allied work. They make it possible to read direct answers without struggling with formulas and computations. They are tremendous time-savers for

RADIO CALCULATOR

Type A

This calculator is useful for the problems that confront the average 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 mego-cycles; a wave length-in-meters scale from two to 600 meters; a capacity scale from 3 to 1,000 micro-micro-farads; two inductance scales with a range of from one micro-henry 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, wave length in meters, inductance in micro-henrys and capacity in micro-farads, 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.

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CALCULATORS

A.R.R.L.

nateurs, engineers, servicemen and experimenters. They are practically accurate and omputations made by them have greater mathematical accuracy than can be measured by rdinary means. Each calculator has on its reverse side detailed instructions for its use; the eatest 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 ghtning calculators the most useful gadgets you ever owned.

Wire Date 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.

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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.

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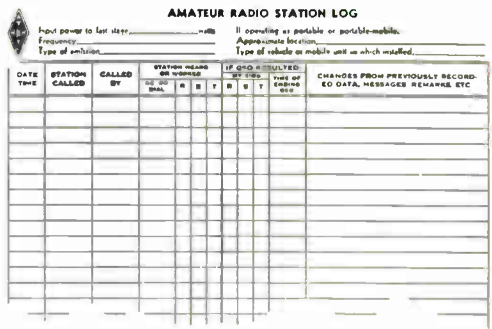
STATION SUPPLIES

Designed by A.R.R.L. Communications Department

The Log Book

The A.R.R.L. Log Book provides space for all pertinent facts pertaining to transmission or reception. The new page heading makes the log as useful for mobile or portable operation as it is for fixed. In book form — 38 ruled pages with an equal number of blank pages for notes. One sheet of graph paper. 40c each, 3 for $1.00.



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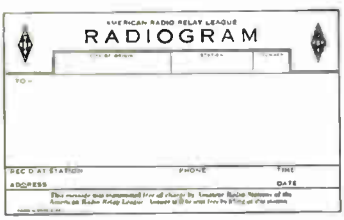
The Message File is an expanding file with pockets for each of the 12 months and with space provided on the front for a traffic record. This is a very convenient and serviceable device which helps to keep a station orderly. It may be used successive years or as permanent storage. 40c each, 3 for $1.00.

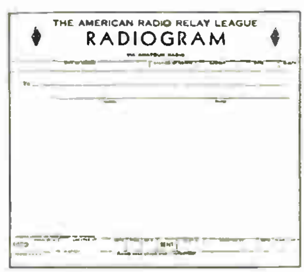


The Message Delivery Card

The Message Delivery Card answers the need for inexpensive deliveries. Postcard size. Available either on Government stamped postcards or plain cards for Canadian and foreign use. Stamped, 2c each. Plain, 1c each.

The Message Blank

The Message Blank is designed as an easy and presentable form for message delivery. There is room not only for the message but also for such handling data as you may wish to note on it. Padded — 100 7½ x 8½ sheets to the pad. High-grade bond paper — lithographed in green ink. 35c each, 3 for $1.00.



MEMBERSHIP SUPPLIES

Available only to A.R.R.L. members

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. Postpaid, 100 sheets, 50c; 250 sheets, $1.00; 500 sheets, $1.75.

THE EMBLEM

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, in heavy rolled-gold and black enamel, is available in either pin or button type.

In addition, there are three special colors for Communications Department appointees.

- *Red background for the SCM*
- *Blue background for the ORS*
- *Green background for the RM and PAM*

(Red and green available in pin type only. Blue may be had in either pin or button style.)

THE EMBLEM CUT: A mounted printing electrotype, ⅝" high, for use by members on amateur printed matter, letterheads, cards, etc.

All emblems priced the same

50¢ *postpaid*

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A balanced selection of good technical books, additional to the A.R.R.L. publications, should be on every amateur's bookshelf. We have arranged, for the convenience of our readers, to handle through the A.R.R.L. Book Department those works which we believe to be most useful. Make your selection from the following, add to it from time to time and acquire the habit of study for improvement. *Prices quoted include postage.* Please remit with order.

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