RADIO

Handbook

SIXTH EDITION

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The

"Radio"

Handbook

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The
"Radio" Handbook

By
The Editors of "Radio"

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SIXTH
EDITION

PUBLISHED AND DISTRIBUTED BY
RADIO, LTD.
1300 KENWOOD ROAD, SANTA BARBARA, CALIFORNIA

First Printing
OCTOBER, 1939

PRINTED IN U. S. A.

THE RADIO HANDBOOK

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Written by

THE EDITORS OF "RADIO"

The "Radio" Handbook

FOREWORD

THE Editors of RADIO have unquestionably become in recent years the outstanding group in radio not affiliated with a definite commercial interest. They are all practical radio engineers and active amateurs of many years' experience. They are the source of the reputation and prestige of RADIO, envied by publications of greater circulation.

Starting several years ago with an extensive set of "notes" compiled for their own use, the Editors of RADIO have developed the present "RADIO" HANDBOOK, which is now in its sixth edition. Each edition is thoroughly revised, not merely brought up to date. To keep up with rapid developments in commercial equipment, the great majority of items shown in the constructional pages are newly built for each edition. Though a few outstanding items were selected from other publications by the same publishers, the greater portion are built especially for this handbook. All have been tried in actual practice.

Taken all in all, no effort has been spared in an attempt to compile the most comprehensive book on the subject, both as a reference for those with wide knowledge of the field and as a practical text for those of limited knowledge and means.

In closing, we wish to thank those whose year-after-year purchases have indicated their approval of such an unusual policy. This policy has only been possible, however, with the additional cooperation of our advertisers. In similar technical fields texts such as this sell from $5.00 upwards; whatever value this book may have for you over its purchase price is a gift to you from our advertisers. We hope that you will reciprocate by using their products when suited to the job at hand.

THE PUBLISHERS

SANTA BARBARA, CALIFORNIA
October, 1939

The Editors of RADIO *in preparing this work have not only drawn upon their own knowledge and extensive experience, but also have drawn upon nearly the whole current field of radio literature, wherefore it is impossible to give due acknowledgment to all whose work has been consulted to some extent. We wish to acknowledge particularly the kind permission of the RCA Manufacturing Co., Inc., to use certain of the formulas in the theoretical pages, as well as extensive data and specifications on vacuum tubes.*

Introduction to Amateur Radio

WHILE much of the information in this handbook is of interest to engineers, students, sound men, experimenters, servicemen, and commercial operators, undoubtedly the largest single group having use for the material herein is composed of radio amateurs. Hence, to them the major portion of this book is dedicated; the material is written from their point of view.

Naturally an amateur finds much use for a text that caters primarily to him. But the person interested in *becoming* an amateur has still greater need for such a book. Hence this book is not only dedicated primarily to the radio amateur, but is so written that previous experience with amateur radio or previous knowledge of amateur radio is not required for comprehension of its contents.

The Amateur

A radio amateur is one who makes radio operating a hobby. While the definition of "amateur" would seem to include shortwave listeners as radio amateurs, the term is ordinarily used to indicate specifically those possessing a government license and amateur call letters.

More than 50,000 licensed amateurs in the U.S.A. and many more thousands throughout the rest of the world are actively engaged in this field for purposes of experimentation, adventure, and personal enjoyment. It is interesting to consider what there is about amateur radio that captures and holds the interest of so many people throughout the world and from all walks of life, for unquestionably there is something about it which generates a lasting interest in its varied problems and activities.

Many famous men, holding high-salaried positions of importance in the radio industry today, got their start in the radio business by discovering an interest in amateur radio. A large number of these executives and engineers continue to enjoy amateur radio as an avocation even though commercially engaged in the radio industry, so strong is the fascination afforded by this hobby.

Technical Achievement

Although "hamming" generally is considered to be "only a hobby" by the general public, its history contains countless incidents of technical achievements by its members which have served to improve radio communication and broadcasting. Many of the more important advancements in the art of radio communication can be chalked up to the ingenuity of radio amateurs. Experiments conducted by inquisitive amateurs have led to important developments in the fields of electronics, television, radio therapy, sound pictures, and public address, as well as in radio communication and broadcasting.

Fellowship

Amateurs are a most hospitable and fraternal lot. Their common interest

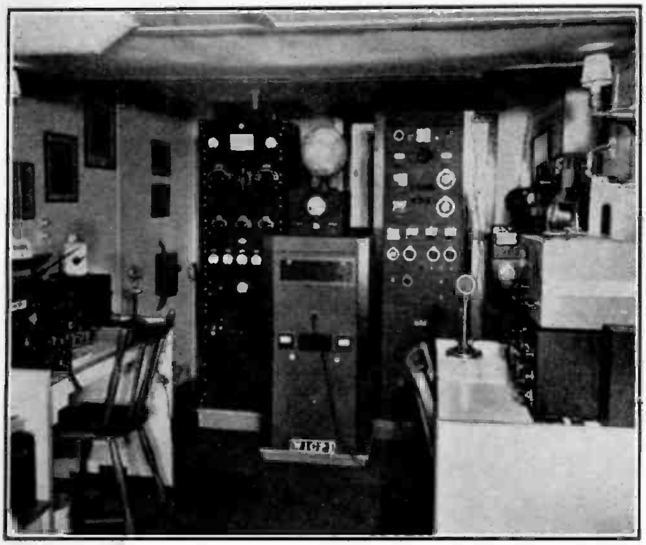


Figure 1.

While many amateurs have talked all over the world with home-constructed equipment costing less than $50 to build, the dream of every "ham" is a de luxe station like the one of O. W. Greene, Jr., W1CPI.

makes them "brothers under the skin" and binds them together as closely as would membership in any college fraternity, lodge, or club. When visiting a strange town an amateur naturally first will look up any friends in that town he has made over the air. But even if he is unknown to any amateurs in that town, his amateur call is an "open sesame." The local amateurs will hang out the welcome sign and greet him like a long lost brother.

It is not unusual for an amateur in one country to boast a large circle of friends, scattered throughout the world, with whom he chats nightly while seated comfortably at home. He gets to know these people intimately, many of whom he will never meet personally. Frequently he is of service to them, and they to him, in delivering messages to other people.

Amateur radio clubs have been formed in nearly all of the principal cities in the United States. The first thing a newcomer should do is to attend one of these club meetings and let the members know that he is interested in joining the ranks of radio amateurs. The veteran amateurs will be glad to lend a hand with any difficult problems you might encounter and often can give invaluable advice as a result of their own experience. Also, you will be introduced to others who have recently taken an interest in amateur radio, and will have someone with whom to study. A "study companion" is especially helpful when it comes to learning the code.

Public Service

The radio amateur, or "ham" as he is often called, is of great social importance. When hurricane, flood, earthquake, or heavy ice wreaks havoc with telephone and telegraph lines and the mails, the newspapers invariably follow with an account of how aid was summoned to the devastated area and communication maintained with the outside world largely through the efforts of radio amateurs. Radio amateurs are justly proud of their record of heroism and service in times of emergency. Many expeditions to remote places have kept in touch with home and business by "working" amateurs on the short waves.

A Diversified Hobby

Amateur radio is a hobby with several phases. There are those who revel in long-distance contacts with amateurs in far-off lands and try to excel in number of distant stations "worked." These enthusiasts are called "dx" men.

Others make a specialty of relaying messages free of charge for people in their communities, and these fellows often perform meritorious services. Still others prefer not to specialize, but simply to "chew the rag" with any other hams who happen to be on the air.

Then, there are the experimenters, indefatigable individuals always striving for perfection. They are everlastingly building up and tearing down transmitters and receivers, deriving as much enjoyment from the construction or improvement of equipment as from its operation on the air. Whichever phase most strongly captures your fancy, you will find amateur radio an absorbing hobby.

Before you may join the others on the air, however, you must be licensed by the government to operate a transmitting station; so your first task will be to acquire sufficient knowledge to pass the test. Those who attempt to operate (on the air) *any kind of transmitting* equipment without a license are liable to a fine and imprisonment.

HOW TO OBTAIN YOUR LICENSE

To obtain an amateur transmitting license from the U.S. government, you must be a citizen of the U.S.A., master the code, know how amateur transmitters and receivers work and how they must be adjusted, and be familiar with regulations pertaining to amateur operators and stations. An application blank for amateur radio operator and station license can be obtained from your district office of the Federal Communications Commission. A list of district offices is printed in chapter 22.

When you have filled out this application properly, sworn to it before a notary public, and returned it to the district office, the inspector in charge will notify you of the time and place of your examination. There is no charge for an amateur operator and station license, and there are no age limits.

It is necessary that your station not be located on premises under the *control* of an alien. Remember this when determining the proposed site of your transmitter and filling out the application blanks. If you rent from an alien, the premises are under your "control" and you have nothing to worry about. However, if you merely "board" instead of rent, that does not put the premises under your control.

The examination will consist of a practical code test and a written theoretical examination. The written examination usually includes ten questions. An extensive list of questions, typical of those asked in the examination, is given

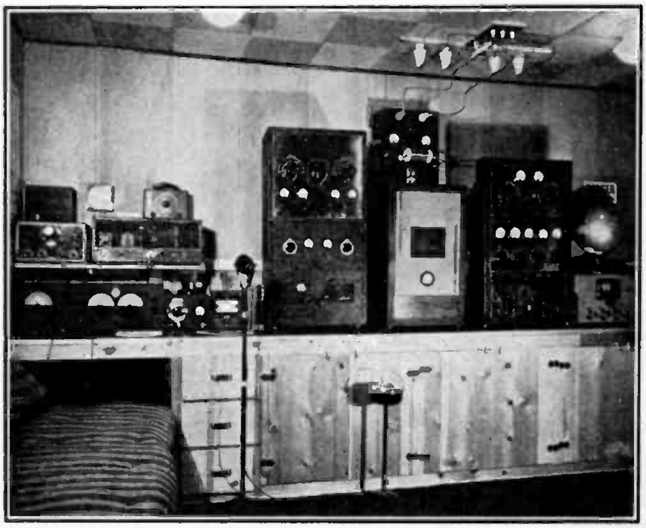


Figure 2.

The commodious "shack" of John R. Griggs, W6KW, was designed not only as an operating room but as a "fat-chewing room" where amateurs could discuss the previous night's dx over a cup of coffee.

Figure 3.
SHOWING TERRITORY EMBRACED BY THE VARIOUS CALL AREAS, OFTEN ERRONEOUSLY REFERRED TO AS DISTRICTS. CALL AREAS SHOULD NOT BE CONFUSED WITH U.S. RADIO DISTRICTS (1 TO 22).

in the Radio Amateur Newcomer. In the code test you will be required to send and receive messages in plain language, including figures and punctuation marks, at a speed of 13 words per minute (5 characters to the word) for a period of one minute, without mistakes.

If you pass both the code and written tests successfully, you will later receive a class B license from the Commission's offices in Washington. This license, when signed by you, becomes valid. It is a combination operator and station license, one being printed on the reverse side of the other.

The station license portion will bear your call letters, which will be made up of the initial letter W or K, your call area numeral (to determine your prefix and in which U.S. *call area* you are residing, refer to figure 3), and two or three additional letters, such as W9ZZZ. The prefix W is assigned to all amateur stations within the *continental* U.S.A. and KA to KH to territories and possessions.

Do not confuse the *call areas* (1 to 9) with the *U.S. Radio Districts* (1 to 22). It is rather confusing to the newcomer because amateurs commonly refer to call areas as districts and indicate a station in, for example, the ninth call area as a "ninth district station."

The class B operator license will authorize you to operate c.w. radiotelegraph transmitters (any licensed amateur transmitter, not just your own) in any amateur band or radiophone transmitters in the 160-, 10-, 5-, 2½-, 1¼-, and ¾-meter bands. You will not be entitled to operate phone in the select 80- and 20-meter bands until you have held your class B license for at least one year and have successfully passed an examination for the class A license. A list of typical class A questions and their correct answers is given in the Radio Telephony Handbook.

The Class C License

If you live more than 125 miles, airline distance, from the nearest examining point maintained by the Federal Communications Commission, you may apply for a class C license, the examination for which is given by mail. Other persons allowed to apply for the class C license include (1) applicants who can show a certificate from a reputable physician stating that the applicant is unable because of protracted disability to appear for examination, (2) persons stationed at a camp of the Civilian Conservation Corps, and (3) persons who are in the *regular* military or naval service of the United States at a military post or naval station.

A licensed radiotelegraph operator (other than an amateur operator who himself holds only a class C license) or a regularly employed government radiotelegraph operator must sign the class C applicant's blank in the presence of a notary public, attesting to the applicant's ability to send and receive the continental Morse code at the required speed of 13 words per minute. Do *not* send for class C blanks containing the examinations and questions until you feel you are *ready to take your examination,* as you are not supposed to hold them indefinitely after receiving them.

Holders of class C licenses *may* be required by the Commission to appear at an examining point for a supervised written examination and practical code test at any time during the term of their licenses. This is seldom done except where the Commission has reason to suspect that the applicant would have difficulty in passing the class B examination. For instance, an amateur holding a class C ticket who regularly is heard on the air with a bad note or modulation, or is heard sending at 8 or 9 words a minute, or repeatedly requests QRS, should not be at all surprised to receive a notice to appear. The class C license will be cancelled if the holder does not appear for examination when called or if he fails to pass when he does appear.

The privileges granted by the class C license are identical with those of the class B.

Your operator and station licenses will run concurrently, both expiring together three years from the date of issuance stated on the face of the license. Both may be renewed without examination if an application is filed at least 60 days prior to the indicated date of expiration and the applicant offers proof that he has communicated via amateur radio with three other amateur stations during the three-month period directly preceding the date of application for renewal.

You may obtain just an operator license (without the station license) if you desire; this will permit you to operate any licensed amateur station. The "station" side of the license will be left blank and you will have no call letters assigned to you. It is not possible to apply for or obtain a station license singly unless you already have an operator license.

Heavy penalties are provided for obtaining an amateur license by fraudulent means, such as by impersonating another person in an examination, copying from notes, books or the like, or misrepresenting the fact of one's U.S. citizenship. Applicants who fail to pass the examination can take it again after two months have passed from the time of the last examination.

There are so many special instances that may arise that no attempt will be made to cover every possible contingency pertaining to the application for and privileges accorded by an amateur license. If you have a special question regarding some point not covered in this book or which is not clear to you, write to the Inspector-in-Charge of your radio district. Don't guess at the proper interpretation or take somebody else's word for it; you may get in trouble.

There is one thing you should *not* write to the inspector about and that is the necessity for a license to *transmit.* A transmitter license is absolutely necessary, regardless of power, frequency, or type of emission; there are no exceptions nor special cases.

Before attempting to take the amateur examination, the reader should have a thorough knowledge of the regulations affecting amateur operators and stations. While "memorizing" procedure is not to be recommended when preparing for the *technical* portion of the amateur examination, the best way to prepare for the questions pertaining to regulations is to memorize the pertinent extracts from the communications law and also the United States amateur regulations, given in chapter 22. They do not necessarily

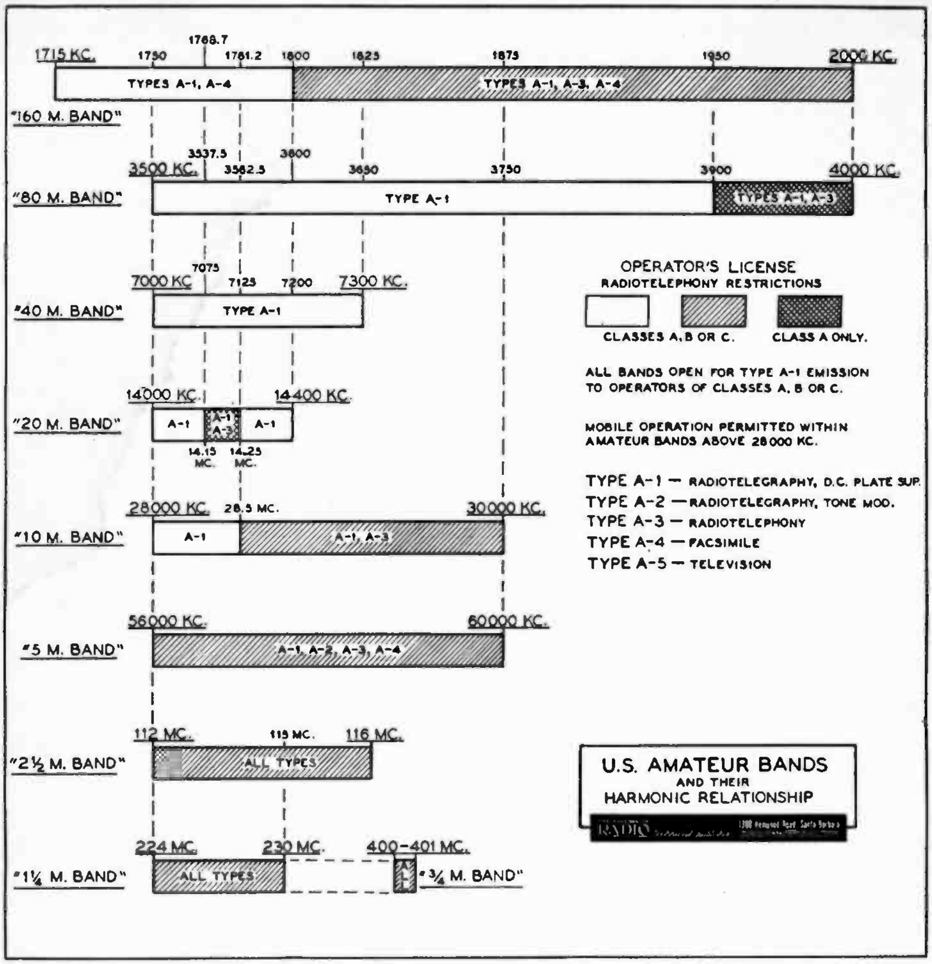


Figure 4.
AMATEUR FREQUENCY BANDS.

The 1715-2000 kc. band is subject to change to 1750-2050 kc. in accordance with the Inter-American Arrangement covering radiocommunication, Havana, 1937. The Commission reserves the right to change or cancel the frequencies 112-116 Mc. and 224-230 Mc. without advance notice or hearing.

have to be memorized verbatim, but the applicant must have at his command *all of the information contained therein.*

It is important that the reader clearly understand the distinction between violations of the basic Communications Act of 1934 and violations of the rules and regulations set up under the basic act by the Federal Communications Commission. The former constitutes the more serious offense, and anyone is liable, whether he be an amateur or not. The difficulty some applicants experience with certain questions is in deciding whether a certain offense is a violation of the basic act or a violation of rules set up by our F.C.C. under the act.

It is not necessary to learn the list of U.S. Radio Districts given in chapter 22. This list is included merely for reference, so that a reader can determine in which district he resides.

Those residing outside of the United States and Canada should get in touch with their national amateur society to learn about the regulations and procedure for obtaining a license before even starting construction on the transmitter, because in most countries the restrictions on transmitting amateurs are much more stringent. The part of this book pertaining to treaties, laws, and regulations of course will not apply, but the equipment described will be found highly suitable for the amateur in *any* country, as will chapters on theory.

In Canada the requirements and procedure are not radically different from those imposed by this country. To obtain an operator's license one must take a code test (10 words per minute) before a radio inspector and pass a verbal examination to test his knowledge of operating procedure and his technical ability. The examination fee is 50 cents.

The station license costs $2.50 per year in Canada. The form for station license is available from either the Radio Division, Department of Transport, Ottawa, Canada, or from a local inspector's office.

Detailed information on becoming a transmitting amateur in the following English-speaking countries may be obtained by writing to the indicated organizations:

Australia. The Wireless Institute of Australia, Box 2127 "L", G. P. O. Sydney, New South Wales.

Great Britain. The Radio Society of Great Britain, 53 Victoria Street, London, S. W. I.

Newfoundland. Newfoundland Amateur Radio Association, P. O. Box 650, St. John's.

New Zealand. N. Z. Association of Radio Transmitters, P. O. Box 837, Dunedin, C1.

South Africa. South African Radio Relay League, Box 7028, Johannesburg.

Starting Your Study

When you start your study to prepare yourself for the amateur examination, you will probably find that the circuit diagrams, tube characteristic curves, and formulas first appear confusing and difficult of comprehension. However, after putting in a few evenings of study, one becomes sufficiently familiar with basic concepts and fundamentals that the acquisition of further knowledge is not only easy but fascinating.

As it takes considerable time to become proficient at sending and receiving code, it is a good idea to start by interspersing technical study sessions with short periods of code practice. There are two reasons for this: many short code practice sessions benefit one much more than a fewer number of comparatively longer sessions. Also, it keeps one from getting "stale" while studying theory and regulations by serving as a rest period, thus serving to maintain one's interest. Each kind of study serves as a respite from the other.

You can even start on one of the simpler receivers described in the chapter on *receiver construction* if you wish, though at first you will be unable to decipher many of the dots and dashes you pick up on it. However, many interesting hours can be spent listening to the conversations of amateur phone stations. The numerous references to "QSA", "Rig", "Rotary", and other mysterious terms will begin to take on significance.

When you have practiced the code long enough, you will be able to follow the gist of the conversation of slower sending code stations, and fish for "dx". Many stations send slower than "13 per". Stations repeat their calls many times when calling "CQ", and one need not have achieved much proficiency to make out their calls and thus determine their location. Granted that it is advisable to start right in with learning the code, you will want to know how to go about mastering it in the shortest possible time with the least amount of effort.

LEARNING THE CODE

The applicant for an amateur license must be able to send and receive the Continental code at a speed of 13 words per minute, with an average of 5 characters to the word. Thus 65 characters must be copied consecutively without error in one minute. Similarly, 65 consecutive characters must be transmitted without error in that time. The applicant, however, is given sufficient opportunity to pass this code test, since sending and receiving tests are both five minutes in length. If 65 consecutive characters, at the required rate, are copied correctly, somewhere during the first five-minute period, the applicant may then attempt a transmission. Again, if 65 consecutive characters are sent correctly somewhere during this second period, a passing mark is received.

Failure to pass the code test results in a two-month rest period during which the applicant can improve his mastery of the code; thereafter, he may again appear for another try.

Approximately 30 per cent of the amateur license applicants fail to pass the code examination. This may be attributed to several things: excitement and nervousness during the examination; a false sense of security with regard to their speed capabilities, resulting in their attempting the examination before actually being ready for it; and incorrect method of learning the code.

The first two of these reasons may be considered together, since they are somewhat related. It should be expected that nervousness and excitement—at least to some degree—will hinder the applicant's code ability. The best prevention against this is to be able to master the code at a little better than the required speed, under ordinary conditions. Then a little slowing down due to nervousness will not prove "fatal" during the strain and excitement of the examination. As to the correct method of learning the code, the following is recommended. Unfortunately, no "trick" short cut to learning the code has been found generally successful.

Memorizing the Code

Though the code itself may be memorized thoroughly in a few days of diligent application, the time required to build up the speed will be entirely dependent upon individual ability and regularity of drill, and may take any length of time from a few weeks to many months.

Since code reading requires that individual letters be recognized instantly, any memorizing scheme which depends upon an orderly sequence, such as learning all "dot" letters and all "dash" letters in separate groups, is to be discouraged.

Each letter and figure must be recognized by its *sound* rather than by its appearance. Telegraphy is a system of sound communication, the same as is the spoken word. The letter A, for example, is one short and one long sound in combination, sounding like *did-dah,* and it must be remembered as such, not *dot-dash.*

If you listen to the sound of a letter transmitted slowly by a buzzer and key in the hands of some experienced operator, you will notice how closely the dots resemble the sound *did* and the dashes *dah.*

Before beginning practice with a code-practice set, it is necessary to memorize the whole alphabet perfectly. A good plan is to study only two letters a day and to drill with those letters until they become part of your consciousness. Mentally translate each day's letters into their sound equivalent wherever they are seen—on signs, in papers; indoors and outdoors. Tackle two additional letters in the code chart each day, at the same time reviewing all of the characters already learned.

Avoid memorizing by routine. Be able to sound out any letter immediately without so much as hesitating to think about the letters preceding or following the one in question. Know C, for example, apart from the sequence A, B, C. Skip about among all of the characters learned, and before very long sufficient letters will have been acquired to enable you to spell out simple words to yourself in *"did-dahs."* This is interesting exercise, and for that reason it is good to memorize all of the vowels first, the most common letters next.

Actual code practice should start only when the entire code, including numerals and the few *commonly used* punctuation marks, have been memorized so thoroughly that any letter or figure can be sounded at a moment's notice without hesitation.

Once you have memorized the code thoroughly, you should concentrate on increasing your *receiving* speed. True, if you practice with another newcomer who is learning the code, you will both have to do some sending. But do not attempt to practice *sending* just for the sake of increasing your sending *speed.*

When transmitting on the code practice set to your partner, so that he can get receiving practice, concentrate on the *quality* of your sending, not on your speed. Your partner will appreciate it, and he could not copy you if you "opened up" anyhow. If you want to get a reputation as having an excellent "fist" on the air, just remember that speed alone won't do the trick. Proper execution of your letters and spacing will make much more of an impression. Fortunately, as you get so that you can send evenly and accurately, your sending speed will automatically increase. Remember, try to see how *evenly* you can *send* and how *fast* you can *receive.*

Because it is comparatively easy to learn to send rapidly, especially when no particular care is given to the quality of the sending, many amateurs who have just received their licenses get on the air and send mediocre code at 20 words a minute when they can barely receive *good* code at 13. While most old timers on the air remember their own period of initiation and are only too glad to be patient and considerate if you tell them you are a beginner, the surest way to incur their scorn is to try to impress them with your "lightning sending" and then request "QRS" when they come back to you at the same speed.

Code Practice Sets

If you don't feel too foolish doing it, you can secure a measure of code practice with the help of a partner by sending "did dah" messages to each other while riding to work, eating lunch, etc. It is better, however, to use a buzzer or

THE RADIOTELEGRAPH CODE

A	• —	N	— •
B	— • • •	O	— — —
C	— • — •	P	• — — •
D	— • •	Q	— — • —
E	•	R	• — •
F	• • — •	S	• • •
G	— — •	T	—
H	• • • •	U	• • —
I	• •	V	• • • —
J	• — — —	W	• — —
K	— • —	X	— • • —
L	• — • •	Y	— • — —
M	— —	Z	— — • •

NUMERALS, PUNCTUATION MARKS, ETC.

1	• — — — —	6	— • • • •
2	• • — — —	7	— — • • •
3	• • • — —	8	— — — • •
4	• • • • —	9	— — — — •
5	• • • • •	0	— — — — —

INTERNATIONAL DISTRESS SIGNAL	• • • — — — • • •
PERIOD	• — • — • —
COMMA	— — • • — —
INTERROGATION	• • — — • •
QUOTATION MARK	• — • • — •
COLON	— — — • • •
SEMICOLON	— • — • — •
PARENTHESIS	— • — — • —
FRACTION BAR	— • • — •
WAIT SIGN	• — • • •
DOUBLE DASH (BREAK)	— • • • —
ERROR (ERASE) SIGN	• • • • • • • •
END OF MESSAGE	• — • — •
END OF TRANSMISSION	• • • — • —

The Continental code shown above is used for all radio communications. The Morse code, used for land line telegraphic communication within the U.S.A., is more complicated. Attention is called to the new Continental code symbols for the comma and period, also the elimination of the exclamation point.

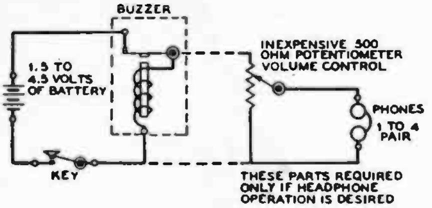


Figure 5.

A KEY AND BUZZER MAKE THE SIMPLEST CODE PRACTICE SET.

The buzzer should be adjusted to give a steady, high pitched "whine." The phones and volume control may be omitted if desired, in which case the buzzer should be mounted firmly on a sounding board.

code practice oscillator in conjunction with a regular telegraph key.

As a good key may be considered an investment, it is wise to make a well-made key your first purchase. Regardless of what type code practice set you use, you will need a key, and later on you will need one to key your transmitter. If you get a good key to begin with, you won't have to buy another one later.

The key should be rugged and have fairly heavy contacts. Not only will the key stand up better, but such a key will contribute to the "heavy" type of sending so desirable for radio work. Morse (telegraph) operators use a "light" style of sending and can send somewhat faster when using this light touch. But in radio work static and interference are often present, and a slightly heavier dot is desirable. If you use a husky key, you will find yourself automatically sending in this manner.

Special types of keys, especially the semi-automatic "bug" type, should be left alone by the beginner. Mastery of the standard type key should come first. The correct manner of using such a key will be discussed later.

To generate a tone simulating a code signal as heard on a receiver, either a mechanical buzzer or an audio oscillator (howler) may be used. The buzzer may be mounted on a sounding board in order to increase the fullness and volume of the tone; or it may be mounted in a cardboard box stuffed with cotton in order to silence it and the signal fed into a pair of earphones. The latter method makes it possible to practice without annoying other people as much, though the clicking of the key will no doubt still bother someone in the same room.

A buzzer-type code practice circuit is shown in figure 5. The buzzer should be of good quality or it will change tone during keying; also the contacts on a cheap buzzer will soon wear out. The volume control, however, (used only for headphone operation) may be of the least expensive type available, as it will not be subjected to constant adjustment as in a radio receiver. For maximum buzzer and battery life, use the least amount of voltage that will provide stable operation of the buzzer and sufficient volume. Some buzzers operate stably on 1½ volts, while others require more.

A vacuum tube audio oscillator makes the best code practice oscillator, as there is no sound except that generated in the earphones and the note more closely resembles that of a radio signal. Such a code practice oscillator is diagrammed schematically in figure 6. The parts are all screwed to a wood board and connections made to the phones and batteries by means of Fahnestock clips, as illustrated in figure 7. A single dry

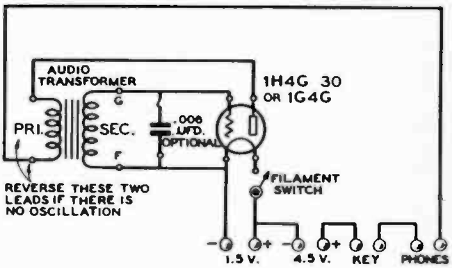


Figure 6.

THE SIMPLEST V.T. CODE PRACTICE OSCILLATOR.

A dry cell and a 4½-volt C battery furnish power. Omitting the .006-μfd. condenser will result in a higher pitched note. Use the smallest, cheapest audio transformer you can find, or the note may have too low a pitch even with the condenser omitted.

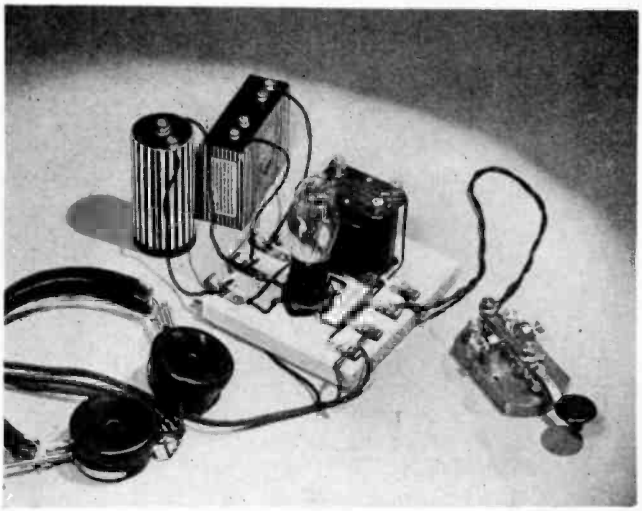


Figure 7.

A BATTERY OPERATED CODE OSCILLATOR USING THE CIRCUIT OF FIGURE 6.

The oscillator consists essentially of a tube and audio transformer. Connections are made to batteries, key, and phones by means of Fahnestock clips screwed to the baseboard.

cell supplies filament power and a 4½-volt C battery supplies plate voltage. Both filament and plate current are very low, and long battery life can be expected. The vacuum tube is the biggest item from the standpoint of cost, but it can later be used in a field-strength meter with the same batteries supplying power. Such a device is very handy to have around a station, as it can be used for neutralizing, checking the radiation characteristics of your antenna, etc.

A 1H4, 30, or 1G4G may be used with the same results. The tubes are listed in the order of their cost at the time of this writing. The first two are 2-volt tubes, but will work satisfactorily on a 1.5-volt filament battery because of the very small amount of emission required for the low value of plate current drawn. Be sure to get a socket that will accommodate the particular tube you buy.

Oddly, it is important that the audio transformer used *not* be of good quality; if it is, it may have so much inductance that it will be impossible to get a sufficiently high pitched note. If you buy a new transformer, get the smallest, cheapest one you can buy. The old transformers used in moderately priced sets of 12 years ago are fine for the purpose, and can oftentimes be picked up for a small fraction of a dollar at the "junk parts" stores. The turns ratio is not important; it may be anything between 1.5/1 and 6/1.

Correct transformer polarity is necessary for oscillation. If oscillation is not obtained, reverse the two wires going to the primary terminals of the transformer.

The tone may be varied by substituting a larger (.025 μfd.) or smaller (.001 μfd.) condenser for the .006-μfd. capacitor shown in the diagram. A lower capacity condenser will raise the pitch of the note somewhat and vice versa. The highest pitch that can be obtained with a given transformer will result when the condenser is left out of the circuit altogether. Lowering the plate voltage to 3 volts will also have a noticeable effect upon the pitch of the note. If the particular transformer you use does not provide a note of a pitch that suits you, the pitch can be altered in this manner.

Using a 1H4G, a standard no. 6 dry cell for filament power, and a 4½-volt C battery for plate power, the oscillator may be constructed for about $2.00 exclusive of key and earphones. The filament battery life will be about 700 hours, the plate battery life considerably more. This set has an advantage over an a.c. operated practice set in that it can be used where there is no 110-volt power available; you can take it on a Sunday picnic if you wish. Also, there is no danger of electrical shock.

Automatic Code Machines

The two practice sets just described—the buzzer and the v.t. oscillator—are of most value when you have someone with whom to practice. If you are unable to enlist a code partner and have to practice by yourself, the best way to get receiving practice is by use of a set of phonograph code practice records or a tape machine (automatic code-sending machine) with several practice tapes. The records are of use only if you have a phonograph whose turntable speed is readily adjustable. The tape machine can be rented by the month for a reasonable fee. Once you can copy close to 10 w.p.m., you can get receiving practice by listening to slow-sending amateurs on your receiver, as amateurs usually send quite slowly when working extreme dx. However, until you can copy around 10 w.p.m., your receiver isn't of much use and either another operator or a tape machine or code records are necessary for getting receiving practice after you have once memorized the code.

The student must observe the rule always to write down each letter as soon as it is received, never dots and dashes to be translated later. If the alphabet has actually been mastered beforehand, there will be no hesitation from failure to recognize most of the characters unless the transmission speed is too high.

Don't practice too long at one stretch; it does more harm than good. Twenty-five or thirty minutes should be the limit.

Time must not be spent trying futilely to recall a missed letter. Dismiss it and center the attention on the next letter. In order to prevent guessing and to give you equal practice on seldom-used letters such as X, Y, etc., the transmitted material should not be plain language except perhaps for a few minutes out of each practice period.

During the first practice period, the speed should be such that a substantially solid copy can be made of the entire transmission without strain. Then, in the next period, the speed should be increased slightly to a point where all of the characters can be caught only through conscious effort. When the student becomes proficient at this new speed, another slight increase may be made, progressing in this manner until a speed of about 16 words per minute is attained. The margin of 3 w.p.m. is recommended to overcome the possible excitement factor at examination time. Then when you take the test you don't have to worry about excitement or an "off day."

The speed must not be increased to a new level until the student finally makes solid copy for a 5-minute period at the old level. How frequently increases of speed can be made depends upon individual ability and the number of practice hours. Each increase is apt to prove decidedly disconcerting, but keep in mind the statement by Dr. G. T. Buswell, "You are never learning when you're comfortable."

Using a Key

See figure 8 for the proper position of the hand, fingers, and wrist when manipulating the telegraph key. The forearm rests naturally on the desk. The knob of the key is grasped lightly with the thumb along the edge and the index and third fingers resting on the top towards the front edge. The hand moves with a free up and down motion, the wrist acting as a fulcrum. The power comes entirely from the arm muscles. The third and index fingers will bend *slightly* during sending, but not because of conscious effort to manipulate the finger muscles. Keep your finger muscles just tight enough to act as a "cushion" for the arm motion and let the slight movement of the fingers take care of itself.

The key spring is adjusted to the individual wrist and should be neither stiff nor "sloppy." Use a moderately stiff tension at first and gradually lighten it as you get more proficient. The separation between the contacts must be the proper amount for the desired speed, being about 1/16 inch for slow speeds and correspondingly closer together (about 1/32 inch) for faster speeds. Avoid extremes in either direction. It is preferable that the key be placed far enough from the edge of the table (about 18 inches) that the elbow can rest on the table.

The characters must be properly spaced and timed with the dot as the yardstick. A standard dash is three times as long as a dot. The spacing between parts of the same letter is equal to one dot; between letters, three dots; between words, five dots.

This does *not* apply when sending slower than about 10 words per minute for the benefit of someone learning the code and desiring receiving practice. When sending at say 5 w.p.m., the individual letters should be made the same as though the sending rate were about 10 w.p.m. except that the spacing between letters and words is greatly exaggerated. The reason for this is obvious. The letter L, for instance, will sound exactly the same at 10 w.p.m. as at 5 w.p.m., and when the speed is increased above 5 w.p.m., the student will not have to become familiar with a new sound (faster combination of dots and dashes). He will merely have to learn the identifying of the *same* sounds without taking so long to do so.

It has been shown that it does not aid a student to identify a letter by sending the individual components of the letter at a speed corresponding to less than 10 words per minute. By sending the letter moderately fast, a longer space can be left between letters for a given code speed, giving the student more time to identify the letter.

When two co-learners have memorized the code and are ready to start sending to each other for practice, it is a good idea to enlist the aid of an experienced operator for the first practice session so that you will get an idea of what properly formed letters sound like.

When you are practicing with another beginner, don't gloat because you seem to be learning to receive faster than he. It may mean that his *sending* is better than yours. Remember that the quality of sending affects the maximum copying speed of a beginner by as much as 100 per cent. Yes, if the sending is bad enough, a newcomer won't be able to read it at all, even though an old timer may be able to get the general drift of what you are trying to send. A good test for any "fist" is to try it on someone who is just getting to the "13 per" stage.

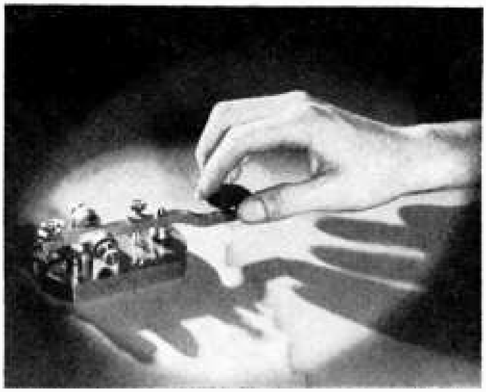


Figure 8.

CORRECT POSITION OF FINGERS WHEN WORKING A TELEGRAPH KEY.

The hand should rest lightly on the key. The wrist is used merely as a fulcrum, the fingers to hold the knob and act as a cushion. A "wrist motion" is used in sending, but it is the muscles of the forearm that provide the power.

If You Have Trouble

While there is no justification for the contention sometimes made that "some people just can't learn the code", there is no denying that it is more difficult for some people than others. It is not a matter of intelligence; so don't feel ashamed if you seem to experience a little more than the usual difficulty in learning the code. Your reaction time may be a little slower, your coordination not quite so good. If this is the case, remember that you can *still learn the code.* You may never learn to send and receive at 40 w.p.m., but you can learn to send and receive 13 w.p.m. if you have patience and if you refuse to be discouraged by the fact that others seem to pick it up much more rapidly.

While the slow learner can ultimately get his 13 per by following the same learning method if he has *perseverance,* the following system of auxiliary practice will oftentimes prove of great aid in increasing one's speed when progress by the usual method of practice seems to have reached a temporary standstill. All that is required is the usual key-buzzer-headset outfit, plus an extra operator. This last item should be of good quality, guaranteed to pay proper attention to spacing, and capable of good speed regulation.

Suppose we call the fellow at the key the teacher and the other member of the crew the student. All set?

Assume the usual positions, but for the moment lay aside the paper and pencil. Instead, the student will read from a duplicate newspaper the *same text the operator is sending.*

The teacher is to start sending at a rate just slower than the student's top speed, judged by his last test. This will allow the student to follow accurately each letter as it is transmitted. After a warming-up period of about one minute, the sending speed is to be increased gradually but steadily and continued for about a period of five minutes. An equal rest period is beneficial before the second session. Speed for the second period should be started at half way between the original starting speed and the speed used at the end of the first period. Follow the same procedure for the second and third practice periods.

At the end of the third *reading* practice period, start copying immediately, using the *same text as before,* at a speed just above the student's previous copying ability. It will be found that one session of the *reading* practice will for the time being increase the student's *copying* ability from 10 to 20 per cent. The teacher should watch the student and not increase the sending speed too much above the copying ability of the student, as this brings about a condition of confusion and is more injurious than beneficial.

Code Classes

A certain number of altruistic amateurs send code practice on schedule once or twice each week, and excellent practice can be obtained after you have built or constructed your receiver by taking advantage of these sessions. Call letters, time schedules, and frequency in kilocycles of the stations currently sending code practice can be obtained by writing the American Radio Relay League, West Hartford, Conn. Enclose a stamped, self-addressed envelope.

If you live in a large city, the chances are that at least one of the radio clubs or amateur part stores conducts a free code class. If you inquire around a bit, you can usually discover how to get in on these practice sessions.

TWO

Introductory Electricity and Fundamental Radio Theory

IT is now generally accepted that all matter is made up of approximately 92 fundamental constituents commonly called *elements*. These elements can exist either in the free state such as iron, oxygen, carbon, copper, tungsten, and aluminum, or in chemical unions commonly called *compounds*. The smallest unit which still retains all the original characteristics of an element is the *atom*.

Combinations of atoms, or subdivisions of compounds, result in another fundamental unit, the *molecule*. The molecule is the smallest unit of any compound. All reactive elements when in the gaseous state also exist in the molecular form, made up of two or more atoms. The nonreactive or noble gaseous elements helium, neon, argon, krypton, xenon, and radon are the only elements that ever exist in a truly atomic state.

An atom is an extremely small unit of matter—there are literally billions of them making up so small a piece of material as a speck of dust. But to understand the basic theory of electricity and hence of radio, we must go further and divide the atom into its main components, a positively charged nucleus and a cloud of negatively charged particles that surround the nucleus. These particles, swirling around the nucleus in elliptical orbits at an incredible rate of speed, are called orbital electrons. It is upon the behavior of these electrons that depends the study of electricity and radio, as well as allied sciences. Actually it is possible to subdivide the nucleus of the atom into other particles: the proton, nuclear electron, negatron, positron, and neutron; but this further subdivision can be left to quantum mechanics and atomic physics. As far as radio theory is concerned it is only necessary to think of the normal atom as being composed of a nucleus having a net positive charge that is exactly neutralized by the orbital electrons surrounding it.

The atoms of different elements differ in respect to the charge on the positive nucleus and in the number of electrons revolving around this charge. They range all the way from hydrogen, having a net charge of one on the nucleus and one orbital electron, to uranium with a net charge of 92 and 92 orbital electrons. The number of orbital electrons is called the *atomic number* of the element.

From the above it must not be thought that the electrons revolve in a haphazard manner around the nucleus. Rather the electrons in an element having a large atomic number are grouped into "shells" having a definite number of electrons. In the first shell there is room for only two electrons; in the next, 2, the next, 6, then 2, 6, 10, 2, 6, 10, etc., until a total of 92 electrons can be accommodated in the heaviest atom, that of uranium. The only atoms in which these shells are completely filled are those of the inert or noble gases mentioned before; all other elements have one or more uncompleted shells of electrons. If the uncompleted shell is nearly empty, the element is *metallic* in character, being most metallic when there is only one electron in the outer shell. If the incomplete shell lacks only one or two electrons, the element is usually *non-metallic*. Elements with a shell about half completed will exhibit both non-metallic and metallic character; carbon, silicon and arsenic are examples of this type of element.

In metallic elements (elements in which the outer shell is just started and has only one or two electrons) these outer-shell electrons are rather loosely held. Consequently, there is a continuous helter-skelter movement of these electrons and a continual shifting from one atom to another. The electrons which move about in a substance are called *free electrons* and it is the ability of these electrons to drift from atom to atom which makes possible the *electric current*.

The Electric Current

The free electrons in a conductor move constantly about and change their position in a haphazard manner. If, however, the conductor is connected between the positive and negative terminals of a battery, there will be a steady movement of electrons from the negative to positive terminal, in *addition* to the irregular movement of the electrons. This flow constitutes an electric current, but as soon as the battery is removed, the current will cease.

When the battery was first connected to the wire there was an electrostatic attraction between the positive terminal of the battery and the negative electrons, and at the same time there was a repulsion due to the negative terminal of the battery at the other end of the wire. It is the combined action of this attraction and repulsion which causes the current to flow. When the battery is removed the electron drift from one end of the wire to the other ceases and we say that the circuit has been broken and the current stopped.

However, from the above it must not be thought that each free electron that has been set into drift by the current flow travels from one end of the wire to the other. Quite the opposite is true; each free electron travels only an extremely short distance, then instantly passes on its motion, bucket brigade fashion, to a succeeding free electron. Thus in the general drift of electrons along a wire carrying an electric current each electron travels only a short distance and the excess of electrons at one end and the deficiency at the other are balanced by the battery. When the battery is removed the state of normalcy returns; there is still the rapid interchange of free electrons between atoms but there is no general trend in either one direction or the other.

Insulators and Conductors

In the molecular structure of many materials such as glass, porcelain, and mica all electrons are tightly held within their orbits and there are comparatively few free electrons. This type of substance will conduct an electric current only with great difficulty and is known as an *insulator*. An insulator is said to have a high electrical *resistance*.

On the other hand, materials that have a large number of free electrons are known as *conductors*. Most metals, those elements which have only one or two electrons in their outer shell, are good conductors. Silver, copper, and aluminum, in that order, are the best of the common conductors and are said to have the greatest *conductivity*, or lowest resistance to the flow of an electric current.

Resistance

Certain materials have a molecular structure such that when the free electrons are made to flow in a definite direction, there are frequent collisions between them and the individual atoms in the material. The result of these collisions is a *decrease* in the total electron flow. This property of a substance which causes it to resist a steady electron flow is called its *resistance*.

It will require a greater *electromotive force* to produce a given current through a substance with high resistance than to produce the same current in a good conductor. In the case of the conductor virtually all of the electromotive force is effective in producing current, whereas in the resistor a portion is wasted in the form of lost energy due to electron collisions. These collisions cause the material to become heated, and part of the initially-applied electromotive force is thus ultimately lost in the form of heat. This same phenomenon of heat is exhibited when a metal is repeatedly struck by a hammer.

The resistance of a uniform length of material is directly proportional to its length and inversely proportional to its cross sectional area. A wire with a certain resistance for a given length will have twice as much resistance if the length of the wire is doubled. For a given length, doubling the area of cross section of the wire will *halve* the resistance.

It is interesting to note that the resistance of most metals will increase with an increase in temperature. Thus the filament of a vacuum tube or a tungsten-filament lamp will have a much lower resistance when cold than when at normal operating temperature. On the other hand non-metallic conductors such as carbon and silicon and insulators such as glass and porcelain have a lower resistance at high temperatures than when cold.

The resistance of a material or circuit can be expressed by a constant, R, which is equal to the ratio of the applied electromotive force to the current produced. Expressed as an equation:

$$R = \frac{\text{electromotive force}}{\text{current}}$$

This equation constitutes the basis for *Ohm's Law,* which is treated at length in the succeeding text.

The commonly-used unit of resistance is the *ohm* although the expression *megohm* (1,000,000 ohms) is sometimes used when very large quantities are involved. By definition, if a voltage of one volt is applied across a resistance of one ohm, a current of one ampere will flow.

The Coulomb and the Ampere

The *coulomb* is a *quantity* of electricity; it is equal to 6.28×10^{18} electrons flowing by a point and will deposit 1.118 milligrams of silver from a solution of a silver salt. The *rate* of current flow is measured in terms of the *ampere.* If 6.28×10^{18} electrons, or one coulomb, pass a given point in a conductor in *one second,* a current of one ampere is flowing. Thus we see that *coulomb* indicates *amount,* and *ampere* indicates *rate of flow.*

The Volt—the Unit of E.M.F.

The electrons are driven through the wires and components of a circuit by a force called an *electromotive force,* usually abbreviated *e.m.f. or E.M.F.* The unit that denotes this force is called the *volt.* This force or pressure is measured in terms of the difference in the number of electrons at one point with respect to another. This is known as the *potential difference.*

The relationship between the electromotive force (voltage) to the flow of current (amperes), and the resistance which impedes the flow of current (ohms), is very clearly expressed in a simple but highly valuable law known as *Ohm's law.*

Ohm's Law

This law states that *the current in amperes is equal to the voltage divided by the resistance in ohms.* Expressed as an equation:

$$I = \frac{E}{R}.$$

If the voltage (E) and resistance (R) are known, the current (I) can be readily found. If the voltage and current are known, and the resistance is unknown, the resistance (R) is equal to $\frac{E}{I}$. When the voltage is the unknown quantity, it can be found by multiplying

I × R. These three equations are all secured from the original by simple transposition. The expressions are here repeated for quick reference:

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

where I is the current in amperes,
R is the resistance in ohms,
E is the electromotive force in volts.

Applying Ohm's Law

As a practical example suppose we take the case where it is desired to place a bleeder resistor which will draw 40 ma. across a 500-volt power supply. In this example both the voltage and the current are known and the resistance value is the unknown; hence, we use the second of the two above equations which states that the voltage in volts divided by the current in amperes will give the desired resistance value in ohms. The current value is given in milliamperes; to convert ma. into amperes the decimal point is moved three points to the left. Hence 40 ma. = .040 amperes.

$$R = \frac{E}{I} \qquad R = \frac{500}{.04} = 12{,}500 \text{ ohms}$$

Thus if a 12,500-ohm resistor is placed across a 500-volt plate supply the current passing through the resistor will be 40 ma. or .040 amperes.

Another typical problem for the application of Ohm's law would be a resistance-coupled amplifier whose plate resistor has a value of 50,000 ohms, with a measured current through this resistor of 5 milliamperes. The problem is to find the actual voltage applied to the plate of the tube.

The resistance R is 50,000 ohms. The current I is given as 5 milliamperes; milliamperes must, therefore, first be converted into amperes; .005 amperes equals 5 milliamperes. The electromotive force or voltage, E, is the unknown quantity. Ohm's law is applied as follows:

Formula: $E = I \times R$
$R = 50{,}000$ ohms
$I = .005$ amperes

Solution: $.005 \times 50{,}000 = 250$ volts drop across the resistor.

If the power supply delivers 300 volts, the actual voltage on the plate of the tube would be only 50 volts. This means that 250 volts of the supply voltage would be consumed in forcing a current of .005 amperes through the 50,000-ohm plate resistor.

As another example suppose that given supply voltage is 300, and that the (measured) voltage on the plate of the tube is 100 volts. Find the current flowing through the plate resistor of 20,000 ohms.

From Ohm's law, $I = \frac{E}{R}$, and E equals the *difference* between supply and measured plate voltages.

Therefore:

$$I = \frac{200}{20{,}000},$$

$I = 0.010$ amperes, or 10 milliamperes.

Resistances in Series and Parallel

When resistances are connected in series the total value of resistance is equal to the sum of each of the individual resistances. Thus a 2000-ohm resistor in series with a 3000-ohm one would make a total of 5000 ohms—and if another resistor of 5000 ohms were connected in series with the other two the total value would be the sum of all three or 10,000 ohms.

However, when resistors are connected in *parallel* (or shunt as such a connection is sometimes called) the resultant value of resistance is always less than the value of the lowest of the paralleled resistors. It is well to bear this simple law in mind as it will assist greatly in approximating the value of paralleled resistors at a later time. The calculation of the exact values of paralleled resistors will be discussed in the succeeding paragraphs.

Like Values of Resistance in Parallel

When two or more resistances of the same value are placed in parallel the effective resultant of the paralleled resistors is equal to the value of one of the resistors divided by the number of resistors in parallel. This can be expressed mathematically as:

$$R_{(\text{N resistors in parallel})} = \frac{R_{(\text{each resistor})}}{\text{N (number in parallel)}}$$

Thus if (2) resistors of (5000) ohms are placed in parallel the resultant value is 5000 divided by 2, or 2500 ohms. As another example, if (4) resistors of (100,000) ohms are placed in parallel the effective resistance of the paralleled combination is 100,000 divided by 4 or 25,000 ohms.

Unlike Resistances in Parallel

The resultant value of placing a number of unlike resistors in parallel is equal to the reciprocal of the sum of the reciprocals of the various resistors. This can be expressed as:

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots . \frac{1}{R_n}}$$

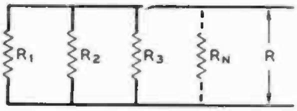


Figure 1.
RESISTORS IN PARALLEL.

The effective value of placing any number of unlike resistors in parallel can be determined from the above formula. However, it is commonly used only when there are three or more resistors under consideration since the simplified formula given in the following paragraph is more convenient when only two resistors are being used.

Two Unlike Paralleled Resistors

When two resistances of unlike values are to be used in parallel the following formula may be used to determine their effective resistance:

$$R = \frac{R_1 \times R_2}{R_1 + R_2}$$

where R is the unknown quantity,
R_1 is the resistance of the first resistor,
R_2 is the resistance of the second resistor.

A typical example would be an a.v.c. resistor of 500,000 ohms, which is to be shunted (paralleled) with another resistor of some value, in order to bring the *effective* resistance value *down* to a value of 300,000 ohms. Substituting these values in the equation for two unequal resistances in parallel:

$$300{,}000 = \frac{500{,}000 \times R_2}{500{,}000 + R_2}.$$

By transposition, factoring and solution, the effective value of R will be 750,000 ohms. Thus a 750,000-ohm resistance must be connected across the 500,000-ohm resistance in order to secure an effective resistance of 300,000 ohms.

In solving for values other than those given, the simplified equation becomes:

$$R_2 = \frac{R_1 \times R}{R - R_1},$$

where R is the resistance present,
R_1 is the resistance to be obtained,
R_2 is the value of the unknown resistance necessary to give R_1 when in parallel with R.

Resistances in Series-Parallel

Resistances in series-parallel can be solved from the equation:

$$R = \frac{1}{\frac{1}{R_1 + R_2} + \frac{1}{R_3 + R_4} + \frac{1}{R_5 + R_6 + R_7}}$$

Power in Resistive Circuits

Heat is generated when a source of voltage causes a given current to flow through a resistor. If the flow of cur-

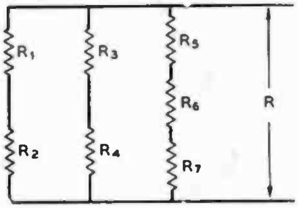


Figure 2.

RESISTORS IN SERIES-PARALLEL.

rent is continually being impeded as a result of an insufficient number of free electrons, there will be countless collisions between the moving electrons and the atoms and the electrons must, therefore, be *forced* through in order that a given number will move continuously through the conducting medium. This phenomenon results in heating of the conductor, and the heating is the result of loss of useful *power* or *energy*.

Wattage

The power in an electrical circuit is expressed in *watts* and is equal to the product of the voltage and the current flowing in that circuit. Hence W (watts) = EI. Since it is often convenient to express power in terms of the resistance of the circuit and the current flowing through it, a substitution of IR for E (E = IR) in the above formula gives: $W = IR \times I$ or $W = I^2R$.

In terms of voltage and resistance, $W = E^2/R$. Here, $I = E/R$ and when this was substituted for I the formula became $W = E \times E/R$ or $W = E^2/R$. To repeat these three expressions for determining wattage in an electrical circuit:

$W = EI$, $W = I^2R$, and $W = E^2/R$,
where W is the power in watts,
E is the electromotive force in volts,
and *I is the current in amperes.*

To apply the above equation to a typical problem: The voltage drop across a cathode resistor in a power amplifier stage is 50 volts; the plate current flowing through the resistor is 150 milliamperes. The number of watts the resistor will be required to dissipate is found from the formula: W (watts) = $E \times I$, or $50 \times .150 = 7.5$ watts (.150 amperes is equal to 150 milliamperes). From the foregoing it is seen that a 7.5-watt resistor will safely carry the required current, yet a 10- or 20-watt resistor would ordinarily be used to provide a safety factor.

In another problem, the conditions being similar to those above, but with resistance and current being the *known* factors, the solution is obtained as follows: $W = I^2 \times R = .0225 \times 333.33 = 7.5$.

If only the voltage and resistance are known, $W = \frac{E^2}{R} = \frac{2500}{333.33} = 7.5$ watts. It is seen that all three equations give the same result; the selection of the particular equation depends only upon the known factors.

Bleeder Resistors

Resistors are often connected across the output terminals of power supplies in order to bleed off a constant value of current or to serve as a constant fixed load. The regulation of the power supply is thereby improved and the voltage is maintained at a more or less constant value, regardless of load conditions. When the load is entirely removed from a power supply, the voltage may rise to such a high value as to ruin the filter condensers.

The amount of current which can be drawn from a power supply depends upon the current rating of the particular power transformer in use. If a transformer will carry a maximum safe current of 100 milliamperes, and if 75 milliamperes of this current is required for operation of a radio receiver, there remains 25 milliamperes of current available which can be wasted in the bleeder resistor.

An example for calculating bleeder resistor values for safe wattage rating is as follows: The power supply delivers 300 volts. The power transformer can safely supply 75 milliamperes of current of which 60 milliamperes will be required for the receiver. The problem is to find the correct value of resistance to give a bleeder current of 15 milliamperes.

Ohm's law gives the solution: $R = \frac{E}{I} = \frac{300}{.015} = 20{,}000$ ohms. (15 milliamperes is equivalent to .015 ampere.) Therefore, it is seen that the bleeder resistor should have a resistance of 20,000 ohms.

Another problem would be to find the required safe wattage rating of the bleeder, under the same conditions as given in the previous example. The answer is secured as follows: $W = E \times I = 300 \times .015 = 4.5$ watts. It is considered good practice to allow an overload factor of at least 100 per cent, since the voltage will increase somewhat when all load except the bleeder is removed. Therefore, a 10-watt resistor should be chosen.

Voltage Dividers

A voltage divider is exactly what its name implies: a resistor or a series of resistors connected across a source of voltage from which various lesser values of voltage may be obtained by connection to various points along the resistor.

A voltage divider serves a most useful purpose in a radio receiver, transmitter or amplifier, because it offers a simple means of obtaining plate, screen and bias voltages of different values from a common power supply source. It may also be used to obtain very low voltages of the order of .01 to .001 volts with a high degree of accuracy, even though a means of measuring such voltages is lacking. The procedure for making these measurements can best be given in the following example:

Assume that an accurately calibrated 0-150 voltmeter is available and that the source of voltage is exactly 100 volts. This 100 volts is then impressed through a resistance of exactly 1,000 ohms. It will, then, be found that the voltage along various points on the resistor, with respect to the grounded end, will be exactly proportional to the resistance at that point. From Ohm's law, the current would be 0.1 ampere; this current remains unchanged since the original value of resistance (1,000 ohms) and the voltage source (100 volts) are unchanged. Thus, at a 500-ohm point on the resistor (half its entire resistance), the voltage will likewise be halved or reduced to 50 volts.

The equation ($E = I \times R$) gives the proof: $E = 500 \times 0.1 = 50$. At the point of 250 ohms on the resistor, the voltage will be one-fourth the total value or 25 volts ($E = 250 \times 0.1 = 25$). Continuing with this process, a point can be found where the resistance measures exactly one ohm and where the voltage equals 0.1 volt. It is, therefore, obvious that if the original source of voltage and resistance can be measured, it is a simple matter to predetermine the voltage at any point along the resistor, provided that the current remains constant.

Design of Voltage Divider

Proper design of a voltage divider for any type of radio equipment is a relatively simple matter. The first consideration is the amount of bleeder current to be drawn, which is dictated largely by the examples previously given. In addition, it is also necessary that the desired voltage and the exact current at each tap on the voltage divider be known.

The current does not flow from the tap-on point through the resistor to ground or negative terminal, but rather from the positive side, then out through the tap, then through the device to ground. This explanation can be more easily followed by referring to figure 3, wherein the arrows indicate the direction of current flow through the external load and through the voltage divider.

The device which secures current from the voltage divider is indicated as C. The current drawn by C flows through section A of the bleeder resistor, then through C, and back to ground. The bleeder current, however, flows through the entire divider, i.e., through both A and B. Therefore, it becomes apparent that when a tap-on point is chosen to

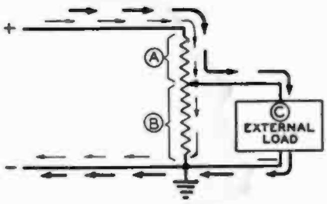


Figure 3.

Flow of current through an adjustable voltage divider and to an external load.

give the voltage desired, it is necessary to consider not only the current drawn by the device C, but also the bleeder current.

The design of more complex voltage dividers can best be illustrated by means of the following problems:

A power supply delivers 300 volts and is conservatively rated to supply all needed current for the receiver and still allow a bleeder current of 10 milliamperes. The following voltages are wanted: 250 volts at 20 milliamperes for the plates of the tubes, 100 volts at 5 milliamperes for the screens of the tubes, and 75 volts at 2 milliamperes for the detector tube. The voltage drop from the 300-volt value to the required 250 volts would be 50 volts; for the 100-volt value, the drop will be 150 volts; for the 75-volt value, the drop will be 225 volts. These values are shown in the diagram of figure 4. The respective current values are also indicated.

Tabulating the foregoing:

$$A = \frac{\text{Voltage Drop}}{\text{Current}} = \frac{50}{.037} = 1{,}351 \text{ ohms.}$$

Dissipation = .037 × 50 = 1.85 watts.

$$B = \frac{\text{Voltage Drop}}{\text{Current}} = \frac{150}{.017} = 8{,}823 \text{ ohms}$$

Dissipation = .017 × 150 = 2.25 watts.

$$C = \frac{\text{Voltage Drop}}{\text{Current}} = \frac{26}{.012} = 2{,}083 \text{ ohms.}$$

Dissipation = .012 × 25 = 0.3 watts

$$D = \frac{\text{Voltage Drop}}{\text{Current}} = \frac{75}{.010} = 7{,}500 \text{ ohms.}$$

Dissipation = .010 × 75 = 0.75 watts.

The divider has a total resistance of 19,757 ohms; this value is secured by adding together the four resistance values of 1,351, 8,823, 2,083 and 7,500 ohms. A 20,000-ohm resistor with three sliding taps will, therefore, be of the approximately correct size and, therefore, would ordinarily be used because of the difficulty in securing four separate resistors of the exact odd values indicated and because no adjustment would be possible to compensate for any slight error in estimating the probable currents through the various taps.

While the wattage dissipation across all the individual sections is only 5.15 watts, the selection of a single resistor, such as a large resistor with several sliders, should be based not only on the

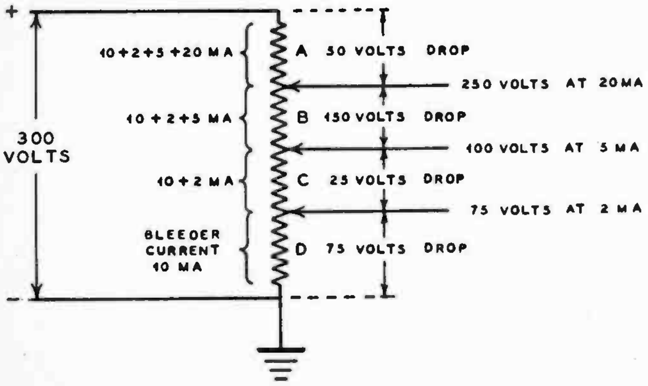


Figure 4.

Combined bleeder and adjustable voltage divider resistor as commonly used in radio receivers.

wattage rating but also on the current that it will safely carry. In the above example, the wattage of the section carrying the heaviest current is only 1.85 watts. The maximum dissipation of any particular section is 2.25 watts. Yet, if a 5-watt resistor were selected, it would very soon burn up. The reason for this is that *part* of the divider must handle 37 ma.

The selection for wattage rating is, therefore, made on the basis of *current* because wattage rating of resistors assumes uniform current distribution. Most manufacturers rate their resistors in this manner; if not, it can be calculated from the resistance and wattage rating.

When the sliders on the resistor once are set to the proper point, as in the above example, the voltages will remain constant at the values shown as long as the current remains a constant value.

One of the serious disadvantages of the voltage divider becomes evident when the current drawn from one of the taps changes. It is obvious that the voltage drops are interdependent and, in turn, the individual drops are in proportion to the current which flows through the respective sections of the divider resistor. The only remedy lies in providing a heavy steady bleeder current in order to make the individual currents so small a part of the total current that any change in current will result in only a slight change in voltage. This can seldom be realized in practice because of the excessive values of bleeder current which would be required.

When a power supply is used for C-bias service, still another factor must be taken into consideration. Rectified grid current from the class B or C stages will flow through the divider in the same direction as the bleeder current. If this grid current changes, the voltage applied to the grid will also correspondingly change. Adjustments of a C-bias supply should be made while the amplifier draws its proper amount of grid current; otherwise, the C-bias resistor setting will be greatly in error. Heavy bleeder currents are thus required for C-bias supplies, especially where the grid current is changing and the bias must remain constant, as in certain types of phone transmitters.

Since the grid current in a C-bias supply flows from the tap on the divider to ground, and in the same direction as the bleeder current, it is important to remember that in this case the regulation is in the opposite direction from the case where power is being taken from a tap on the divider. In other words, the greater the grid current that is flowing through the bleeder, the *higher* will be the voltage at this tap on the divider—and for that matter, at all other taps in the same divider.

Applying the Previous Equations: Operating Vacuum Tube Filaments in Series

Not only do the following problems regarding series and parallel operation of vacuum tube filaments have practical application in the design of radio receivers, but they serve as excellent examples for those who want to follow the solution of typical problems involving calculations of resistance, current, voltage and wattage.

When computations are made for the operation of vacuum tube filaments or heaters in series connection, it should be remembered that each has a definite resistance and that Ohm's law here again holds true, just as it does in the case of a conventional resistance.

No particular problem is involved when two exactly similar tubes of the same voltage and current rating are to be operated with their filaments or heaters connected in series in order to operate them from a source of voltage twice as high as is required for the tubes. If two six-volt tubes, each requiring 0.5 ampere for heater operation, are connected in series across a 12-volt power source, each tube will have the same voltage drop (6 volts), and the total current drawn from the power supply will be the same as for one tube or 0.5 ampere. By making this connection, the resistance has actually been doubled; yet, because the voltage is doubled, each tube automatically secures its proper voltage drop.

In this example, the resistance of each tube would be 12 ohms (6 divided by 0.5). In series, the resistance would be twice this value or 24 ohms. The current I would then equal $\frac{12}{24}$ or 0.5 ampere, from which it can be seen that the current drawn from the supply is the same as for a single tube.

It is important to understand that in a series connection the sum of the voltage drops across all of the tubes in the circuit cannot be more than the voltage of the supply. It is not possible to connect six similar 6-volt tubes in series across a 32-volt supply and expect to realize 6 volts on the filaments of each, since the sum of the various voltage drops is equal to 36 volts. The tubes can, however, be connected in such a manner that the correct voltage drop will be secured as will be explained later.

The following examples and diagrams give all needed design information for series- and series-parallel connections:

Example—One 6F6 and one 6L6 tube are to be operated in a low-power airplane transmitter. The power supply delivers 12.6 volts. The problem is to connect the heaters of the two tubes in such a manner that each tube will have exactly the same voltage drop across its heater terminals. The *tube tables* show that a type 6F6 tube draws 0.7 ampere at 6.3 volts. Its resistance, accordingly, equals $R = \frac{E}{I} = \frac{6.3}{0.7} = 9$ ohms. The 6L6 tube draws 0.9 ampere at 6.3 volts, and its resistance equals $\frac{6.3}{0.9} = 7$ ohms.

If these tubes are connected in series without precautionary measures, the total resistance of the two will be 16 ohms (9 + 7). A potential of 12.6 volts will pass a current of 0.787 ampere through this value of 16 ohms. The drop across each separate resistor is found from Ohm's law, as follows: $9 \times 0.787 = 7.083$ volts, and $7 \times 0.787 = 5.4$ volts. Thus, it is seen that neither tube will have the correct voltage drop.

One of the resistor values must, therefore, be changed so that it will be equal to the other in order that the voltage drop will be equal across both tubes. If the larger of the two resistors is taken and another resistor connected in parallel across it, the value of the larger resistor can then be brought down to that of the smaller.

Substituting these values in an equation previously given, $R = \frac{9 \times 7}{9 - 7} = 31.5$ ohms. By connecting a resistance of 31.5 ohms in parallel with the 9-ohm resistance, the effective resistance will be exactly 7 ohms or equal to that of the other resistor.

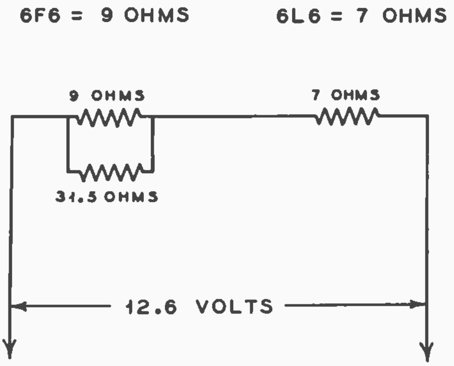


Figure 5.

The problem is made more simple by the following procedure:

If the tubes are regarded on the basis of their respective current ratings, it will be found that the 6L6 draws 0.9 ampere and the 6F6 0.7 ampere, or a difference of 0.2 ampere. If the resistance of the 6F6 is made equal to that of the 6L6, both tubes will draw the same current. Simply take the difference in current, 0.2 ampere, and divide this value into the proper voltage drop, 6.3 volts; the answer will be 31.5 ohms, which is the exact same value obtained in the previous roundabout method of calculation.

The diagram in figure 6 shows other possible connections for tubes of dis-

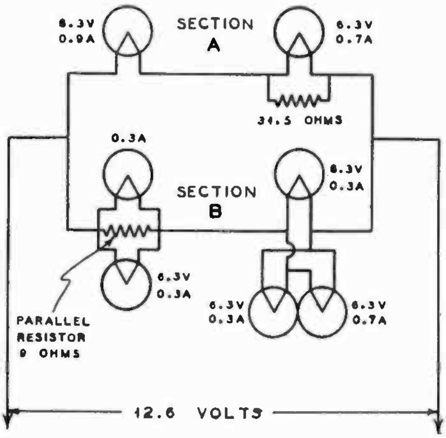


Figure 6.

similar heater for filament current ratings. Although section B in figure 6 appears formidable, it is a simple matter to make the necessary calculations for operating the tubes from a common source of supply. In section B there are three tubes with their heaters connected in parallel. The current, therefore, will be 0.3 + 0.3 + 0.7 = 1.3 amps. The two tubes in parallel draw 0.3 + .03 = 0.6 amp. The difference between 1.3 and 0.6 is 0.7 amp. The drop across each section is the same or 6.3 volts; therefore $\frac{6.3}{0.7} = 9$ ohms. This value of resistance across the two parallel-connected tubes gives their sections the same resistance as that of the three tubes; consequently, all tubes secure the proper voltage.

When tube heaters or filaments are operated in series, the current is the same throughout the entire circuit. The resistance of all tube filaments must then be made the same if each is to have the same votage drop across its terminals. The resistance of a tube heater or filament should never be measured when cold because the resistance will be only a fraction of the resistance present when the tube functions at proper heater or filament temperature. The resistance can be calculated satisfactorily by using the current and voltage ratings given in the tube tables.

Electromagnetism

Everyone is familiar with the common bar or horseshoe magnet. The magnetic field which surrounds it allows the magnet to attract nails, washers, or other pieces of iron to it. A peculiarity of an electric current, hence of electrons in motion in general, is that a magnetic field is set up in the vicinity of the conductor of the current for as long a period of time as the current is flowing. A field set up by an electric current is called an *electromagnetic* field to distinguish it from the permanent field surrounding the bar magnet.

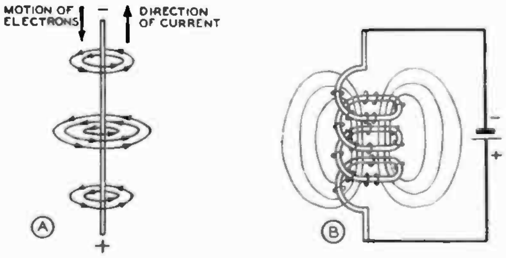


Figure 7.

(A) shows the magnetic lines of force produced around a conductor carrying an electric current. (B) indicates how the effectiveness of the field may be increased by winding the conductor into a coil.

The field, or *magnetic lines of force,* set up in the vicinty of the conductor extend outwardly from the conductor in a plant at right angles to its direction. It is these lines of magnetic force that make up the *magnetic flux*. The strength of this flux in the vicinity of a simple conductor is proportional to the strength of the current. However, if the conductor is wound into a coil the flux for each turn of wire becomes additive to that of the others and the flux becomes proportional to the number of turns as well as to the current flow. Since the flux is linearly proportional to both the current and the number of turns, the magnetizing effect of a coil may be described as a function of the ampere-turns of that coil; the magnetizing effect of a coil is proportional to the product of the current strength and the number of turns in the coil.

The magnetic flux increases or decreases in direct proportion to the change in the current. The ratio of the change in flux to the change in current has a constant value known as the *inductance* of a coil.

Electromagnetic Effects

In drawing an analogy of voltage, current and resistance in terms of magnetic phenomena, magnetic flux might be termed *magnetic current, magnetomotive force or magnetic voltage.* The *reluctance* of a magnetic circuit can be thought of as the resistance of the magnetic path. The relation between the three is exactly the same as that between current, voltage and resistance (Ohm's law).

The magnetic flux depends upon the material, cross section and length of the magnetic circuit, and it varies directly as the current flowing in the circuit. The *reluctance* is dependent upon the length, cross section, permeability and air gap, if any, of the magnetic circuit.

In the electrical circuit, the current would equal the voltage divided by the resistance, and so it is in the magnetic circuit.

$$\text{Magnetic Flux } (\phi) = \frac{\text{magnetomotive force (m.m.f.)}}{\text{reluctance } (r)}$$

Permeability

Permeability describes the difference in the magnetic properties of any magnetic substance as compared with the magnetic properties of air. Iron, for example, has a permeability of around 2000 times that of air, which means that a given amount of magnetizing effect produced in an iron core by a current flowing through a coil of wire will produce 2000 times the *flux density* that the same magnetizing effect would produce in air. The permeabilities of different iron *alloys* vary quite widely and permeabilities up to 100,000 can be obtained.

Permeability is similar to *electric conductivity.* There is, however, one important difference: the permeability of iron is not independent of the magnetic current (flux) flowing through it, although electrical conductivity is usually independent of electric current in a wire. After a certain point is reached in the flux density of a magnetic conductor, an increase in the magnetizing field will not produce a material increase in flux density. This point is known as the *point of saturation.* The inductance of a choke whose core is saturated declines to a very low value.

Counter E.M.F.

A fundamental law of electricity is: when lines of force cut across a conductor, a voltage is induced in that conductor. Therefore, it can be readily seen that in the case of the coil previously mentioned the flux lines from one turn cut across the adjacent turn, and a *voltage* is induced in that turn. The effect of these induced voltages is to create a voltage across the entire coil of opposite polarity or in the opposite direction to the original voltage. Such a voltage is called *counter e.m.f.* or *back e.m.f.*

If a direct current potential such as a battery is connected across a multiturn coil or inductance, the back e.m.f. will exist only at the instant of connection at which time the flux is rising to its maximum value. While it is true that a current is flowing through the turns of the coil and that a magnetic field exists around and through the center of the inductance, an induced voltage may only be produced by a *changing flux.* It is only such a changing flux that will cut across the individual turns and induce a voltage in them. By a changing flux is meant a flux that is increasing or decreasing as would occur if the e.m.f. across the coil were alternating or changing its direction periodically.

The Unit of Self-Inductance: The Henry

As the current increases, the back e.m.f. reaches a maximum; as the current decreases, the back e.m.f. is maximum in the *same* direction as the current. This back voltage is always *opposite* to the exciting voltage and, hence, always acts to resist any *change* in current in the inductance. This property of an inductance is called its *self-inductance* and is expressed in *henrys*, the henry being the unit of inductance. A coil has an inductance of one henry when a voltage of one volt is induced by a current change of one ampere per second. The unit, *henry*, is too large for reference to inductance coils such as those used in radio-frequency circuits; *millihenry* or *microhenry* are more commonly used, in the following manner:

1 *henry* = 1,000 *millihenrys, or* 10^3 *millihenrys.*
1 *millihenry* = 1/1,000 *of a henry*, .001 *henry, or* 10^{-3} *henry.*
1 *microhenry* = 1/1,000,000 *of a henry, or* .000001 *henry, or* 10^{-6} *henry.*
One one-thousandth of a millihenry = .001 *or* 10^{-3} *millihenrys.*
1,000 *microhenrys* = 1 *millihenry.*

Mutual Inductance

If two inductances are so placed in relation to each other that the lines of force encircling one coil are interlinked with the turns of the other, a voltage will be set up or *induced* in the second coil. As in the case of self-inductance, the *induced voltage* will be opposite in direction to the exciting voltage. This effect of linking two inductances is called *mutual inductance*, abbreviated *M*, and is also expressed in henrys. Two circuits thus joined are said to be *inductively coupled*.

The magnitude of the mutual inductance depends upon the shape and size of the two circuits, their positions and distances apart and the permeability of the medium. The extent to which two inductances are coupled is expressed by a relation known as *coefficient of coupling*. This is the ratio of the mutual inductance actually present to the maximum possible value.

Inductances in Parallel

Inductances in parallel are combined exactly as are resistors in parallel, provided that they are far enough apart so that the mutual inductance is entirely negligible, i.e., if the coupling is very loose.

Inductances in Series

Inductances in series are additive, just as are resistors in series, again provided that no mutual inductance exists. In this case, the total inductance L is:

$$L = L_1 + L_2 + \dots\dots\dots\dots \text{ etc.}$$

Where mutual inductance does exist:

$$L = L_1 + L_2 + 2M,$$

where M is the mutual inductance.

This latter expression assumes that the coils are connected in such a way that all flux linkages are in the same direction, i.e., additive. If this is not the case and the mutual linkages *subtract* from the self-linkages, the following formula holds:

$$L = L_1 + L_2 - 2M,$$

where M is the mutual inductance.

Calculation of Inductance

The inductance of coils with magnetic cores can be determined with reasonable accuracy from the formula:

$$L = 1.257 \times N^2 \times P \times 10^{-3}$$

where
L is the inductance in henrys,
N is the number of turns,
P is the permeability of the core material.

From this formula it can be seen that the inductance is proportional to the *permeability* as well as to the square of the number of turns. Thus, it is possible to secure greater values of inductance with a given number of turns of wire wound on an iron core than would be possible if an air core coil were used.

The inductance of an air core is proportional to the square of the number of turns of wire, provided that the length and diameter remain constant as the turns are changed (actually an impossibility, strictly speaking). The formula for inductance of air core coils is given with good accuracy, as follows:

$$L = N^2 \times d \times F,$$

where:

L = inductance in microhenrys,

d = diameter of coil, measured to center of wire,

N = number of turns,

F = a constant, dependent upon the ratio of length-to-diameter.

This formula is explained under the heading of *Coil Calculation*, where a graph for the constant F is given.

Core Material

Ordinary magnetic cores cannot be used for radio frequencies because the *eddy current losses* in the core material become enormous as the frequency is increased. The principal use for magnetic cores is in the audio-frequency range below approximately 15,000 cycles, whereas at very low frequencies (50 to 60 cycles) their use is mandatory if an appreciable value of inductance is desired.

An air core inductor of only one henry inductance would be quite large in size, yet values as high 500 henrys are commonly available in small iron core chokes. The inductance of a coil with a magnetic core will vary with the amount of direct current which passes through the coil. For this reason, iron core chokes that are used in power supplies have a certain inductance rating at a *predetermined value of d.c.*

One exception to the statement that metal core inductances are highly inefficient at radio frequencies is in the *powdered* iron cores used in some types of intermediate frequency transformers. These cores are made of very *fine particles* of powdered iron, which is first treated with an insulating compound so that each particle is insulated from the other. These particles are then molded into a solid core around which the wire is wound. Eddy current losses are greatly reduced, with the result that these special iron cores are entirely practical in circuits which operate up to 1500 kc. in frequency.

Electrical Storage of Energy

So far we have dealt only with the storage of energy in an electromagnetic field in the form of an inductance. The storage of energy in a magnetic field is expressed in *joules* and is equal to $(LI^2)/2$. (A joule is equal to one watt-second.) Electrical energy can also be stored in an electrostatic field. A device capable of storing energy in such a field is called a *condenser* and is said to have a certain *capacitance*. The energy stored in an electrostatic field is also expressed in *joules* and is equal to $CE^2/2$, where C is the capacity in *farads* (a unit of capacity to be discussed) and E is the potential in volts.

Capacitance and Condensers

Two metallic plates separated from each other by a thin layer of insulating material (called a *dielectric*, in this case), become a *condenser*. When a source of d.c. potential is momentarily applied across these plates, they may be said to become charged. If the same two plates are then joined together momentarily by means of a wire, the condenser will *discharge*.

When the potential was first applied, electrons immediately attempted to flow from one plate to the other through the battery or such source of d.c. potential as was applied to the condenser plates. However, the circuit from plate to plate in the condenser was *incomplete* (the two plates being separated by an insulator) and thus the electron flow ceased, meanwhile establishing a shortage of electrons on one plate and a surplus of electrons on the other.

Remember that when a deficiency of electrons exists at one end of a conductor, there is always a tendency for the electrons to move about in such a manner as to reestablish a state of balance. In the case of the condenser herein discussed, the surplus quantity of electrons on one of the condenser plates cannot move to the other plate because the circuit has been broken; that is, the battery or d.c. potential was removed. This leaves the condenser in a *charged* condition; the condenser plate with the electron *deficiency* is *positively* charged, the other plate being *negative*.

In this condition, a considerable stress exists in the insulating material (dielectric) which separates the two condenser plates, due to the mutual attraction of two unlike potentials on the plates. This stress is known as *electrostatic* energy, as contrasted with *electromagnetic* energy in the case of an inductance. This charge can also be called *potential energy* because it is capable of performing work when the charge is released through an external circuit.

The Unit of Capacitance: The Farad

If the external circuit of the two condenser plates is completed by joining the terminals together with a piece of wire, the electrons will rush immediately from one plate to the other through the external circuit and establish a state of equilibrium. This latter phenomenon explains the *discharge* of a condenser. The amount of stored energy in a charged condenser is dependent upon the charging potential, as well as a factor which takes into account the *size* of the plates, *dielectric thickness, nature* of the dielectric and the *number* of plates. This factor, which is determined by the foregoing, is called the *capacity* of a condenser and is expressed in *farads.*

The farad is such a large unit of capacity that it is rarely used in radio calculations, and the following more practical units have, therefore, been chosen:

1 *microfarad* = 1/1,000,000 *of a farad, or* .000001 *farad, or* 10^{-6} *farads.*

1 *micro-microfarad* = 1/1,000,000 *of a microfarad, or* .000001 *microfarad, or* 10^{-6} *microfarads.*

1 *micro-microfarad* = *one-million-millionth of a farad, or* .000000000001 *farad, or* 10^{-12} *farads.*

If the capacity is to be expressed in *microfarads* in the equation given under *energy storage,* the factor C would then have to be divided by 1,000,000, thus:

$$\text{Stored energy in joules} = \frac{C \times E^2}{2 \times 1{,}000{,}000}$$

This storage of energy in a condenser is one of its very important properties, particularly in those condensers which are used in power supply filter circuits.

Dielectric Constant

The capacity of a condenser is largely determined by the thickness and nature of the dielectric separation between plates. Certain materials offer a greater capacity than others, depending upon their physical makeup. This property is expressed by a constant K, called the dielectric constant. A table for some of the commonly used dielectrics is given here:

Material	*Dielectric Constant*
Air	1.00
Mica	2.94
Hard rubber	2.50 to 3.00
Glass	4.90 to 7.00
Bakelite derivatives	3.50 to 6.00
Celluloid	4.10
Fiber	4 to 6
Wood (without special preparation):	
Oak	3.3
Maple	4.4
Birch	5.2
Transformer oil	2.5
Castor oil	5.0
Porcelain, Steatite	6.5
Lucite	2.8
Quartz	4.2
Victron, Trolitul	2.6

Dielectric Breakdown

The nature and thickness of a dielectric have a very definite bearing on the amount of charge of a condenser. If the charge becomes too great for a given thickness of dielectric, the condenser will break down, i.e., the dielectric will puncture. It is for this reason that condensers are rated in the manner of the amount of voltage they will safely withstand. This rating is commonly expressed as the *d.c. working voltage.*

Capacity Calculation

The capacity of two parallel plates is given with good accuracy by the following formula:

$$C = 0.2244 \times K \times \frac{A}{t},$$

where C = capacity in micro-micro-farads,
K = dielectric constant of spacing material,
A = area of dielectric in square inches,
t = thickness of dielectric in inches.

This formula indicates that the capacity is directly proportional to the area of the plates and inversely proportional to the thickness of the dielectric (spacing between the plates). This simply means that when the area of the plate is doubled, the spacing between plates remaining constant, the capacity will be doubled. Also, if the area of the plates remains constant, and the plate spacing is doubled, the capacity will be reduced to half. The above equation also shows that capacity is directly proportional to the dielectric constant of the spacing material. A condenser that has a capacity of 100 in air would have a capacity of 500 when immersed in castor oil, because the dielectric constant of castor oil is 5.0 or five times greater than the dielectric constant of air.

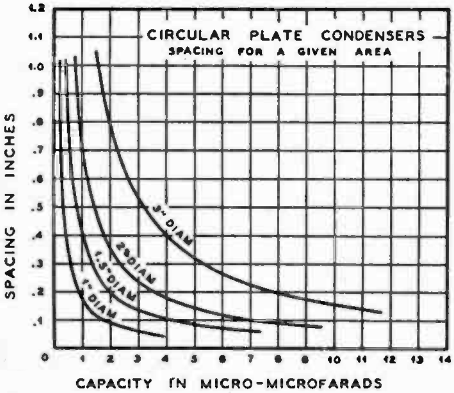


Figure 8.

In order to determine the capacity of a parallel plate condenser, the following transposition is of value when the spacing between plates is known:

$$A = \frac{C \times t}{0.2244 \times K},$$

where A = area of plates in square inches,
K = dielectric constant of spacing material,
C = capacity in micro-micro-farads,
t = thickness of dielectric (plate spacing) in inches.

Where the area of the plates is definitely set, and when it is desired to know the spacing needed to secure a required capacity,

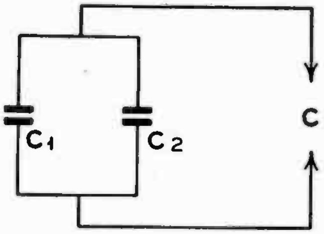
$$t = \frac{A \times 0.2244 \times K}{C},$$

where all units are expressed just as in the preceding formula. This formula is not confined to condensers having only square or rectangular plates, but also applies when the plates are circular in shape. The only change will be the calculation of the *area* of such circular plates; this area can be computed by squaring the *radius* of the plate, then multiplying by 3.1416, or "pi". Expressed as an equation:

$$A = 3.1416 \times r^2,$$

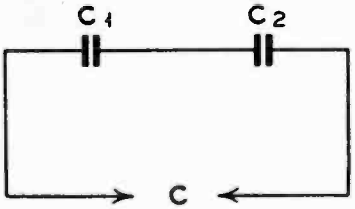
where r = radius in inches.

The capacity of a multi-plate condenser can be calculated by taking the ca-



CONDENSERS IN PARALLEL

Figure 9.



CONDENSERS IN SERIES

Figure 10.

pacity of one section and multiplying this by the number of dielectric spaces. In such cases, however, the formula gives no consideration to the effects of edge capacity so that the capacity as calculated will not be entirely accurate. These additional capacities will be but a small part of the effective total capacity, particularly when the plates are reasonably large, and the final result will, therefore, be within practical limits of accuracy.

Equations for calculating capacities of condensers in *parallel* connection are the same as those for resistors in *series:*

$$C = C_1 + C_2, \text{ etc.}$$

Condensers in *series* connection are calculated in the same manner as are resistors in *parallel.*

The formulas are repeated: (1) For two or more condensers of *unequal* capacity in series:

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

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

(2) *Two* condensers of *unequal* capacity in series:

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

(3) Three condensers of *equal* capacity in series:

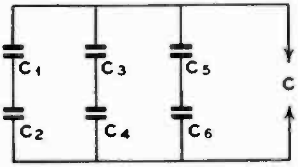
$C = \frac{C_1}{3}$, where C_1 is the common capacity.

(4) Three or more condensers of *equal* capacity in series:

$$C = \frac{\text{Value of common capacity}}{\text{Number of condensers in series}}$$

(5) Six condensers in series parallel:

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}} + \frac{1}{\frac{1}{C_3} + \frac{1}{C_4}} + \frac{1}{\frac{1}{C_5} + \frac{1}{C_6}}$$



CONDENSERS IN SERIES – PARALLEL

Figure 11.

Voltage Rating of Series Condensers

Any good paper dielectric filter condenser has such a high internal resistance (indicating a good dielectric) that the exact resistance will vary considerably from condenser to condenser even though they are made by the same manufacturer and are of the same rating. Thus, when 1000 volts d.c. is connected across two 1-μfd. 500-volt condensers, the chances are that the voltage will divide unevenly and one condenser will receive more than 500 volts and the other less than 500 volts.

By connecting a half-megohm 1-watt carbon resistor across each condenser, the voltage will be equalized because the resistors act as a voltage divider and the internal resistances of the condensers are so much higher (many megohms) that they have but little effect in disturbing the voltage divider balance.

Carbon resistors of the inexpensive type are not particularly accurate (not being designed for precision service); therefore it is advisable to check several on an accurate ohmmeter to find two that are as close as possible in resistance. The exact resistance is unimportant, just so it is the same for the two resistors used.

When two condensers are connected in series, *alternating* current pays no heed to the relatively high internal resistance of each condenser, but divides across the condensers in inverse proportion to the *capacity*. Because, in addition to the d.c. across a capacitor in a filter or audio amplifier circuit, there is usually an a.c. or a.f. voltage component, it is inadvisable to series-connect condensers of unequal capacitance even if dividers are provided to keep the d.c. within the ratings of the individual capacitors.

For instance, if a 500-volt 1-μfd. capacitor is used in series with a 4-μfd. 500-volt condenser across a 250-volt a.c. supply, the 1-μfd. condenser will have 200 volts a.c. across it and the 4-μfd.-condenser only 50 volts. An equalizing divider to do any good in this case would have to be of very low resistance because of the comparatively low impedance of the condensers *to a.c.* Such a divider would draw excessive current and be impracticable.

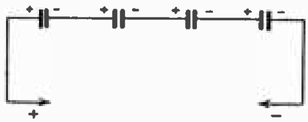
The safest rule to follow is to use only condensers of the same capacity and voltage rating and to install matched high resistance proportioning resistors across the various condensers to equalize the d.c. voltage drop across each condenser. This holds regardless of how many capacitors are series-connected.

Electrolytic Condensers in Series

Similar electrolytic capacitors, of the same capacity and made by the same manufacturer, have more nearly uniform (and much lower) internal resistance though it still will vary considerably. However, the variation is not nearly as great as encountered in paper condensers, and the lowest d.c. voltage is across the weakest (leakiest) electrolytic condensers of a series group.

As an electrolytic capacitor begins to show signs of breaking down from excessive voltage, the leakage current goes up, which tends to heat the condenser and aggravate the condition. However, when used in series with one or more others, the lower resistance (higher leakage current) tends to put less d.c. voltage on the weakening condenser and more on the remaining ones. Thus, the capacitor with the *lowest* leakage current, usually the *best* capacitor, has the highest voltage across it. For this reason, dividing resistors are not essential across series-connected electrolytic capacitors.

Electrolytic condensers use a very thin film of oxide as the dielectric, and are polarized; that is, they have a positive and a negative terminal which must be properly connected in a circuit; otherwise, the oxide will boil, and the condenser will no longer be of service. When electrolytic condensers are connected in series, the positive terminal is always connected to the positive lead of the power supply; the negative terminal of the condenser connects to the positive terminal of the *next* condenser in the series combination. The method of connection is illustrated in figure 12.



POLARIZED CONDENSERS, (ELECTROLYTIC) IN SERIES

Figure 12.

Alternating Current

To this point in the text, consideration has been given primarily to a current consisting of a steady flow of electrons in one direction. This type of current

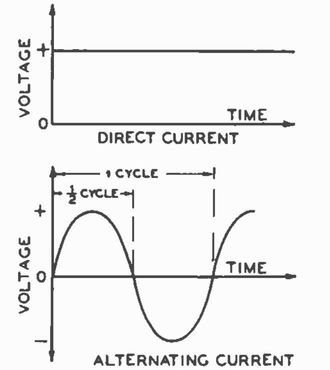


Figure 13.

Graphical comparison of unidirectional or direct current and alternating current.

flow is known as *unidirectional* or *direct* current, abbreviated *d.c.* Equally as important in radio work and more important in power practice is another and altogether different type of current, known as *alternating current* and abbreviated *a.c.* Power distribution from one point to another and into homes and factories is almost universally a.c. On the other hand, the plate supply to vacuum tubes delivers d.c.

An alternating current begins to flow in one direction, meanwhile changing its amplitude from zero to a maximum value, then down again to zero, from which point it changes its direction, and again goes through the same procedure. Each one of these zero-maximum-zero amplitude changes in a given direction is called a *half cycle.* The complete change in two directions is called a *cycle.* The number of times per second that the current goes through a complete cycle is called the *frequency.* The frequency of common house-lighting alternating current is generally 60 cycles, meaning that it goes through 60 complete cycles (120 reversals) per second. However, 25- and 50-cycle power is to be found quite frequently and 40-, 133-, and 240-cycle power is found in certain foreign countries.

Radio frequency currents, on the other hand, go through so many of these alternations per section that the term cycle becomes unwieldy. As an example, it can be said that a certain station on the ten-meter amateur band is operating on 28,640,000 cycles per second. However it is much more convenient to say that the carrier frequency is 28,640 kilocycles, or 28.64 megacycles, per second. A conversion table for simplifying this terminology is given here:

1,000 *cycles* = 1 *kilocycle. The abbreviation for kilocycle is kc.*
1 *cycle* = 1/1,000 *of a kilocycle,* .001 *kc. or* 10^{-3} *kc.*
1 *megacycle* = 1,000 *kilocycles, or* 1,000,000 *cycles,* 10^{3} *kc. or* 10^{6} *cycles.*
1 *kilocycle* = 1/1,000 *megacycle,* .001 *megacycle, or* 10^{-3} *Mc. The abbreviation for megacycles is Mc.*

Applying Ohm's Law to Alternating Current

Ohm's law applies equally to direct or alternating current, *provided* the circuits under consideration are purely resistive, that is, circuits which have neither inductance (coils) nor capacitance (condensers). Problems which involve tube filaments, drop resistors, electric lamps, heaters or similar resistive devices can be solved from Ohm's law, regardless of whether the current is direct or alternating. When a condenser or a coil is made a part of the circuit, a property common to either, called *reactance,* must be taken into consideration.

Inductive Reactance

As was previously stated, when an alternating current flows through an inductance, a back- or counter-electromotive force is developed; this force opposes any change in the initial e.m.f. The property of an inductance to offer opposition to a change in current is known as its *reactance* or *inductive reactance.* This is expressed as X_L:

$$X_L = 2\pi fL,$$

where X_L = inductive reactance expressed in ohms.

$\pi = 3.1416\ (2\pi = 6.283)$,
f = frequency in cycles,
L = inductance in henrys.

It is very often necessary to compute inductive reactance at radio frequencies. The same formula may be used, except that the units in which the inductance and the frequency are expressed will be changed. Inductance can, therefore, be expressed in *millihenrys* and frequency in *kilocycles.* For higher frequencies and smaller values of inductance, frequency is expressed in *megacycles* and inductance in *microhenrys.* The basic equation need not be changed since the multiplying factors for inductance and frequency appear in numerator and denominator, and hence are cancelled out. However, it is not possible in the same equation to express L in millihenrys and f in cycles without conversion factors.

Should it become desirable to know the value of inductance necessary to give a certain reactance at some definite frequency, a transposition of the original formula gives the following:

$$L = \frac{X_L}{2 \pi f}$$

or when X_L and L are known:

$$f = \frac{X_L}{2 \pi L}$$

Condensers in A. C. and D. C. Circuits

When a condenser is connected into a direct current circuit, it will block the d.c., or stop the flow of current. Beyond the initial movement of electrons during which the condenser is charged, there will be no flow of current because the circuit is effectively broken by the dielectric of the condenser. Strictly speaking, a very small current may actually flow because the dielectric of the condenser may not be a perfect insulator. This minute current flow is the leakage current previously referred to and is dependent upon the internal d.c. resistance of the condenser. This leakage current is usually quite noticeable in most types of electrolytic condensers.

When an alternating current is applied to a condenser, it will charge and discharge a certain number of times per second in accordance with the frequency of the alternating voltage. The electron flow in the charge and discharge of a condenser when an a.c. potential is applied constitutes an alternating current, in effect. It is for this reason that a condenser will pass an alternating current yet offer practically infinite opposition to a direct current. These two properties are repeatedly in evidence in a radio circuit.

Capacitive Reactance

It has been explained that inductive reactance is the ability of an inductance to oppose a change in an alternating current. Condensers have a similar property although in this case the opposition is to the *voltage* which acts to charge the condenser. This action is called *capacitive reactance* and is expressed as follows:

$$X_c = \frac{1}{2 \pi fC},$$

where X_c = capacitive reactance in ohms,
π = 3.1416,
f = frequency in cycles,
C = capacity in farads.

Here again, as in the case of inductive reactance, the units of capacity and frequency can be converted into smaller units for practical problems encountered in radio work. The equation may be written:

$$X_c = \frac{1,000,000}{2 \pi fC},$$

where f = frequency in megacycles,
C = capacity in micro-microfarads.

In the design of filter circuits, it is often convenient to express frequency (f) in *cycles* and capacity (C) in *microfarads,* in which event the same formula applies.

Comparison of Inductive to Capacitive Reactance with Changing Frequency

From the equation for *inductive* reactance, it is seen that as the frequency becomes greater the reactance increases in a corresponding manner. The reactance is doubled when the frequency is doubled. If the reactance is to be very large when the frequency is low, the value of inductance must be very large.

The equation for capacitive reactance shows that the reactance varies *inversely* with frequency and capacity. With a fixed value of capacity, the reactance will become less as the frequency increases. When the frequency is fixed, the reactance will be greater as the capacity is lowered. In order to have high reactance, it is necessary to have low capacitance although in power filter circuits the reactance is always made low so that the alternating current component from the rectifier will be by-passed. The capacitance must be made large in this case because the frequency is quite low (60-120 cycles).

A comparison of the two types of reactance, inductive and capacitive, shows that in one case (inductive) the reactance *increases* with frequency, whereas in the other (capacitive) the reactance *decreases* with frequency.

Reactance and Resistance in Combination

When a circuit includes a capacity or an inductance or both, in addition to a resistance, the simple calculations of Ohm's law will *not* apply when the total impedance to alternating current is to be determined. Reference is here made to the passage of an *alternating current* through the circuit; the reactance must be considered in addition to the d.c. resistance because reactance offers an opposition to the flow of alternating current.

When alternating current passes through a circuit which contains only a condenser, the voltage and current relations are as follows:

$$E = I X_c, \text{ and } I = \frac{E}{X_c},$$

where E = voltage,
I = current in amperes,
X_c = capacitive reactance or $\frac{1}{2\pi fC}$
(expressed in ohms).

When the circuit contains inductance only, yet with the same conditions as above, the formula is as follows:

$$E = IX_L, \text{ and } I = \frac{E}{X_L},$$

where E = voltage,
I = current in amperes,
X_L = inductive reactance or $2\pi fL$
(expressed in ohms).

When a circuit has resistance, capacitive reactance and inductive reactance in *series*, the effective total opposition to the alternating current flow is known as the *impedance* of the circuit. Stated otherwise, impedance of a circuit is the vector sum of the resistance and the difference between the two reactances.

$$Z = \sqrt{r^2 + (X_L - X_c)^2} \text{ or}$$

$$Z = \sqrt{r^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}$$

where Z = impedance in ohms,
r = resistance in ohms,
X_L = inductive reactance ($2\pi fL$) in ohms,
X_c = capacitive reactance $\left(\frac{1}{2\pi fC}\right)$ in ohms.

An example will serve to clarify the relationship of resistance and reactance to the total impedance. If a 10-henry choke, a 2-μfd. condenser and a resistance of 10 ohms (which is represented by the d.c. resistance of the choke) are all connected in *series* across a 60-cycle source of voltage:

for reactance $X_L = 6.28 \times 60 \times 10 =$ 3,750 ohms (approx.),

$$X_c = \frac{1{,}000{,}000}{6.28 \times 60 \times 2} =$$

1,300 ohms (approx).
r = 10 ohms

Substituting these values in the impedance equation:

$$Z = \sqrt{10^2 + (3750 - 1300)^2} = 2450$$ ohms.

This is nearly 250 times the value of the d.c. resistance of 10 ohms. The subject of impedance is more fully covered under *Resonant Circuits.*

Generation of Alternating Current

Again recalling previous text, an alternating current is one which rises to a maximum, then decreases to zero from that point, and then goes through the same pulse in the opposite direction. This continual change of amplitude and direction is maintained as long as the current continues to flow. The number of times that the current changes direction in a given length of time is called the frequency of change, or more generally, it is simply called the *frequency.*

Alternating currents which range from nearly zero to many millions of cycles per second are commonplace in radio applications. Such a current is produced by the rotating machine which generates the common 60-cycle house-lighting current; it is likewise produced by oscillatory circuits for the high radio frequencies. A machine that produces alternating current for house-lighting, industrial and other uses is called an *alternator.* It is also called an *a.c. generator.*

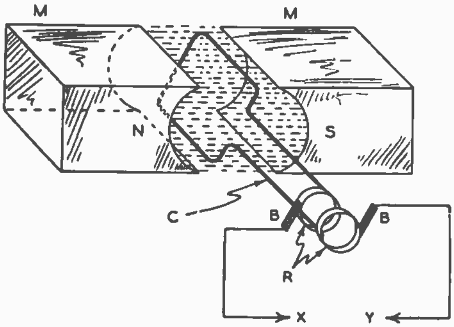


Figure 14.

BASIC FORM OF ALTERNATOR.

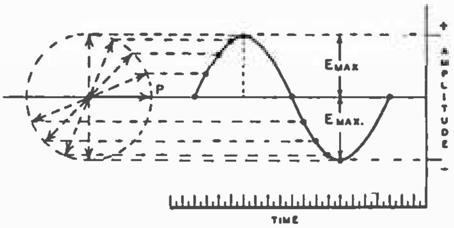


Figure 15.

An alternator in its very basic form is shown in figure 14. It consists of two permanent magnets, M, the opposite poles of which face each other, and the poles being machined so that they have a common radius. Between these two poles, *north* (N) and *south* (S), magnetic lines of force exist; these lines of force constitute a *magnetic field.* If a conductor in the form of C is so suspended that it can freely rotate between the two poles, and if the opposite ends of conductor C are brought to collector rings, R, which are contacted by brushes, there will be a flow of alternating current when conductor C is rotated. This is the basic method of producing alternating current.

If the conductor loop is rotated so that it cuts or passes through the magnetic lines of force between the pole pieces (magnets), a current will be induced in the loop, and this current will flow out through the collector rings R and brushes B to the external circuit, X-Y. As the rotation continues, the current becomes increasingly greater as the center of each pole piece is approached by the loop. The field intensity of the magnets is greatest at the center, and gradually falls to a low value either side of center.

Figure 15 will serve to clarify the operation of the alternator. The point P is taken as the revolving conductor, which is C in figure 14. As point P is revolved in a circular manner, the change in field intensity with consequent change in voltage can be visualized. It will be seen that as the conductor P begins its rotation, it starts through the lesser field intensity, gradually coming into the maximum field, then away again to another field of minimum intensity. The conductor then cuts the magnetic field in the *opposite* direction, going through the same varying intensity as previously related, then reaching a maximum, and then falling away to zero, from which point the current again increases in the original direction. When the conductor has completed its 360° rotation, two complete changes (*one cycle*) will have been completed.

Actually the voltage does *not* increase directly as the angle of rotation, but rather as the *sine* of the angle; hence, such a current has the mathematical form of a *sine wave.* Although most electrical machinery does not produce a strictly pure sine curve, the departures are usually so slight that the assumption can be regarded as fact for most practical purposes.

Referring to figure 16, it will be seen that if a curve is plotted for an alternating voltage, such a curve would assume the shape of a sine wave and by plotting amplitude against time, the voltage at any instant could be found. When dealing with alternating current of sine wave character, it becomes necessary to make constant use of terms which involve the number of changes in *polarity* or, more properly, the *frequency* of the current. The instantaneous value of voltage at any given instant can be calculated as follows:

$$e = E_{max} \sin 2\pi ft,$$

where e = the instantaneous voltage,

sin = the sine of the angle formed by the revolving point P at the instant of time, t.

E = maximum crest value of voltage (figure 16).

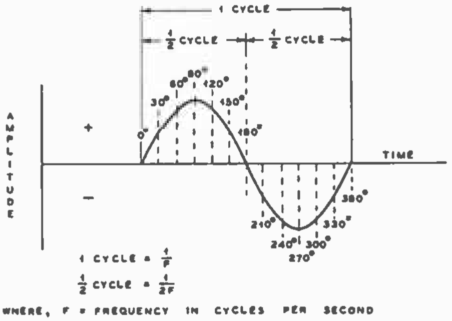


Figure 16.

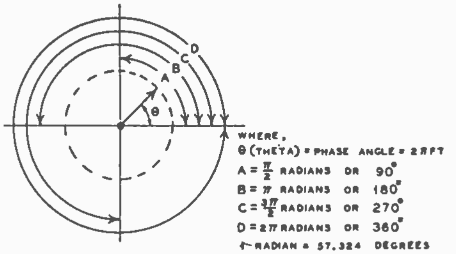


Figure 17.

The term 2πf should be thoroughly understood because it is of basic importance. Returning again to the rotating point P (figure 15), it can be seen that when this point leaves its horizontal position and begins its rotation in a counter-clockwise direction, through a complete revolution back to its initial starting point, it will have traveled through 360 electrical degrees. Instead of referring to this movement in terms of degrees, mathematical treatment dictates that the movement be expressed in *radians* or segments equal to the radius.

If radians must be considered in terms of degrees, there are approximately 57.32 degrees in one radian. In simple language, the radian is nothing more than a unit for dividing a circle into many parts. In a complete circle (360 degrees), there are 2π radians. Figure 17 shows lesser divisions of a circle in radians.

When the expression *2π radians* is used, it implies that the current or voltage has gone through a complete circle of 360 electrical degrees; this rotation represents two complete changes in direction during one cycle, as was previously shown. 2πf then represents one cycle, multiplied by the number of such cycles per second or the frequency of the alternating voltage or current. The expression *2πft* is a means of showing how far point P has traveled from its zero position toward a possible change of *2π radians* or 360 electrical degrees.

In the case of an alternating current with a frequency of 60 cycles per second, the current must pass through *twice* 60 or 120 changes in polarity in the same length of time. This time can be expressed as:

$$\frac{1}{2f}.$$

However, the only consideration at this point is one half of one alternation, and because the wave is symmetrical between 0 and 90 degrees rising, and from 90 degrees to zero when falling, the expression therefore becomes:

$$\frac{1}{4f}.$$

The actual time t in the formula is seen to be only a fractional portion of a second; a 60-cycle frequency would make $\frac{1}{4f}$ equal to $\frac{1}{240}$ of a second at the maximum value, and correspondingly less at lower amplitudes. $2\pi ft$ represents the *angular velocity*, and since the instantaneous voltage or current is proportional to the *sine* of this angle, a definite means is secured for calculating the voltage at any instant of time, provided that the wave very closely approximates a sine curve.

Current and voltage are synonymous in the foregoing discussion since they both follow the same laws. The instantaneous current can be found from the same formula, except that the maximum current would be used as the reference, viz:

$i = I_{max} \sin 2\pi ft$,

where i = instantaneous current,

I_{max} = maximum or peak current.

Effective Value of Alternating Voltage or Current

An alternating voltage or current in an a.c. circuit is rapidly changing in direction, and since it requires a definite amount of time for the indicator needle on a d.c. measuring instrument to show a deflection, such instruments cannot be used to measure alternating current or voltage. Even if the needle had such negligible damping that it could be made to follow the a.c. changes, it would merely vibrate back and forth near the zero point on the meter scale.

Alternating and direct current can be expressed in similar terms from the standpoint of heating effect. In other words, an alternating current will have the same value as a direct current in that it produces the same heating effect. Thus, an alternating current or voltage will have an equivalent value of one ampere when it produces the same heating effect in a resistance as does one ampere of direct current. This is known as the *effective value*; it is neither the maximum nor the instantaneous value, but an entirely different value.

This effective value is derived by taking the instantaneous values of current over a cycle of alternating current, then squaring these values, then taking an average of this value, and then taking the square root of the average thus obtained. By this procedure, the *effective* value becomes known as the *root mean square* or *r.m.s.* This is the value that is read on alternating current voltmeters and ammeters. The r.m.s. value is 70.7 per cent of the peak or maximum instantaneous value and is expressed as follows:

$E_{eff} = 0.707 \times E_{max}$, or

$I_{eff} = 0.707 \times I_{max}$,

where E_{max} and I_{max} are peak values of voltage and current respectively, and E_{eff} and I_{eff} are effective or r.m.s. values.

The following relations are extremely useful in radio and power work:

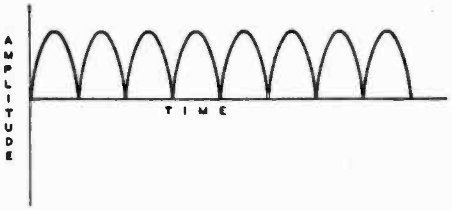
$E_{rms} = 0.707 \times E_{max}$,

$E_{max} = 1.414 \times E_{rms}$.

In order to find the peak value when the effective or r.m.s. value is known, simply multiply the r.m.s. value by 1.414. When the peak value is known, multiply it by 0.707 to find the r.m.s. value.

Rectified Alternating Current or Pulsating Direct Current

If an alternating current is passed through a full-wave rectifier, it emerges in the form of a current of *varying am-*



OUTPUT FROM FULL-WAVE RECTIFIER

Figure 18.

plitude which flows in *one* direction only. Such a current is known as *rectified a.c.* or *pulsating d.c.* A typical wave form of a current of this nature is shown in figure 18.

Measuring instruments designed for d.c. operation will not read the peak or instantaneous maximum value of the pulsating d.c. output from the rectifier; it will read only the *average value.* This can be explained by assuming that it could be possible to cut off some of the peaks of the waves, using the cutoff portions to fill in the spaces that are open, thereby obtaining an *average* d.c. value. A milliammeter and voltmeter connected to the adjoining circuit, or across the output of the rectifier, will read this average value. It is related to *peak* value by the following expression:

$$E_{avg} = 0.636 \times E_{max}$$

It is thus seen that the average value is 63.6 per cent of the peak value.

Phase

When an alternating current flows through a purely resistive circuit, it will be found that the current will go through maximum and minimum in perfect step with the voltage. In this case the current is said to be in step or *in phase* with the voltage. For this reason, Ohm's law will apply equally well for a.c. or for d.c. where pure resistances are concerned, provided that the *effective* values of a.c. are used in the calculations.

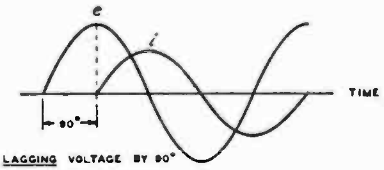
If a circuit has capacity or inductance or both, in addition to resistance, the current does not reach a maximum at the same instant as the voltage; therefore Ohm's law will *not* apply. It has been stated that inductance tends to resist any change in current; when an inductance is present in a circuit through which an alternating current is flowing, it will be found that the current will reach its maximum *behind* or later than the voltage. In electrical terms, the current will *lag* behind the voltage or, conversely, the voltage will *lead* the current.

If the circuit is *purely* inductive, i.e., if it contains neither resistance nor capacitance, the current does not start until the voltage has first reached a maximum; the current, therefore, *lags* the voltage by 90 degrees as in figure 19. The angle will be less than 90 degrees if resistance is present in the circuit.

When pure *capacity* alone is present in an a.c. circuit (no inductance or resistance of any kind), the opposite effect will be encountered; the current will reach a maximum at the instant the voltage is starting and, hence, will *lead* the voltage by 90 degrees. The presence of resistance in the circuit will tend to decrease this angle.

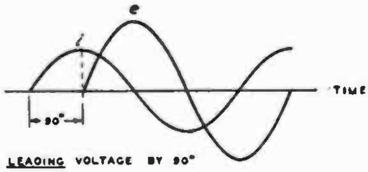
Power Factor

It should now be apparent to the reader that in such circuits that have reactance as well as resistance, it will not be



CURRENT LAGGING VOLTAGE BY 90°

(CIRCUIT CONTAINING PURE INDUCTANCE ONLY)



CURRENT LEADING VOLTAGE BY 90°

(CIRCUIT CONTAINING PURE CAPACITY ONLY)

Figure 19.

Illustrating the opposite effects of inductance and capacity in a.c. circuits.

possible to calculate the power as in a d.c. circuit or as in an a.c. circuit in which current and voltage are in-phase. The reactive components cause the voltage and current to reach their maximums at different times, as was explained under *phase,* and to calculate the power in such a circuit we must use a figure called the *power factor* in our computations.

The *power factor* in a resistive-reactive a.c. circuit may be expressed as the *actual* watts (as measured by a wattmeter) divided by the product of voltage and current or:

$$\frac{W}{E \times I}$$

where W = watts as measured,
E = voltage (r.m.s.)
I = current in amperes (r.m.s.).

Stated in another manner:

$$\frac{W}{E \times I} = \cos\theta$$

The character θ is the angle of phase difference between current and voltage. The product of volts times amperes gives the *apparent* power of the circuit, and this must be multiplied by the $\cos\theta$ to give the *actual* power. This factor $\cos\theta$ is called the *power factor* of the circuit.

When the current and voltage are in-phase, this factor is equal to 1. Resonant or purely resistive circuits are then said to have unity power factor, in which case

$$W = E \times I,\ W = I^2R,\ W = \frac{E^2}{R}.$$

Resonant Circuits

The reader is advised to review at this point the subject matter on inductance, capacity and alternating current in order that he may gain a complete understanding of the action of resonant circuits. Once the basic conception of the foregoing has been mastered, the more complex circuits in which they appear in combination will present no great problem.

Figure 20 shows an inductance, a capacitance and a resistance arranged in series, with a variable frequency source, E, of a.c. applied across the combination.

Figure 20.

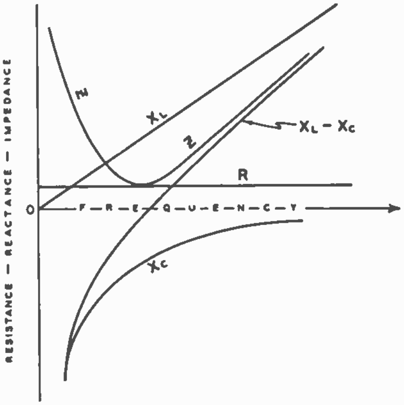
Some resistance is always present in a circuit because it is possessed in some degree by both the inductance and capacitor. If the frequency of the alternator E is varied from nearly zero to some high frequency, there will be one particular frequency at which the inductive reactance, and capacitive reactance will be equal. This is known as the *resonant frequency,* and in a series circuit it is the frequency at which the circuit current will be a maximum. Such series resonant circuits are chiefly used when it is desirable to allow a certain frequency to pass through the circuit (low impedance to this frequency), while at the same time the circuit is made to offer considerable opposition to currents of other frequencies.

If the values of inductance and capacity both are fixed, there will be only one resonant frequency.

For mechanical reasons, it is more common to change the capacitance rather than the inductance when a circuit is tuned, yet the inductance can be made variable if desired.

In the following table there are five radically different ratios of L to C (inductance to capacitance) each of which satisfies the resonant condition, $X_L = X_C$. When the frequency is constant, L must increase and C must decrease in order to give equal reactance. Figure 21 shows how the two reactances change with frequency; this illustration will greatly aid in clarifying this discussion.

If both the inductance and capacitance are made variable, the circuit may then be changed or *tuned,* so that a number of combinations of inductance and capacitance can resonate at the same frequency. This can be more easily understood when one considers that inductive reactance and capacitive reactance travel



SERIES CIRCUIT REACTANCE VARIATION WITH CHANGE OF APPLIED FREQUENCY

Figure 21.

in opposite directions as the frequency is changed. For example, if the frequency were to remain constant and the values of inductance and capacitance were then changed, the following combinations would have equal *reactance:*

Frequency is constant at 60 cycles.

L is expressed in henrys.

C is expressed in microfarads (.000001 farad.)

L	X_L	C	X_C
.265	100	26.5	100
2.65	1,000	2.65	1,000
26.5	10 000	.265	10,000
265.00	100,000	.0265	100,000
2,650.00	1,000,000	.0026	1,000,000

Formula for Frequency

From the formula for resonance,

$2\pi f L = \frac{1}{2\pi f C}$, the resonant frequency can readily be solved. In order to isolate f on one side of the equation, merely multiplying both sides by $2\pi f$, thus giving:

$$4\pi^2 f^2 L = \frac{1}{C}.$$

Divided by the quantity $4\pi^2 L$, the result is:

$$f^2 = \frac{1}{4\pi^2 LC}$$

Then, by taking the square root of both sides: $f = \frac{1}{2\pi\sqrt{LC}}$,

where f = frequency in cycles,
L = inductance in henrys,
C = capacity in farads.

It is more convenient to express L and C in smaller units, especially in making radio-frequency calculations; f can also be expressed in megacycles or kilocycles. A very useful group of such formulas is:

$$f^2 = \frac{25{,}330}{LC} \text{ or } L = \frac{25{,}330}{f^2 C} \text{ or } C = \frac{25{,}330}{f^2 L}$$

where f = frequency in megacycles,
L = inductance in microhenrys,
C = capacity in micromicrofarads.

In order to clarify the original formula, $f = \frac{1}{2\pi\sqrt{LC}}$, take two values of inductance and capacitance from the previously given chart and substitute these in the formula. It was stated that the frequency is 60 cycles; therefore f = 60. Substituting these values to check the frequency:

$$60 = \frac{1}{2\pi\sqrt{LC}};\ 3600 = \frac{1}{4\pi^2 LC};$$

$$L = \frac{1}{3600 \times 4\pi^2 \times .000026}$$

$L = 0.265$

The significant point here is that the formula calls for C in *farads,* whereas the capacity was actually in microfarads. Recalling that one microfarad equals .000001 farad, it is, therefore, possible to express 26 microfarads as .000026 farads. This consideration is often overlooked when computing for frequency and capacitive reactance because capacitance is expressed in a totally impractical unit, viz: the *farad.*

Impedance of Series Resonant Circuits

The impedance across the terminals of a series resonant circuit (figure 20) is

$$Z = \sqrt{r^2 + (X_L - X_C)^2},$$

where Z = impedance in ohms,
r = resistance in ohms,
X_C = capacitive reactance in ohms,
X_L = inductive reactance in ohms.

From this equation, it can be seen that the impedance is equal to the vector sum of the circuit resistance and the *difference* between the two reactances. Since at the resonant frequency X_L equals X_C, the difference between them (figure 21) is obviously zero so that at resonance the impedance is simply equal to the resistance of the circuit; therefore, because the resistance of most normal radio-frequency circuits is of a very low order, the impedance is also low.

At frequencies higher and lower than the resonant frequency, the difference between the reactances will be a definite quantity and will add with the resistance to make the impedance higher and higher as the circuit is tuned off the resonant frequency.

Current and Voltage in Series Resonant Circuits

Formulas for calculating series resonance are similar to those of Ohm's law.

$$I = \frac{E}{Z}. \qquad E = IZ.$$

The complete equations:

$$I = \frac{E}{\sqrt{r^2 + (X_L - X_C)^2}}$$

$$E = I\sqrt{r^2 + (X_L - X_C)^2}$$

Inspection of the above formulas will show the following to apply to series resonant circuits: When the impedance is low, the current will be high; conversely, when the impedance is high, the current will be low.

Since it is known that the impedance will be very low at the resonant frequency, it follows that the current will be a maximum at this point. If a graph is plotted of the current against the frequency either side of resonance, the resultant curve becomes what is known as a *resonance curve*. Such a curve is shown in figure 22.

Several factors will have an effect on the shape of this resonance curve, of which resistance and L-to-C ratio are the important considerations. The curves B and C in figure 22 show the effect of adding increasing values of resistance to the circuit. It will be seen that the peaks become less and less prominent as the resistance is increased; thus, it can be said that the *selectivity* of the circuit is thereby *decreased*. Selectivity in this case can be defined as the ability of a circuit to discriminate against frequencies adjacent to the resonant frequency.

Referring again to figure 22, it can be seen from curve A that a signal, for instance, will drop from 19 to 5, or more than 10 decibels, at 50 kc. off resonance. Curve B, which represents considerable resistance in the circuit, shows a signal drop of from 4 to 3, or approximately 2.5 decibels, when the signal is also 50 kilocycles removed from the resonant point. From this it becomes evident that

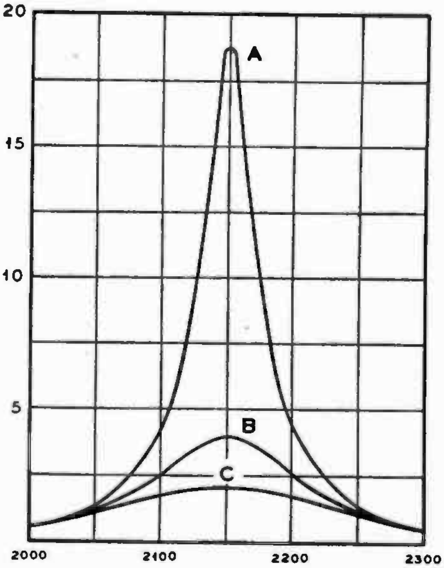


Figure 22.
RESONANCE CURVE.
Showing effect of resistance upon selectivity of the circuit.

the steeper the resonant curve, the greater will be the change in current for a signal removed from resonance by a given amount. The effect of adding more resistance to the circuit is to flatten off the peaks without materially affecting the sides of the curve. Thus, signals far removed from the resonance frequency give almost the same value of current, regardless of the amount of resistance present.

Voltage Across Coil and Condenser in Series Circuit

Because the a.c. or r.f. voltage across a coil and condenser is proportional to the reactance (for a given current), the actual voltages across the coil and across the condenser may be many times greater than the *terminal* voltage of the circuit. Furthermore, since the individual reactances can be very high, the voltage across the condenser, for example, may be high enough to cause flashover even though the applied voltage is of a value considerably below that at which the condenser is rated.

Circuit Q — Sharpness of Resonance

An extremely important property of an inductance is its factor-of-merit, more generally called its Q. It is this factor, Q which primarily determines the sharpness of resonance of a tuned circuit. This factor can be expressed as the ratio of the reactance to the resistance, as follows:

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

where R = total d.c. and r.f. resistances.

The actual resistance in a wire or inductance can be far greater than the d.c. value when the coil is used in a radio-frequency circuit; this is because the current does not travel through the entire cross-section of the conductor, but has a tendency to travel closer and closer to the surface of the wire as the frequency is increased. This is known as the *skin effect.*

The actual current-carrying portion of the wire is decreased, therefore, and the resistance is increased. This effect becomes even more pronounced in square or rectangular conductors because the principal path of current flow tends to work outwardly toward the four edges of the wire.

Examination of the equation for Q may give rise to the thought that even though the resistance becomes greater with frequency, the inductive reactance does likewise, and that the Q might be a constant. In actual practice, however, the resistance usually increases more rapidly with frequency than does the reactance, with the result that Q normally decreases with increasing frequency.

Parallel Resonance

In radio circuits, parallel resonance is more frequently encountered than series resonance; in fact, it is the basic foundation of receiver and transmitter circuit operation. A circuit is shown in figure 23.

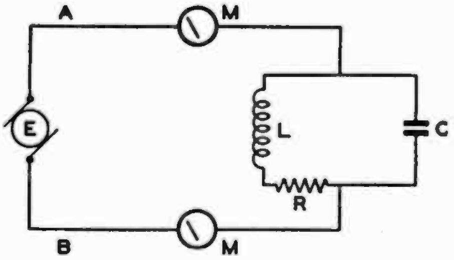


Figure 23.

In this circuit, as contrasted with a circuit for series resonance, L (inductance) and C (capacitance) are connected in *parallel,* yet the *combination* can be considered to be in series with the remainder of the circuit. This combination of L and C, in conjunction with R, the resistance which is principally included in L, is sometimes called a *tank* circuit because it effectively functions as a storage tank when incorporated in vacuum tube circuits.

Contrasted with series resonance, there are two kinds of current which must be considered in a parallel resonant circuit: (1) the line current, as read on the indicating meters M, (2) the circulating current which flows within the parallel L-C-R portion of the circuit. See figure 23.

At the resonant frequency, the line current (as read on the meters M) will drop to a very low value although the circulating current in the L-C circuit may be quite large. It is this line current that is read by the milliammeter in the plate circuit of an amplifier or oscillator stage of a radio transmitter, and it is because of this that the meter shows a sudden *dip* as the circuit is tuned through its resonant frequency. The current is, therefore, a minimum when a parallel resonant circuit is tuned to resonance, although the *impedance* is a *maximum* at this same point. It is interesting to note that the parallel resonant circuit acts in a distinctly opposite manner to that of a series resonant circuit, in which the current is at a maximum and the impedance is minimum at resonance. It is for this reason that in a parallel resonant circuit the principal consideration is one of impedance rather than current. It is also significant that the *impedance* curve for *parallel* circuits is very nearly identical to that of the *current* curve for *series* resonance. The impedance at resonance is expressed as:

$$Z = \frac{(2\pi f L)^2}{R},$$

where Z = impedance in ohms,
L = inductance in henrys,
f = frequency in cycles,
R = resistance in ohms.

The curves illustrated in figure 22 can be applied to parallel resonance in addition to the purpose for which they are illustrated.

Reference to the impedance curve will show that the effect of adding resistance to the circuit will result in both a broadening out and a lowering of the peak of the curve. Since the voltage of the circuit is directly proportional to the impedance, and since it is this voltage that is applied to the grid of the vacuum tube in a detector or amplifier circuit, the impedance curve must have a sharp peak in order for the circuit to be *selective.* If the curve is broadtopped in shape, both the desired signal and the interfering signals at close proximity to resonance will give nearly equal voltages on the grid of the tube, and the circuit will then be *nonselective;* i.e., it will tune broadly.

Effect of L/C Ratio In Parallel Circuits

In order that the highest possible voltage can be developed across a parallel resonant circuit, the impedance of this circuit must be very high. The impedance will be greater when the ratio of inductance-to-capacitance is great, that is, when L is large as compared with C. When the resistance of the circuit is very low, X_L will equal X_C at resonance and of course, there are innumerable ratios of L and C that will have *equal* reactance, at a given resonant frequency, exactly as is the case in a series resonant circuit. Contrasted with the necessity for a high L/C ratio for high *impedance,* the capacity for maximum *selectivity* must be *high* and the *inductance low.* While such a ratio will result in lower *gain,* it will offer greater *rejectivity* to signals adjacent to the resonant signal.

In practice, where a certain value of inductance is tuned by a variable capacitance over a fairly wide range in frequency, the L/C ratio will be small at the lowest frequency and large at the high-frequency end. The circuit, therefore, will have unequal selectivity at the two ends of the band of frequencies which is being tuned. At the low-frequency end of the tuning band, where the capacitance predominates, the selectivity will be greater and the gain less than at the high-frequency end, where the opposite condition holds true. Increasing the Q of the circuit (lowering the series resistance) will obviously increase *both* the selectivity and gain.

Circulating Tank Current at Resonance

The Q of a circuit has a definite bearing on the circulating tank current at resonance. This tank current is very nearly the value of the line current multiplied by the circuit Q. For example: an r.f. line current of 0.050 amperes, with a circuit Q of 100, will give a circulating tank current of approximately 5 amperes. From this it can be seen that the inductance and connecting wires in a circuit with a high Q must be of very low resistance, particularly in the case of high power transmitters, if heat losses are to be held to a minimum.

Effect of Coupling on Impedance

If a parallel resonant circuit is coupled to another circuit, such as an antenna output circuit, the impedance of the parallel circuit is decreased as the coupling becomes closer. The effect of closer (tighter) coupling is the same as though an actual resistance were added to the parallel circuit. The resistance thus coupled into the tank circuit can be considered as being *reflected* from the output or load circuit to the driver circuit.

If the load across the parallel resonant tank circuit is purely resistive, just as it might be if a resistor were shunted across part of the tank inductance, the load will not disturb the resonant setting. If, on the other hand, the load is reactive, as it could be with too-long or too-short antenna for the resonant frequency, the setting of the tank tuning condenser will have to be changed in order to restore resonance.

Tank Circuit Flywheel Effect

When the plate circuit of a class B or class C operated tube (defined in the following chapter) is connected to a parallel resonant circuit, the plate current serves to maintain this L/C circuit in a state of oscillation. If an initial impulse is applied across the terminals of a parallel resonant circuit, the condenser will become charged when one set of plates assumes a positive polarity, the other set a negative polarity. The condenser will then discharge through the inductance; the current thus flowing will cut across the turns of the inductance and cause a counter e.m.f. to be set up, charging the condenser in the opposite direction.

In this manner, an alternating current is set up within the L/C circuit and the oscillation would continue indefinitely with the condenser charging, discharging and charging again if it were not for the fact that the circuit possesses some resistance. The effect of this resistance is to dissipate some energy each time the current flows from inductance to condenser and back, so that the amplitude of the oscillation grows weaker and weaker, eventually dying out completely.

The frequency of the initial oscillation is dependent upon the L/C constants of the circuit. If energy is applied in short spurts or pushes at just the right moments, the L/C circuit can be maintained in a constant oscillatory state. The plate current pulses from class B and class C amplifiers supply just the desired kind of kicks.

Whereas the class B plate current pulses supply a kick for a longer period, the short pulses from the class C amplifier give a pulse of very high amplitude, thus being even more effective in maintaining oscillation. So it is that the positive half cycle in the tank circuit will be reinforced by a plate current kick, but since the plate current of the tube only flows during a half cycle or less, the *missing* half cycle in the tank circuit must be supplied by the discharge of the *condenser*.

Since the amplitude of this half cycle will depend upon the charge on the plates of the condenser, and since this in turn will depend upon the capacitance, the value of capacitance in use is very important. Particularly is this true if a distorted wave shape is to be avoided, as would be the case when a transmitter is being modulated. The foregoing applies particularly to single-ended amplifiers. If push-pull were employed, the negative half cycle would secure an additional kick, thereby greatly lessening the necessity of the use of higher C in the L/C circuit.

Impedance Matching: Impedance, Voltage and Turns Ratio

A fundamental law of electricity is that the maximum transfer of energy results when the impedance of the load is equal to the impedance of the driver. Although this law holds true, it is not necessarily a desirable one for every condition or purpose. In many cases where a vacuum tube works into a parallel resonant circuit load, it is desirable to have the load impedance considerably higher than the tube plate impedance, so the maximum power will be dissipated by the load rather than in the tube. On the other hand, one of the notable conditions for which the law holds true is in the matching of transmission lines to an antenna impedance.

Often a vacuum tube circuit requires that the plate impedance of a driver circuit be matched to the grid impedance of the tube being driven. When the driven tube operates in such a condition that it draws grid current, such as in all transmitter r.f. amplifier circuits, the grid impedance may well be lower than the plate tank impedance of the driver stage. In this case it becomes necessary to tap down on the driver tank coil in order to select the proper number of turns that will give the desired impeddance. If the desired working load impedance of the driver stage is 10,000 ohms, for example, and if the tank coil has 20 turns, the grid impedance of the driven stage being 5000 ohms, it is evident that there will be required a step-down *impedance* ratio of $\frac{10,000}{5000}$ or 2-to-1. This impedance value is *not* secured when the driver inductance is tapped at the center. It is of importance to stress the fact that the impedance is decreased *four times* when the number of turns on the tank coil is *halved*. The following equations show this fact:

$$\frac{N_1}{N_2} = \sqrt{\frac{Z_1}{Z_2}} \text{ or } \frac{N_1^2}{N_2^2} = \frac{Z_1}{Z_2}$$

where $\frac{N_1}{N_2}$ = turns ratio,

$\frac{Z_1}{Z_2}$ = impedance ratio

In the foregoing example, a step-down *impedance* ratio of 2-to-1 would require a *turns* step-down ratio of the square root of the impedance or 1.41. Therefore, if the inductance has 20 turns, a tap would be taken on the sixth turn down from the hot end or 14 turns up from the cold end. This is arrived at by taking the resultant for the turns ratio, i.e., 1.41, and then dividing it into the total number of turns, as follows:

$$\frac{20}{1.41} = 14 \text{ (approx.)}$$

Either an impedance step-up or step-down ratio can be secured from a parallel resonant circuit. One type of antenna impedance matching device utilizes this principle. Here, however, two condensers are effectively in series across the inductance; one has quite a high capacitance (500 $\mu\mu$fd.), the other is a conventional size condenser used principally to restore resonance. The theory of the device is simply that the impedance is proportional to the reactances of the condensers and, by changing the ratio of the two, the antenna is effectively connected into the tank circuit at impedance points which reach higher or lower values as the ratio of the condensers is changed.

In practice, however, it is usually necessary to change the value of inductance in order to maintain resonance while still correctly matching it to the antenna or feeder. This method is discussed at greater length in *Chapter 17.*

As the impedance step-down ratio becomes larger, the voltage step-down becomes correspondingly great. Such a condition takes place when a resonant circuit is tapped down for reasons of impedance matching; the voltage will be stepped down in direct proportion to the turn step-down ratio. The reverse holds true for step-up ratios. As the step-up ratio is increased, the voltage is increased.

TRANSFORMERS

When two coils are placed in such inductive relation to each other that the lines of force from one cut across the turns of the other and induce a voltage in so doing, the combination can be called a *transformer*. The name is derived from the fact that energy is transformed from one coil into another. The inductance in which the original flux is produced is called the *primary;* the inductance which *receives* the induced voltage is called the *secondary*. In a radio receiver power transformer, for example, the coil through which the 110-volt a.c. passes is the *primary*, and the coil from which a higher or lower voltage than the a.c. line potential is obtained is the *secondary*.

Transformers can have either air or magnetic cores, depending upon whether they are to be operated at radio or audio frequencies. The reader should thoroughly impress upon his mind the fact that current can be transferred from one circuit to another *only* if the primary current is changing or alternating. From this it can be seen that a power transformer cannot possibly function as such when the primary is supplied with nonpulsating d.c.

A power transformer usually has a magnetic core which consists of laminations of iron, built up into a square or rectangular form, with a center opening or window. The secondary windings may be several in number, each perhaps delivering a different voltage. The secondary voltages will be proportional to the number of turns and to the primary voltage.

If a primary winding has an a.c. potential of 110 volts applied to 220 turns of wire on the primary, it is evident that this winding will have two turns per volt. A secondary winding of 10 turns, wound on an adjacent leg of the transformer core, would have a potential of 5 volts. If the secondary winding has 500 turns, the potential would be 250 volts, etc. Thus, a transformer can be designed to have either a step-up or step-down ratio, or both simultaneously. The same applies to air core transformers for radio-frequency circuits.

Transformer Action

Transformers are used in alternating-current circuits to transfer power at one voltage and impedance to another circuit at another voltage and impedance. There are three main classifications of transformers: those made for use in power-frequency circuits (25, 50, and 60 cycles), those made for use at radio frequencies, and those made for audio-frequency applications. Power transformers will be discussed in the section devoted to *Power Supplies* and r.f. transformers are analyzed later on in this chapter; a few of the pertinent facts concerning audio transformers will be covered in the following paragraphs.

Impedance Matching in Audio Circuits

In most audio applications it will be the function of the audio transformer to match the impedance of the plate circuit of a vacuum-tube amplifier to a load circuit of a different impedance. The information given under the paragraph headed *Impedance Matching* is very easily applied to this type of calculation.

In all audio-frequency circuit applications, it is only necessary to refer to the *tube tables* in this book in order to find the recommended load impedance for a given tube and a given set of operating conditions. For example, the table shows that a type 42 pentode tube requires a load impedance of 7000 ohms. Audio transformers are always rated for both their primary and secondary impedance, which means that the primary impedance will be of the rated value *only* when the secondary is terminated in its rated impedance.

If a 7000-ohm plate load is to work into a 7-ohm loudspeaker voice coil, the impedance ratio of the transformer would be $\frac{7000}{7} = 1000$-to-1. Hence, the turns-ratio will be the square root of 1000 or 31.6. This does not mean that the primary will have only 31.6 turns of wire and only one turn on the secondary. The primary must have a certain *inductance* in order to offer a high impedance to the lower audio frequencies. Consequently, it must have a large number of turns of wire in the primary winding. The *ratio* of total primary turns to total secondary turns must remain constant, regardless of the number of turns in the primary if the correct primary impedance is to be maintained.

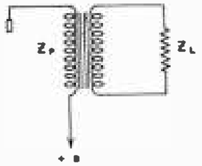


Figure 24.

The reflected impedance Z_P varies directly in proportion to Z_L and the square of the turns ratio.

To summarize, a certain transformer will have a certain impedance ratio (determined by the square of the turns ratio) which will remain constant. If the transformer is terminated with an impedance or resistance *lower* than the original rated value, the reflected impedance on the primary will also be lower than the rated value. If the transformer is terminated in an impedance *higher* than rated, the reflected primary impedance will be higher.

For push-pull amplifiers the recommended primary impedance is stated as some certain value, *plate to plate;* this refers to the impedance of the total winding without consideration of the center tap. The reflected impedance across the total primary will follow the same rules as previously given for single-ended stages.

The voltage relationship in primary and secondary is the same as the turns ratio. For a step-down turns ratio of 10-to-1, the corresponding *voltage* step-down would be 10-to-1 though the *impedance* ratio would be 100-to-1. This information is useful when it is desired to convert the turns ratios given on certain types of driver transformers into impedance ratios.

The same type of reasoning and subsequent calculation would be used in determining the turns ratio for a modulation transformer to couple a certain pair of class-B modulators to a class-C final amplifier. The recommended plate-to-plate load impedance for the modulator tubes can be obtained from the tube tables given later on. The final amplifier load resistance is then determined by dividing its plate voltage by the plate current at which it is to operate. The turns ratio of the modulation transformer is then equal to the square root of the ratio between the modulator load impedance and the amplifier load resistance; the transformer may be either step-up or step-down as the case may be.

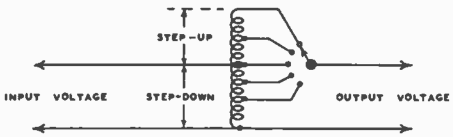


Figure 25.

Illustrating design and method of connecting an auto transformer.

The Auto Transformer

The type of transformer in figure 25 when wound with heavy wire and over an iron core is a common device in primary power circuits for the purpose of increasing or decreasing the line voltage. In effect, it is merely a continuous winding with taps taken at various points along the winding, the input voltage being applied to the bottom and also to one tap on the winding. If the output is taken from this same tap, the voltage ratio will be 1-to-1; i.e., the input voltage will be the same as the output voltage. On the other hand, if the out-

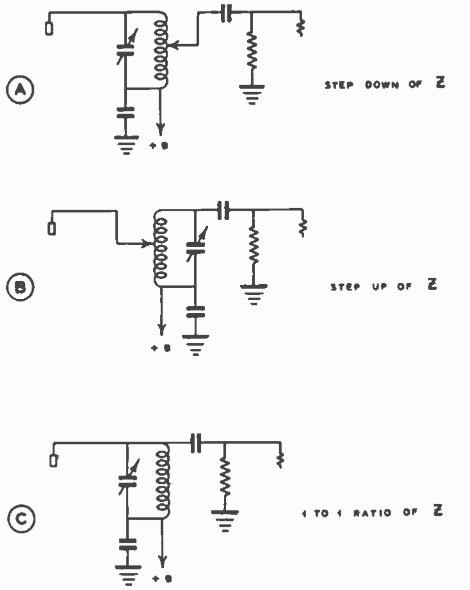


Figure 26.

Impedance step-up and step-down may be obtained by utilizing the plate tank circuit of a vacuum tube as an auto transformer.

put tap is moved down toward the common terminal, there will be a step-down in the turns ratio with a consequent step-down in voltage.

The opposite holds true if the output terminal is moved upward from the middle input terminal; there will be a voltage step-up in this case. The initial setting of the middle input tap is chosen so that the number of turns will have sufficient reactance to keep the no-load primary current at a reasonably low value.

In the same manner as voltage is stepped up and down by changing the number of turns in a winding, so can impedance be stepped up or down. Figure 26A shows an application of this principle as applied to a vacuum tube circuit which couples one circuit to another.

Assuming that the grid impedance may be of a lower value than the plate tank impedance of the preceding stage, a step-down ratio will be necessary in order to give maximum transfer of energy. In B of figure 26, the grid impedance is very high as compared with the tank impedance of the driver stage, and thus there is required a step-up ratio to the grid. The driver plate is tapped down on its plate tank coil in order to make this impedance step-up possible. A driver tube with very low plate impedance must be used if a good order of plate efficiency is to be realized.

In C of figure 26, the grid impedance very closely approximates the plate impedance and this connection is used when no transformation is required. The grid and plate impedances are not generally known in many practical cases; hence, the adjustments are made on the basis of maximum grid drive consistent with maximum safe input to the driver stage.

Inductive Coupling — The Radio-Frequency Transformer

Inductive coupling is often used when two circuits are to be coupled. This method of coupling is shown in figures 27A and 27B.

The two inductances are placed in such inductive relation to each other that the lines of force from the primary coil cut across the turns of the secondary coil, thereby inducing a voltage in the secondary. As in the case of capacitive coupling, impedance transformation here again becomes of importance. If two

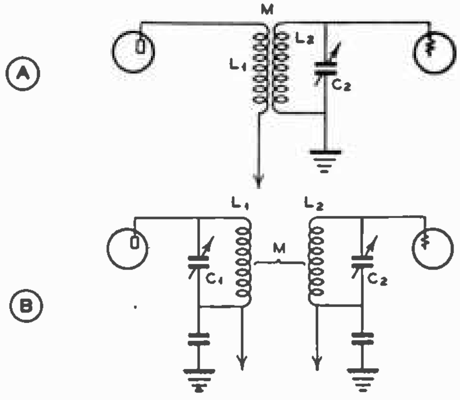


Figure 27.

TWO COMMON EXAMPLES OF INDUCTIVE COUPLING IN RADIO CIRCUITS.

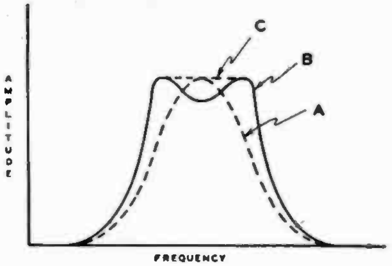


Figure 28.

EFFECT OF COUPLING UPON RESONANCE CURVE.

Curve B shows what happens when the coils are overcoupled; curve C is intermediate coupling.

parallel tuned circuits are coupled very closely together, the circuits can in reality be overcoupled. This is illustrated by the curve in figure 28.

The dotted line curve A is the original curve or that of the primary coil *alone.* Curve B shows what takes place when two circuits are overcoupled; the resonance curve will have a definite dip on the peak, or a double hump. This principle of overcoupling is advantageously utilized in bandpass circuits where, as shown in C, the coupling is adjusted to such a value as to reduce the peak of the curve to a virtual flat top, with no dip in the center as in B.

Some undesirable capacitive coupling will result when circuits are closely or tightly coupled; if this capacitive coupling is appreciable, the tuning of the circuits will be affected. The amount of capacitive coupling can be reduced by so arranging the physical shape of the inductances as to enable only a minimum surface of one to be presented to the other.

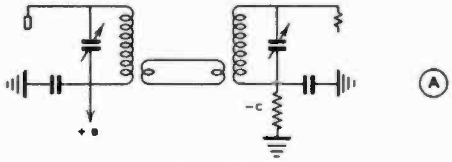
Another method of accomplishing the same purpose is by electrical means. A curtain of closely-spaced parallel wires or bars, connected together only at one end, and with this end connected to ground, will allow electromagnetic coupling but not electrostatic coupling. Such a device is called a *Faraday screen or shield.*

Link Coupling

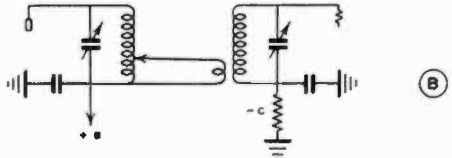
Still another method of decreasing capacitive coupling is by means of a *coupling link* circuit between two parallel resonant circuits. The capacity of the coupling link, with its one or two turns, is so small as to be negligible. Also, one side of the link is often grounded to reduce further any capacitive coupling that may exist.

Link coupling is widely used in transmitter circuits because it adapts itself so universally and eliminates the need of a radio-frequency choke, thereby reducing a source of loss. Link coupling is very simple; it is diagrammed in A and B of figure 29.

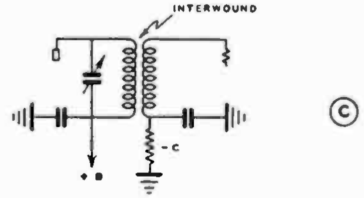
In A of figure 29, there is an impedance step-down from the primary coil to the link circuit. This means that the line which connects the two links or loops will have a low impedance and therefore can be carried over a con-



LINK COUPLING



TAP ON AND LINK COUPLING



UNITY COUPLING

Figure 29.

Two types of link (inductive) coupling and below unity coupling.

siderable distance without introduction of appreciable loss. A similar link or loop is at the output end of the line; this loop is coupled to the grid tank of the driven stage.

Still another link coupling method is shown in B of figure 29. It is similar to that of A, with the exception that the primary line is tapped on the coil, rather than being terminated in a link or loop.

Unity Coupling

Another commonly used type of coupling is that known as *unity coupling,* by reason of the fact that the turns ratio between primary and secondary is one-to-one. This method of coupling is illustrated in C of figure 29. Only one of the windings is tuned although the interwinding of the two coils gives an effect in the untuned winding as though it were actually tuned with a condenser.

Unity coupling is used in some types of ultra-high-frequency circuits although the mechanical considerations are somewhat difficult. The secondary, when it serves as the grid coil, is placed inside of a copper tubing coil; the latter serves as the primary or plate coil.

Conduction of an Electric Current

So far this chapter has dealt only with the conduction of current by a stream of electrons through a conductor or by electrostatic coupling through a capacitor. While this is the most common method of transmission, there are other types of conduction which are equally important in their respective branches of the field. An electric current may also be transmitted by the motion of minute particles of matter, by the motion of charged atoms called *ions,* and by a stream of electrons in a vacuum.

The carrying of current by charged particles, such as bits of dust, is only of academic interest in radio. However, there is a commercial process (called the Cottrell process) which uses this type of conduction in industrial dust precipitation. A highly charged wire inside a grounded metal chamber is placed so that the dust-laden flue gases from certain industrial processes (usually metallurgic refining) must pass through the chamber. The dust particles are first attracted to the wire; there they attain a high electric charge which causes them to be attracted to the sides of the chamber where they are precipitated and subsequently collected. A small electric current between the center electrode and the chamber is the result of the carrying of the charges by the dust particles.

Conduction by Ions

When a high enough voltage is placed between two terminals in air or any other gas, that gas will break down suddenly, the resistance between the two points will drop from an extremely high value to a few hundredths or thousandths of ohms, and a comparatively large electric current will flow to the accompaniment of an amount of visible light either as a flash, an arc, a spark, or a colored discharge such as is found in the "neon" sign. This type of conduction is due to gas ions which are generated when the electric stress between the two points becomes so great that electrons are torn from the molecules of the gas with the production of a quantity of positively charged gas ions and negative electrons. The breakdown voltage for a particular gas is dependent upon the pressure, the spacing of the electrodes, and the type of electrodes.

Lightning, tank condenser flashovers, and ignition sparks in an automobile are such discharges that occur at atmospheric pressure or above. However, the pressure of the gas is usually reduced to facilitate the ease of breakdown of the gas as in the "neon" sign, mercury-vapor lamp, or voltage regulator tubes such as the VR-150-30. If a heated filament is used as one electrode in the discharge chamber, the breakdown voltage is further reduced to a value called the *ionization potential* of the gas. This principle is used in the 866, the 83, and other mercury-vapor rectifiers. Through the use of the heated cathode the breakdown potential is reduced from about

10,000 volts to approximately 15 volts and the conduction of electric current is made unidirectional, enabling the discharge chamber to be used as a rectifier. The applications of the principle of ionic conduction in vacuum tubes (along with discussion of electronic conduction) will be covered in more detail in the chapter devoted to *Vacuum Tube Theory.*

The emission of colored light which accompanies an electric discharge through a gas is due to the re-combination of the ionized gas molecules and the free electrons to form neutral gas molecules. There is a definite color spectrum which is characteristic of every gas—and for that matter for every element when it is in the gaseous state. For neon this color is orange-red, for mercury it is blue-violet, for sodium, almost pure yellow—and so on through the list of the elements. This principle is used in the spectroscopic identification of elements by their characteristic lines in the spectrum (called Fraunhofer lines).

Electrolytic Conduction

Nearly all inorganic chemical compounds (and a few organic ones of certain molecular structure) when dissolved in water undergo a chemical-electrical change known as *electrolytic disassociation* which results in the production of ions similar in certain properties to those formed as a result of the electric breakdown of a gas. For example, when sodium chloride or table salt is dissolved in water a certain percentage of it ionizes or breaks down into positively charged sodium ions, or sodium atoms with a deficiency of one electron, and negatively charged chloride ions, or chlorine atoms with one excess electron. Similarly, sodium hydroxide disassociates into positive sodium ions and negative hydroxyl ions—sulfuric acid into positive hydrogen ions and negative sulfate ions.

This solution of an ionized compound and water renders the aqueous solution a conductor of electricity. (Water in the pure form is a good insulator.) The conductivity of the solution is proportional to the mobility of the ions and to the quantity of them available in the solution. Maximum conductivity is had not when there is a maximum of the compound in solution but rather when there is a maximum of ions in solution; this condition is ordinarily obtained when neither concentrated nor dilute but about midway between. Maximum conductivity in a sulfuric acid solution as used in storage batteries is obtained when there is about 30 per cent by weight of the acid in solution in the water. It is for this reason that acid of about 30 per cent concentration is used as an electrolyte in storage batteries.

Conduction of electricity through an *electrolyte,* as a conducting solution is called, is made possible by the mobility of the charged ions in solution. When a positively and a negatively charged wire are placed in an electrolyte the negative ions are attracted to the positive wire and the positive ions are attracted to the negative wire. As the ions reach the wire carrying the charge opposite to their own, their excess or their deficiency of electrons is neutralized by the respective deficiency or excess of electrons on the wire and the ion changes from the ionic to the atomic or molecular state. If the ion happened to be that of a metal such as copper, copper will be *plated* upon the negative electrode that had been placed into the solution; if the negative ion was that of chlorine (the chloride ion) then chlorine in the gaseous form will appear at the positive electrode. The conduction of an electric current through an electrolyte always results in a chemical change in the electrolyte. This fact is employed commercially in electroplating and electrolytic refining.

The Primary Cell

If two dissimilar metals are placed in an electrolyte a potential difference will appear between the two materials. This postulate is employed commercially in the primary cell or "dry cell" as it is somewhat incorrectly called.

The operation of the primary cell depends upon the differences in the two electrochemical constants for the materials used as the electrodes. With the zinc and carbon used in the dry cell (with a paste containing ammonium chloride as the electrolyte) the potential is 1.53 volts. With other electrolytes and electrodes the potential output of the cell varies from 0.7 to 2.5 volts.

When current is taken from a primary cell the negative electrode (usually the zinc container) dissolves in the electrolyte with the production of hydrogen gas. If only the positive and the negative electrodes and the electrolyte were contained in the cell, this hydrogen gas would collect as a film on the surface of the negative electrode. When this film does form, the internal resistance of the cell increases due to the insulating properties of the film of gas. A cell is said to have become "polarized" when this has taken place. To reduce this effect an oxidizing agent called a "depolarizer" (manganese dioxide in the case of the dry cell) is incorporated into the electrolyte. If current is taken from the cell at a reasonable rate the depolarizer oxidizes the hydrogen into water as fast as it is formed. This formation of water as a result of the normal operation of the cell is one of the reasons that a dry cell "sweats" when it is approaching the end of its useful life.

Dry cells and batteries of them are very commonly employed in portable radio equipment as both filament and plate supply and frequently as plate supply only at locations where there is no source of alternating current. Through recent improvements in cell manufacture and in the design of batteries of these cells it is possible to make very lightweight sources of a quite reasonable amount of power. 45-volt B batteries are available ranging in weight from 16 pounds down to about 2 ounces. The large sizes will stand current drain up to about 75 ma. for a few hundred hours while the smallest sizes will last only a few hours with a drain of one or two milliamperes. Medium sizes capable of producing 8 to 10 ma. for one-hundred hours or so are commonly used in radio-controlled model aircraft and in the new portable broadcast receivers. The average weight of a 45-volt unit in this classification is about 10 ounces.

Dry cells are also commonly used as filament and plate supplies in meteorological balloons (the ultra-light types usually), for ignition purposes on small motors, in some telephone and telegraph systems, in hearing aids, and as sources of grid-bias voltage in amateur transmitters.

The Secondary Cell—Storage Batteries

The primary cell, as described in the preceding paragraphs, produces its voltage as a result of chemical action of the electrolyte on one of the elements. When the material comprising the active element is used up, the cell is no longer useful and must be discarded. The secondary cell, on the other hand, is capable of being recharged to its original energy content when it has been depleted.

There are two common types of secondary cells: the *Edison cell,* which uses iron as the negative pole and nickel oxide as the positive in a 20 per cent solution of potassium hydroxide as the electrolyte; and the *lead cell,* which uses lead as the negative pole and lead dioxide as the positive pole in an electrolyte of 30 per cent sulfuric acid. The output voltage of an Edison cell is about 1.1 volts and the output voltage of a fully charged lead cell is about 2.2 volts. The lead cell is much more common due to its greater output voltage per unit, to its lower cost, and to the fact that a greater *ampere-hour* capacity may be obtained in a given amount of space. It is the lead cell which is used in the storage batteries of automobiles, submarines, and land-wire telephone installations.

THREE

Vacuum Tube Theory

IN 1883 Thomas Edison noticed that if an additional wire or terminal were placed inside an incandescent lamp and the filament lighted, the terminal would acquire a negative charge of electricity. J. A. Fleming began the study of the *Edison Effect* in 1895 and as a result of his findings, in 1904 he patented the two-electrode tube or diode which became known as the Fleming valve. Then in 1906 Lee de Forest discovered that a third element could be placed between the cathode and plate to control the flow of energy between them. This third element was called the *grid* and its insertion into the diode resulted in the most versatile of vacuum tubes, the *triode*.

The Edison Effect and Electronic Emission

The original Edison discovery was that a heated filament would give off electrons which would be attracted to a cold plate in the same evacuated chamber. It was later discovered that if the plate were charged positively with respect to the filament, a large number of the emitted electrons would be attracted to the plate. This discovery, coupled with that wherein it was found a grid could be placed between the two elements to control the electron flow between them, forms the basis for the modern vacuum tube.

The free electrons in a metallic wire are continually in motion at all temperatures, but at all ordinary atmospheric temperatures these electrons do not have sufficient velocity to penetrate the surface of the wire. However, as the wire is heated the velocities of the free electrons increase until at a certain temperature determined by the character of the wire a measurable amount of them are able to penetrate the surface of the wire and be emitted into the surrounding vacuum. As the temperature of the filament is raised above this critical temperature the emission of electrons increases rapidly.

TYPES OF EMITTERS

Emitters as used in present-day vacuum tubes may be classed into two groups: the directly heated or filament type, and the indirectly heated or heater-cathode type. Directly heated emitters may be further subdivided into three important groups, all of which are important and commonly used in modern tubes. These classifications are: the pure tungsten filament, the thoriated-tungsten filament, and the oxide-coated filament.

The Pure Tungsten Filament

Pure tungsten wire was used as the filament in nearly all the earlier transmitting and receiving tubes. However, the thermionic efficiency of tungsten wire as an emitter (the number of milliamperes emission per watt of filament heating power) is quite low, the filaments become fragile after use, their life is rather short, and they are susceptible to burnout at any time. Pure tungsten filaments must be run at bright white heat (about 2500° Kelvin). For these reasons tungsten filaments have been replaced in all applications where another type of filament could be used. They are, however, still universally employed in most water-cooled tubes and in certain large, high-power air-cooled triodes where another filament type would be unsuitable. Tungsten filaments are the most satisfactory for high-power, high-voltage tubes where the emitter is subjected to positive ion bombardment due to the residual gas content of the tubes. Tungsten is not adversely affected by such bombardment.

The Thoriated-Tungsten Filament

In the course of experiments made upon tungsten emitters it was found that filaments made from tungsten having a small amount of thoria (thorium oxide) as an impurity had much greater emission than those made from the pure metal. Subsequent improvements have resulted in the highly efficient carburized thoriated-tungsten filament as used in virtually all medium-power transmitting tubes in use today.

Thoriated-tungsten emitters consist of a tungsten wire containing about one per cent thoria. The new filament is first carburized by heating it to a high temperature in an atmosphere containing a hydrocarbon at reduced pressure. Then the envelope is highly evacuated and the filament is flashed for a minute or two at about 2600° K before being burned at 2200° K for a longer period of time. The flashing causes some of the thoria to be reduced by the carbon to metallic thorium. The activating at a lower temperature allows the thorium to diffuse to the surface of the wire to form a layer of the metal a molecule thick. It is this single-molecule layer of thorium which reduces the work function of the tungsten filament to such a value that electrons will be emitted from a thoriated filament thousands of times more rapidly than from a pure tungsten filament *operated at the same temperature.*

The carburization of the tungsten surface seems to form a layer of tungsten carbide which holds the thorium layer much more firmly than the plain tungsten surface. This allows the filament to be operated at a higher temperature, with consequent greater emission, for the same amount of thorium evaporation. Thorium evaporation from the surface is a natural consequence of the operation of the thoriated-tungsten filament. The carburized layer on the tungsten wire plays another role in acting as a reducing agent to produce new thorium from the thoria to replace that lost by evaporation. This new thorium continually diffuses to the surface during the normal operation of the filament.

One thing to remember about any type of filament, particularly the thoriated type, is that the emitter deteriorates practically as fast when "standing by" (no plate current) as it does with any normal amount of emission load. However, a thoriated filament may be either temporarily or permanently damaged by a heavy overload which may strip the surface emitting layer of thorium from the filament.

Reactivating Thoriated-Tungsten Filaments

Thoriated - tungsten filaments (and only thoriated-tungsten filaments) which have gone "flat" as a result of insufficient filament voltage, a severe temporary overload, a less severe extended overload, or even normal operation may quite frequently be reactivated to their original characteristics by a process similar to that of the original activation. However, only filaments which have been made by a reputable manufacturer and which have not approached too close to the end of their useful life may be successfully reactivated. The filament found in certain makes of tubes may often be reactivated three or four times before the filament will cease to operate as a thoriated emitter.

The actual process of reactivation is simple enough and only requires a filament transformer with taps allowing voltage up to about 25 volts or so. The tube which has gone flat is placed in a socket to which only the two filament wires have been connected. The filament is then "flashed" for about 20 to 40 seconds at from 1½ to 2 times normal rated voltage. The filament will become extremely bright during this time and, if there is still some thoria left in the tungsten and if the tube didn't originally fail as a result of an air leak, some of this thoria will be reduced to metallic thorium. The filament is then burned at 20 to 40 per cent overvoltage for from 30 minutes to three to four hours to bring this new thorium to the surface.

The tube should then be tested to see if it shows signs of renewed life. If it does, but is still weak, the burning process should be continued at about 15 to 20 per cent overvoltage for a few more hours. This should bring it back almost to normal. If the tube checked still very low after the first attempt at reactivation the complete process can be repeated as a last effort.

Thoriated-tungsten filaments are operated at about 1900° K or at a bright yellow heat. A burnout at normal filament voltage is almost an unheard of occurrence. The ratings placed upon tubes by the manufacturers are figured for a life expectancy of 1000 hours. Certain types of tubes may give much longer life than this but the average transmitting tube will give from 1000 to 3000 hours of useful life.

The Oxide-Coated Filament

The most *efficient* of all modern filaments is the oxide-coated type which consists of a mixture of barium and strontium oxides coated upon a wire or strip usually consisting of a nickel alloy. This type of filament operates at a dull-red to orange-red temperature (1050° to 1170° K) at which temperature it will emit large quantities of electrons. The oxide-coated filament is somewhat more efficient than the thoriated-tungsten type in small sizes and it is considerably less expensive to manufacture. For this reason all receiving tubes and quite a number of the low-powered transmitting tubes use the oxide-coated filament. Another advantage of the oxide-coated emitter is its extremely long life—the average tube can be expected to run from 3000 to 5000 hours, and when loaded very lightly tubes of this type have been known to give 50,000 hours of life before their characteristics changed to any great extent.

The oxide-coated filament does have the disadvantage, however, that it is unsuitable for use in tubes which must withstand more than about 600 volts of plate potential. Some years back transmitting tubes for operation up to 2000 volts were made with oxide-coated filaments but they have been discontinued. Much more satisfactory operation is obtainable at high plate potentials with thoriated filaments.

Oxide filaments are unsatisfactory for use at high plate voltages because (1) their activity is seriously impaired by the high temperature necessary to bombard the high-voltage tubes and, (2) the positive ion bombardment which takes place even in the best evacuated high-voltage tube causes destruction of the oxide layer on the surface of the filament.

Oxide-coated filaments operate by virtue of a mono-molecular layer of alkaline-earth metal (barium and strontium) which forms on the surface of the oxide coating. Such filaments do not require reactivation since there is always sufficient reduction of the oxides and diffusion of the metals to the surface of the filament to more than meet the emission needs of the cathode.

Indirectly Heated Filaments — The Heater Cathode

The heater type cathode was developed as a result of the requirement for a type of emitter which could be operated from alternating current and yet would not introduce a.c. ripple modulation even when used in low-level stages. It consists essentially of a small nickel-alloy cylinder with a coating of strontium and barium oxides on its surface similar to that used on the oxide-coated filament. Inside the cylinder is an insulated heater element consisting usually of a double spiral of tungsten wire. The heater may operate on any voltage from 2 to 85 volts although 6.3 is by far the most common value. The heater is operated at quite a high temperature so that the cathode itself may be brought to operating temperature in a matter of 15 to 30 seconds. Heat coupling between the heater and the cathode is mainly by *radiation*, although there is some thermal conduction through the insulating coating on the heater wire, as this coating is also in contact with the cathode thimble.

Indirectly heated cathodes are employed in all a.c. operated tubes which are designed to operate at a low level either for r.f. or a.f. use. However, some receiver power tubes use heater cathodes (6L6, 6V6, 6F6, and 6B4G) as do some of the low-power transmitter tubes (802, 807, T21, and RK39). Heater cathodes are employed exclusively when a number of tubes are to be operated in series as in an a.c.-d.c. receiver. A heater cathode is often called a uni-potential cathode because there is no voltage drop along its length as there is in the filament-type cathode.

TYPES OF VACUUM TUBES

If a cathode capable of being heated either indirectly or directly is placed in an evacuated envelope along with a plate, such a two-element vacuum tube is called a diode. The diode is the simplest of all vacuum tubes and is the fundamental type from which all the others are derived; hence, the diode and its characteristics will be discussed first.

Characteristics of the Diode

When the cathode within a diode is heated, it will be found that a few of the electrons leaving the cathode will leave with sufficient velocity to reach the plate. If the plate is electrically connected back to the cathode, the electrons which have had sufficient velocity to arrive at the plate will flow back to the cathode through the external circuit. This small amount of initial plate current is an effect found in all two-element vacuum tubes.

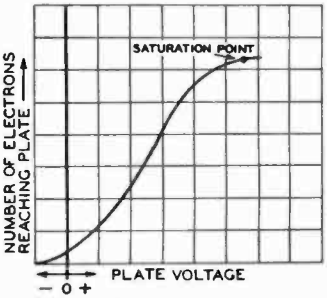


Figure 1.

CURVE SHOWING NUMBER OF ELECTRONS REACHING THE PLATE PLOTTED AS A FUNCTION OF PLATE VOLTAGE.

It will be noticed that there is a small flow of plate current even with zero plate voltage. The flow can be stopped by a small negative plate potential. As the plate voltage is increased in a positive direction, the plate current increases approximately as the 3/2 power of the plate voltage until the saturation point is reached. At this point all the electrons leaving the filament are being attracted to the anode.

If a battery or other source of d.c. voltage is placed in the external circuit between the plate and cathode so that the battery voltage places a positive potential on the plate, the flow of current from the cathode to plate will be increased. This is due to the strong attraction offered by the positively charged plate for any negatively charged electrons. If the positive potential on the plate is increased, the flow of electrons between the cathode and plate will also increase up to the point of *saturation*. Saturation current flows when all of the electrons leaving the cathode are attracted to the plate, and no increase in plate voltage can increase the number of electrons being attracted.

The Space Charge Effect

As a cathode is heated so that it begins to emit, those electrons which have been discharged into the surrounding

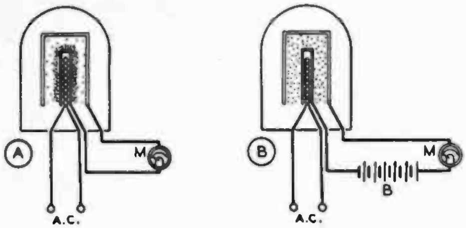


Figure 2.

ILLUSTRATING THE SPACE CHARGE EFFECT IN A DIODE.

(A) shows the space charge existing in the vicinity of the cathode with zero or a small amount of plate voltage. A few high-velocity electrons will reach the plate to give a small plate current even with no plate voltage. (B) shows how the space charge is neutralized and all the electrons emitted by the cathode are attracted to the plate with a battery sufficient to cause saturation plate current.

space form in the immediate vicinity of the cathode a negative charge which acts to repel those electrons which normally would be emitted were the charge not present. This cloud of electrons around the cathode is called the *space charge.* The electrons comprising the charge are continuously changing, since those electrons making up the original charge are attracted back to the cathode and are replaced by others emitted by it.

The effect of the space charge is to make the current through the tube variable with respect to the plate-to-cathode drop across it. As the plate voltage is increased, the positive charge of the plate tends to neutralize the negative space charge in the vicinity of the cathode. This neutralizing action upon the space charge by the increased plate voltage allows a greater number of electrons to be emitted from the cathode which, obviously, causes a greater plate current to flow. When the point is reached at which the space charge around the cathode is neutralized completely, all the electrons that the cathode is capable of emitting are being attracted to the plate and the tube is said to have reached *saturation* plate current as mentioned above.

Insertion of a Grid — The Triode

If an element consisting of a mesh or spiral of wire is inserted concentric with the plate and between the plate and the cathode, such an element will have an effect on the cathode-to-plate current of the tube. The new element is commonly called a grid, and a vacuum tube containing a cathode, grid, and plate is commonly called a three-element tube or, more simply, a *triode.*

If this new element through which the electrons must pass in their course from cathode to plate, is made negative with respect to the filament, the charge on this grid will in effect aid the space charge surrounding the cathode and hence will reduce the plate current of the tube. As a matter of fact, if the charge on this grid is made sufficiently negative the space charge will be increased to such an extent that all the electrons leaving the cathode will be repelled back to it and the plate current will be reduced by zero. Any d.c. voltage placed upon a grid (especially so when speaking of a control grid) is called a *bias.* Hence, the lowest value of voltage which causes cutoff of plate current is called the value of *cutoff bias.*

Figure 3 illustrates the manner in which the plate current of a typical triode will vary with different values of grid bias. This shows graphically the cutoff point, the approximately linear relation between grid bias and plate current over the operating range of the tube, and the point of plate current saturation. However, the point of plate current saturation comes at a different position with a triode as compared to a diode. Plate current non-linearity or saturation may begin either at the point where the full emission capabilities of the filament have been reached or at the point where the positive grid voltage begins to approach the positive plate voltage.

This latter point is commonly referred to as the *diode bend* and is caused by the positive voltage of the grid allowing it to rob from the current stream electrons that would normally go to the

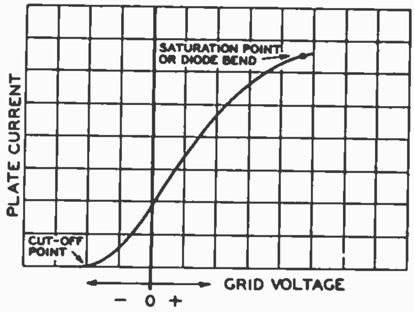


Figure 3.
PLATE CURRENT PLOTTED AGAINST GRID VOLTAGE, WITH CONSTANT PLATE VOLTAGE.
For values of grid bias between those which give plate current cutoff and plate current saturation, the value of plate current varies more or less linearly with respect to changes in grid voltage.

plate. When the plate voltage is low with respect to that required for full current from the cathode, the diode bend is reached before plate current saturation. When the plate voltage is high, saturation is reached first.

From the above it can be seen that the grid acts as a valve in controlling the electron flow from the cathode to the plate. As long as the grid is kept negative with respect to the cathode, only an extremely small amount of grid energy is required to control a comparatively large amount of plate power. Even if the grid is operated in the positive region a portion of the time, so that it will draw current, the grid energy requirements are still very much less than the energy controlled in the plate circuit. It is for this reason that a vacuum tube is commonly called a *valve* in Britain, Australia, and Canada.

Interelectrode Capacitance

In the preceding chapter it was mentioned that two conductors separated by a dielectric form a *condenser,* or that there is *capacitance* between them. Since the electrodes in a vacuum tube are conductors and they are separated by a dielectric, vacuum, there is capacitance between them. Although the interelectrode capacitances are so small as to be of little consequence in audio-frequency work, they are large enough to be of considerable importance when the tubes are operated at radio frequencies.

Figure 4 shows the interelectrode capacitances in a triode as they appear to a circuit in which the tube is operating. The grid-to-filament (C_{gf}) and plate-to-filament (C_{pf}) capacities cause no serious disadvantage for ordinary work since they add only a small amount of capacity to the input and output circuits. However, the grid-to-plate capacity (C_{gp}) acts effectively as a small coupling condenser from the output circuit of the tube back to the input circuit. This capacity can cause undesirable effects in the form of regeneration or oscillation in radio-frequency amplifiers. The effect of this capacity can be balanced out by a bridge circuit of capacitances, a process discussed under *Neutralization* in the chapter devoted to *Transmitter Theory.* The quest for a simpler and more easily usable method of eliminating this capacity or its effects led to the development of the screen-grid tube or tetrode.

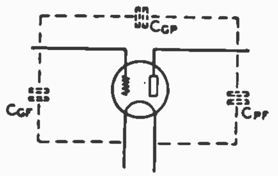


Figure 4.
EFFECTIVE INTERELECTRODE CAPACITIES IN A TRIODE.

The Tetrode or Screen-Grid Tube

When another grid is added to a vacuum tube between the control grid and plate, the tube is then called a *tetrode,* meaning that it has four elements. Such tubes are more familiarly known as *screen-grid* tubes since the additional element is called a *screen.* The interposition of this screen between grid and plate serves as an electrostatic shield between these two elements, with the consequence that the grid-to-plate capacitance is reduced. This effect is accomplished by establishing the screen at r.f. ground potential by by-passing it to ground with a fairly large condenser. The grid-plate capacitance is then so small that the amount of feedback voltage from plate to grid is normally insufficient to start oscillation. The advent of the screen grid tube eliminated the necessity for lossers and neutralization previously required to prevent a triode r.f. amplifier stage from oscillating.

In addition to the shielding effect, the screen grid serves another very useful purpose. Since the screen is maintained at a positive potential, it serves to increase or accelerate the flow of electrons to the plate. There being large openings in the screen mesh, most of the electrons pass through it and on to the plate. Due also to the screen, the plate current is largely independent of plate voltage, thus making for high amplification When the screen is held at a constant value, it is possible tc make radical changes in plate voltage without appreciably affecting the plate current.

Secondary Emission; Pentodes

When the electrons from the cathode travel with sufficient velocity, they dislodge electrons upon striking the plate. This effect of *bombarding* the plate with high velocity electrons, with the consequent dislodgement of other electrons from the plate, is known as *secondary emission*. This effect can cause no particular difficulty in a triode tube because the secondary electrons so emitted are eventually attracted back to the plate. In the screen grid tube, however, the screen is close to the plate and is maintained at a positive potential. Thus, the screen will attract these electrons that have been knocked from the plate, particularly when the plate voltage falls to a lower value than the screen voltage, with the result that the plate current is lowered and the amplification is decreased.

This effect is eliminated when still another element is added between the screen and plate. This additional element is called a *suppressor,* and tubes in which it is used are called *pentodes.* The suppressor grid is sometimes connected to cathode within the tube, sometimes it is brought out to a connecting pin on the tube base, but in any case it is established negative with respect to the minimum plate voltage. The secondary electrons that would travel to the screen if there were no suppressor are diverted back to the plate. The plate current is, therefore, not reduced and the amplification possibilities are increased.

Pentodes for radio applications are designed so that the suppressor increases the limits to which the plate voltage may swing; therefore the consequent power output and gain can be very great. Pentodes for radio-frequency service function in such a manner that the suppressor allows high voltage gain, at the same time permitting fairly high gain at low plate voltage. This holds true even if the plate voltage is the same or slightly lower than the screen voltage.

Beam Power Tubes

A beam power tube makes use of a new method for suppressing secondary emission. In this tube there are four electrodes: a cathode, a grid, a screen and a plate, so spaced and placed that secondary emission from the plate is suppressed without actual power. Because of the manner in which the electrodes are spaced, the electrons which travel to the plate are slowed down when the plate voltage is low, almost to zero velocity in a certain region between screen and plate. For this reason the electrons form a stationary cloud, a *space charge.* The effect of this space charge is to repel secondary electrons emitted from the plate and thus cause them to return to the plate. In this way, secondary emission is suppressed.

Another feature of the beam power tube is the low current drawn by the screen. The screen and the grid are spiral wires wound so that each turn in the screen is shaded from the cathode by a grid turn. This alignment of the screen and the grid causes the electrons to travel in sheets between the turns of the screen so that very few of them flow to the screen. Because of the effective suppressor action provided by the space charge, and because of the low current drawn by the screen, the beam power tube has the advantages of high power output, high power sensitivity and high efficiency. The 6L6 is such a beam power tube designed for use in the power amplifier stages of receivers and speech amplifiers or modulators. Larger tubes employing the beam-power principle are being made by various manufacturers for use in the radio-frequency stages of transmitters. These tubes feature extremely high power sensitivity (a very small amount of driving power is required for a large output), good plate efficiency, and freedom from the requirement for neutralization. Notable among these transmitting beam power tubes are the T21 of Taylor, and the 807, 814, and 813 of RCA.

Television Amplifier Pentodes

There was a need in television work, where extremely wide bands of frequencies must be passed by an amplifier, for vacuum tubes which would give extremely high amplification and still have comparatively low plate impedance and shunt capacitances. This need led to the development of the 1851, 1852, and 1853—all three of which answer this requirement with slight individual variations. Through the use of a large cathode and a very fine mesh grid spaced very close to the cathode, it has been possible to obtain in these pentodes amplification factors of 6000 and above with transconductances of 7500 to 12,000. The true significance of these figures can be grasped after the material in the latter part of this chapter has been studied.

Pentagrid Converters

A pentagrid converter is a multiple grid tube so designed that the functions of superheterodyne oscillator and mixer are combined in one tube. One of the principal advantages of this type of tube in superheterodyne circuits is that the coupling between oscillator and mixer is automatically done; the oscillator elements effectively modulate the electron stream and, in so doing, the conversion conductance is high. The principal disadvantage of these tubes lies in the fact that they are not particularly suited for operation at frequencies much above 20 Mc. because of difficulties encountered in the oscillator section.

Special Purpose Mixer Tubes

Notable among the special purpose multiple grid tubes is the 6L7 heptode, used principally as a mixer in superheterodyne circuits. This tube has *five* grids: control grid, screens, suppressor and special injection grid for oscillator input. Oscillator coupling to control grid and screen grid circuits of ordinary pentodes is effective as far as mixing is concerned, but has the disadvantage of considerable interaction between oscillator and mixer.

The 6L7 has a special *injection grid* so placed that it has reasonable effect on the electron stream without the disadvantage of interaction between the screen and control grid. The principal disadvantage is that it requires fairly high oscillator input in order to realize its high conversion conductance. It may also be used as an r.f. pentode amplifier.

The 6J8G and 6K8 are two tubes specifically designed for converter service. They consist of a heptode mixer unit and a triode unit in the same envelope, internally connected to provide the proper injection for conversion work. While both tubes function as a triode oscillator feeding a heptode mixer, the method of injection is different in the two tubes. In the 6J8G, the control grid of the oscillator is connected internally to a special shielded injector grid in the heptode section. In the 6K8, the number one grid of the heptode is connected internally to the control grid of the oscillator triode.

Single-Ended Tubes

From the introduction of the screen-grid tube to the present time it has been standard practice to bring the control grid (or the no. 1 grid as it is called) of all pentodes and tetrodes designed for radio frequency amplifier use in receivers through the *top* of the envelope. This practice was started because it was much easier to shield the input from the output circuit when one was at the top and the other at the bottom of the envelope. This was true both of the elements and of their associated circuits.

With the introduction of the octal-based metal tube it became feasible to design and manufacture high-gain r.f. amplifier and mixer tubes with all the terminals brought out the base. The metal envelope gives excellent shielding of the elements from external fields, and through the use of a small additional shield inside the locating pin of the octal socket, the diametrically opposite grid and plate pins of the tubes are well shielded from each other. The 6SJ7 and 6SK7 are conventional r.f. amplifier pentodes exemplifying this type of design, the 1852 (6AC7) and 1853 (6AB7) are television amplifier pentodes, the 6SA7 is a new, greatly improved pentagrid converter tube, the 6SQ7 is a diode-high-μ triode and the 6SC7 is a dual triode.

Dual Tubes

Some of the commonly known vacuum tubes are in reality two tubes in one, i.e., in a single glass or metal envelope. Twin triodes, such as the types 53, 6A6, 6SC7, and 6N7 are examples. A disadvantage of these twin-triode tubes for certain applications is the fact that the cathodes of both tubes are brought out to the same base pin.

Of a different nature are the 6H6 twin diode and the 6F8G and 6C8G twin triodes. The cathodes of each of these tubes are brought to a separate base pin on the socket, thus making them true twin triodes. Other types combine the functions of a double diode and either low or high μ triode in the same envelope, as well as a similar combination with a pentode instead of a triode. Still other types combine a pentode and a triode, a pentode and a power supply rectifier, and electron-ray indicating tubes (magic eyes) with their self-contained triode d.c. voltage amplifier.

Manufacturer's Tube Manuals

The larger tube manufacturers offer at a nominal cost tube manuals which are very complete and give much valuable data which, because of space limitations cannot be included in this handbook. Those especially interested in vacuum tubes are urged to purchase one of these books as a supplementary reference.

APPLICATION OF THE VACUUM TUBE

The preceding section of this chapter has been devoted to the theory of vacuum tubes and to the various types in which they commonly appear. The succeeding section will be devoted to the application of the characteristics and abilities of the vacuum tube to the problems of amplification, oscillation, rectification, detection, frequency conversion, and electrical measurements.

THE VACUUM TUBE AS AN AMPLIFIER

The ability of a grid of a vacuum to control large amounts of plate power with a small amount of input energy allows the vacuum tube to be used as an amplifier. It is the ability of the vacuum tube to amplify an extremely small amount of energy up to almost any amount without change in anything except amplitude which makes the vacuum tube such an extremely useful adjunct to modern industry and communication.

The most important considerations of a vacuum tube, aside from its power handling ability (which will be treated later on), are amplification factor, plate resistance, and mutual conductance.

Amplification Factor or Mu

The amplification factor or mu (μ) of a vacuum tube is the ratio of a change in plate voltage to a change in grid voltage, either of which will cause the same change in plate current. Expressed as a differential equation:

$$\mu = \frac{dE_p}{dE_g}$$

The μ can be determined experimentally by making a slight change in the plate voltage, thus slightly changing the plate current. The plate current is then returned to its original value by a change in grid voltage. The ratio of the increment in plate voltage to the increment in grid voltage is the μ of the tube. The foregoing assumes that the experiment is conducted on the basis of rated voltages as shown in the manufacturer's tube tables.

The plate resistance can also be determined by the previous experiment. By noting the change in plate current as it occurs when the plate voltage is changed, and by dividing the latter by the former, the plate resistance can then be determined. Expressed as an equation:

$$R_p = \frac{dE_p}{dI_p}$$

The mutual conductance, also referred to as *transconductance,* is the ratio of the amplification factor (μ) to the plate resistance:

$$S_m = \frac{\mu}{R_p} = \frac{\frac{dE_p}{dE_g}}{\frac{dE_p}{dI_p}} = \frac{dI_p}{dE_g}$$

The amplification factor is the ability of the tube to amplify or increase the voltages applied to the grid. The amount of voltage amplification that can be obtained from a tube is expressed as follows:

$$\frac{\mu R_L}{R_p + R_L}$$

where R_L = ohmic load in the plate circuit. In the case of a type 6F5 tube with a plate resistor of 50,000 ohms, the voltage amplification as calculated from the previous equation would be:

$$\frac{100 \times 50{,}000}{50{,}000 + 66{,}000} = 43$$

From the foregoing it is seen that an input of 1 volt to the grid of the tube will give an output of 43 volts (a.c.).

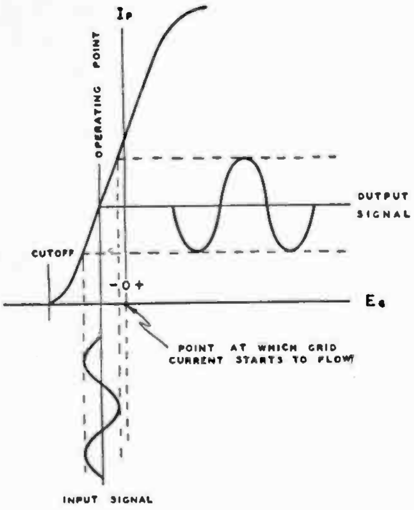
AUDIO-FREQUENCY AMPLIFIERS

Amplifiers designed to operate at a low level at radio, intermediate, and audio frequencies are almost invariably of the class A type. Higher level audio amplifiers can be of the class A, class AB, or class B type; these classifications and their considerations will be considered first. The class B and class C amplifiers as used for medium and high-level radio-frequency work will be considered under *Radio-Frequency Amplifiers.*

The Class A Amplifier

A class A amplifier is, by definition, *an amplifier in which the grid bias and alternating grid voltages are such that plate current in a specific tube flows at all times.* The output waveform from a class A amplifier is a faithful reproduction of the exciting grid voltage upon the grid. For the above conditions to be the case it is necessary that the grid bias, or the operating point, of the amplifier be chosen with care to allow maximum output.

Figure 5 shows the operating characteristic of a typical vacuum tube. It will be noticed that the curve of plate current with varying grid voltage is quite linear



CLASS A OPERATION

Figure 5.

within certain limits—outside these limits it is no longer a straight line. For an amplifier to be able to put out a voltage waveform which is a faithful reproduction of the input waveform, it is necessary that the range over which the grid voltage will be varied shall give a linear variation in plate current. Also, a class A amplifier must not draw grid current; so the operating point must be midway between the point of zero grid bias and the point on the operating characteristic where the curvature becomes noticeable. Such a point has been chosen graphically in figure 5.

When the grid bias is varied around this operating point the fluctuation in grid potential results in a corresponding fluctuation in plate current. When this current flows through a suitable load device, it produces a varying voltage drop which is a replica of the original input voltage, although considerably greater in amplitude.

Should the signal voltage on the grid be permitted to go too far negative, the negative half cycle in the plate output will not be the same as the positive half cycle. In other words, the output wave shape will not be a duplicate of the input, and *distortion* in the output will therefore result. The fundamental property of class A amplification is that the bias voltage and input signal level must not advance beyond the point of zero grid potential; otherwise, the grid itself will become positive. Electrons will then flow into the grid and through its external circuit in much the same manner as if the grid were actually the plate. The result of such a flow of grid current is a lowering of the input impedance of the tube so that power is required to drive it.

Since class A amplifiers are never designed to draw grid current they do not realize the optimum capabilities of any individual tube.

Inspection of the operating characteristic of figure 5 reveals that there is a long stretch of linear characteristic far into the positive grid region. As only the small portion of the operating characteristic below the zero grid bias line can be used, the plate circuit efficiency of a class A amplifier is low. However, they are used because they have very little or negligible distortion and, since only an infinitesimal amount of power is required on the grid, a large amount of voltage amplification may be obtained. Low-level audio and radio frequency amplifying stages in receivers and audio amplifiers are invariably operated class A. The correct values of bias for the operation of tubes as class A amplifiers are given in the *Tube Tables.*

The Class AB Amplifier

A class AB amplifier is one in which the grid bias and alternating grid voltages are such that plate current in a specific tube flows for appreciably more than half but less than the entire electrical cycle when delivering maximum output.

In a class AB amplifier, the fixed grid bias is made higher than would be the case for a push-pull class A amplifier. The resting plate current is thereby reduced and higher values of plate voltage can be used without exceeding the rated plate dissipation of the tube. The result is an increase in power output.

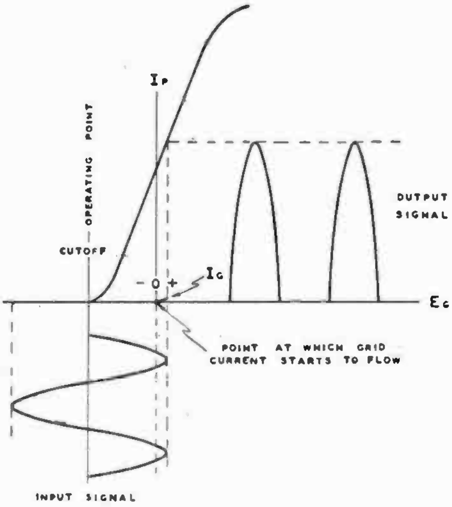
Class AB amplifiers can be subdivided into class AB_1 and class AB_2. There is no flow of grid current in a class AB_1 amplifier; that is, the peak signal voltage applied to each grid does not exceed the negative grid bias voltage. In a class AB_2 amplifier the grid signal is greater than the bias voltage on the peaks, and grid current flows.

The class AB amplifier should be operated in push-pull if distortion is to be held to a minimum. Class AB_2 will furnish more power output for a given pair of tubes than will class AB_1. The grids of a class AB_2 amplifier draw current, which calls for a power driver stage.

The Class B Amplifier

A class B amplifier is one in which the grid bias is approximately equal to the cutoff value so that the plate current is very low (almost zero) when no exciting grid voltage is applied and so that plate current in a specific tube flows for approximately one half of each cycle when an alternating grid voltage is applied.

A class B *audio* amplifier always operates with two tubes in push-pull. The bias voltage is increased to the point where but very little plate current flows.



CLASS B OPERATION

Figure 6.

This point is called the *cutoff point*. When the grids are fed with voltage 180 degrees out of phase, that is, one grid swinging in a positive direction and the other in a negative direction, the two tubes will alternately supply current to the load.

When the grid of tube no. 1 swings in a positive direction, plate current flows in this tube. During this process, grid no. 2 swings negatively beyond the point of cutoff; hence, no current flows in tube no. 2. On the other half-cycle tube no. 1 is idle, and tube no. 2 furnishes current. Each tube operates on one-half cycle of the input voltage so that the complete input wave is reproduced in the plate circuit. Since the plate current rests at a very low value when no signal is applied, the plate efficiency is considerably higher than in a class A amplifier.

There is a much higher, steady value of plate current flow in a class A amplifier, regardless of whether or not a signal is present. The average plate dissipation or plate loss is much greater than in a class B amplifier of the same power output capability.

For the reason that the plate current rises from a very low to a very high peak value on input swings in a class B audio amplifier, the demands upon the power supply are quite severe; a power supply for class B amplifier service must have good *regulation*. A high-capacity output condenser must be used in the filter circuit to give sufficient storage to supply power for the stronger audio peaks, and a choke-input filter system is required for good regulation.

Load Impedance for Amplifiers

The plate current in an amplifier increases and decreases in proportion to the value of applied input signal. If useful power is to be realized from such an amplifier, the plate circuit must be terminated in a suitable resistance or impedance across which the power can be developed. When increasing and decreasing plate current flows through a resistor or impedance, the voltage drop across this load will constantly change because the plate current is constantly changing. The actual value of voltage on the plate will vary in accordance with the IZ drop across the load, even though a steady value of direct current may be applied to the load impedance; hence, for an alternating voltage on the grid of the tube, there will be a constant change in the voltage at the anode.

The static characteristic curves give an indication of the performance of the tube for only one value of plate voltage. If the plate voltage is changed, the characteristic curve will shift. This sequence of change can be plotted in a form that permits a determination of tube performance; it is customary to plot the plate current for a series of permissible values of plate voltage at some fixed value of grid voltage.

The process is repeated for a sufficient number of grid voltage values in order that adequate data will be available. A group or family of plate voltage-plate current curves, each for a different grid potential, makes possible the calculation of the correct load impedance for the tube. Dynamic characteristics include curves for variations in amplification factor, plate resistance, transconductance and detector characteristics.

The correct value of load impedance for a rated power output is always specified by the tube manufacturer. The plate coupling device generally reflects this impedance to the tube. This subject is treated under *Impedance Matching,* Chapter *Two.*

Tubes in Parallel and Push-Pull

Two or more tubes can be connected in parallel in order to secure greater power output; two tubes in parallel will give twice the output of a single tube. Since the plate resistances of the two tubes are in parallel, the required load impedance will be half that for a single tube.

When power is to be increased by the use of two tubes, it is generally advisable to connect them in push-pull; in this connection the power output is doubled and the *harmonic content,* or *distortion,* is reduced. The input voltage applied to the grids of two tubes is 180 degrees out of phase, the voltage usually being secured from a center-tapped secondary winding with the center tap connected to the source of bias and the outer ends of the winding connected to each grid. The plates are similarly fed into a center-tapped winding and plate voltage is introduced at the center tap. The signal voltage supplied to one grid must always swing in a positive direction when the other grid swings negatively. The result is an increase in plate current in one tube with a decrease in plate current in the other at any given instant; one tube *pushes* as the other *pulls;* hence the term: *push-pull.*

Harmonic Distortion in Audio Amplifiers

Distortion exists when the output wave shape of an amplifier departs from the shape of the input voltage wave. Distortion is present mainly in the form of *harmonics,* which are voltages existing simultaneously with the fundamental at frequencies 2, 3, 4, 5, etc. times this fundamental frequency.

The lower order of harmonics, namely, those whose frequencies are twice and three times that of the fundamental frequency, are generally the strongest. The presence of strong harmonics in an audio-frequency amplifier gives rise to speech or music distortion plainly apparent to the human ear. The average ear can tolerate a certain amount of distortion, and audio amplifiers are, therefore, rated in percentage of *harmonic content.* The value of 5% is generally accepted as being the maximum permissible total harmonic distortion from an average audio amplifier.

Voltage and Power Amplification

Practically all amplifiers can be divided into two classifications, *voltage amplifiers* and *power amplifiers.* In a voltage amplifier, it is desirable to increase the voltage to a maximum possible value, consistent with allowable distortion. The tube is not required to furnish *power*

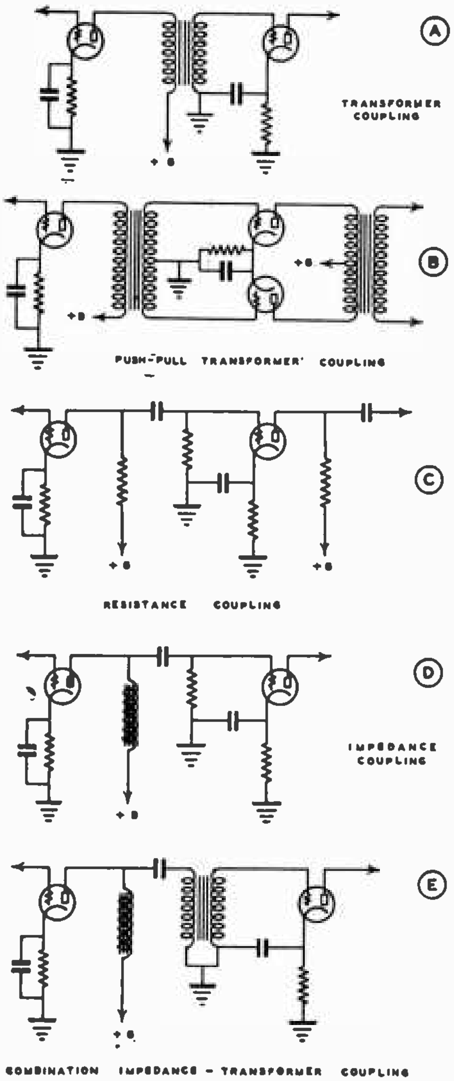


Figure 7.

Five common methods of a.f. interstage coupling.

because the succeeding tube is always biased to the point where no grid current flows. The selection of a tube for voltage amplifier service depends upon the voltage amplification it must provide, upon the load that is to be used and upon the available value of plate voltage. The varying signal current in the plate circuit of a voltage amplifier is employed in the plate load solely in the production of *voltage* to be applied to the grid of the following stage. The plate voltage is always relatively high, the plate current small.

A *power amplifier,* in contrast, must be capable of supplying a heavy current into a load impedance that usually lies between 2000 and 10,000 ohms. Power amplifiers normally furnish excitation to power-consuming devices such as loudspeakers. They also serve as drivers for other larger amplifier stages whose grids require power from the preceding stage. Power amplifiers are common in transmitters.

The difference between the plate power input and output is dissipated in the tube in the form of heat, and is known as the *plate dissipation.* Tubes for power amplifier service have larger plates and heavier filaments than those for a voltage amplifier. High-power audio circuits for commercial broadcast transmitters call for tubes of such proportions that it becomes necessary to cool their plates by means of water or forced air-cooling systems.

Interstage Coupling

Common methods of coupling one stage to another in an audio amplifier are shown in figure 7.

Transformer coupling for a single-ended stage is shown in A; coupling to a *push-pull* stage in B; *resistance coupling* in C; *impedance coupling* in D. A combination impedance-transformer coupling system is shown in E; this arrangement is generally chosen for high permeability audio transformers of small size and where it is necessary to prevent the plate current from flowing through the transformer primary. The plate circuit in the latter is *shunt-fed.* A resistor of appropriate value is often substituted for the impedance in the circuit shown in E.

RADIO-FREQUENCY AMPLIFIERS

Radio-frequency amplifiers as used in transmitters invariably fall into the "power" classification. Also, since they operate into sharply tuned tank circuits which tend to take out irregularities in the plate current waveform and give a comparatively pure sine-wave output, more efficient conditions of operation may be used than for an audio amplifier in which the output waveform must be the same as the input over a wide band of frequencies. The class B and class C r.f. amplifiers fall into this grouping.

The Class B R.F. Amplifier

The definition of a class B r.f. amplifier is the same as that of a class B amplifier for audio use. However, the r.f. amplifier operates into a tuned circuit and covers only a very small range of frequency while the audio type works into an untuned load and may cover a range of 500 or 1000 to 1 in frequency.

Class B radio-frequency amplifiers are used primarily as *linear amplifiers* whose function is to increase the output from a modulated class C stage. The bias is adjusted to the cutoff value. In a single-ended stage, the r.f. plate current flows on alternate half cycles. The power output in class B r.f. amplifiers is proportional to the square of the grid excitation voltage. The grid voltage excitation is doubled in a linear amplifier at 100% modulation, the grid excitation voltage being supplied by the modulated stage; hence, the power output on modulation peaks in a linear stage is increased four times in value. In spite of the fact that power is supplied to the tank circuit only on alternate half cycles, the flywheel effect of the tuned tank circuit supplies the missing half cycle of radio frequency, and the complete waveform is reproduced in the output to the antenna.

The Class C R.F. Amplifier

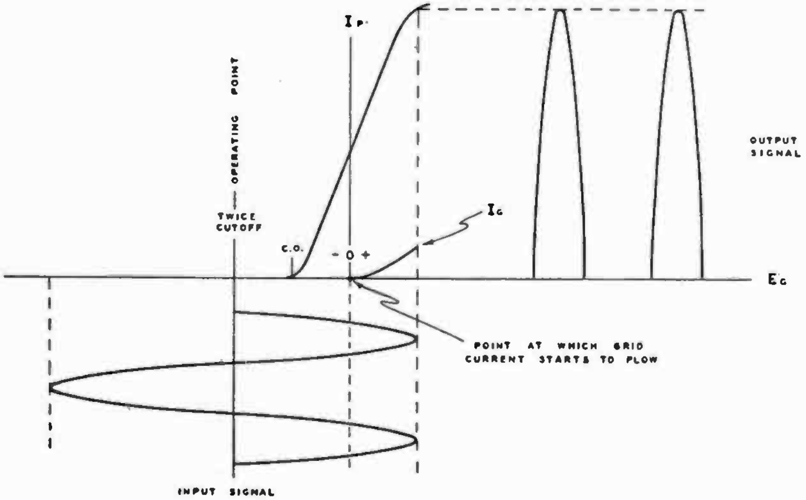
A class C amplifier is defined as an amplifier in which the grid bias is appreciably greater than the cutoff value so that the plate current in each tube is zero when no alternating grid voltage is applied, and so that plate current in a specific tube flows for appreciably less than one half of each cycle when an alternating grid voltage is applied.

The class C amplifier differs from others in that the bias voltage is increased to a point well beyond cutoff. When a tube is biased to cutoff as in a class B amplifier, it draws plate current for a half cycle or 180°. As this point of operation is carried beyond cutoff, that is, when the grid bias becomes more negative, the angle of plate current flow decreases. Under normal conditions, the optimum value for class C amplifier operation is approximately 120°. The plate current is at zero value during the first 30° because the grid voltage is still approaching cutoff. From 30° to 90°, the grid voltage has advanced beyond cutoff and swings to a maximum in a region which allows plate current to flow. From 90° to 150°, the grid voltage returns to cutoff, and the plate current decreases to zero. From 150° to 180°, no plate current flows since the grid voltage is then beyond cutoff.

The plate current in a class C amplifier flows in pulses of high amplitude, but of short duration. Efficiencies up to 75% are realized under these conditions. It is possible to convert nearly all of the plate input power into r.f. output power (approximately 90% efficiency) by increasing the excitation, plate voltage and bias to extreme values.

The r.f. plate current is proportional to the plate voltage; hence, the power output is proportional to the square of the plate voltage. Class C amplifiers are invariably used for plate modulation because of their high efficiency and because they reflect a pure resistance load into the modulator. The plate voltage of the class C stage is doubled on the peaks at 100% modulation; the power output at this point is consequently increased four times.

Figure 8 illustrates graphically the operation of a class C amplifier with twice cutoff bias and with the peak grid swing of such a value as just to approach the diode bend in the plate characteristic. When the excitation voltage is increased beyond this point the plate current waveform will have a dip at the crest due to the taking of electrons from the plate cur-



CLASS C OPERATION

Figure 8.

rent stream by the grid on its highly positive peaks.

THE VACUUM TUBE AS AN OSCILLATOR

The ability of an amplifier tube to control power enables it to function as an oscillator or a generator of alternating current in a suitable circuit. When part of the amplified output is coupled back into the input circuit, sustained oscillations will be generated provided the input voltage to the grid is of the proper magnitude and phase with respect to the plate.

The voltage that is fed back and applied to the grid must be 180° out of phase with the voltage across the load impedance in the plate circuit. The voltage swings are of a frequency depending upon circuit constants.

If a parallel resonant circuit consisting of an inductance and capacitance is inserted in series with the plate circuit of an amplifier tube and a connection is made so that part of the potential drop is impressed 180° out of phase on the grid of the same tube, amplification of the potential across the L/C circuit will result. The potential would increase to an unrestricted value were it not for the limited plate voltage and the limited range of linearity of the tube characteristic, which causes a reversal of the process after a certain point is reached. The rate of reversal is determined by the time constant or resonant frequency of the tank circuit.

The frequency range of an oscillator can be made very great; thus, by varying the circuit constants, oscillations from a few cycles per second up to many millions can be generated. A number of different types of oscillators are treated in detail under the section devoted to *Transmitter Theory.*

THE VACUUM TUBE AS A RECTIFIER

It was stated at the first of this chapter that when the potential of the plate of a two-element vacuum tube or diode is made positive with respect to the cathode, electrons emitted by the cathode will be attracted to the plate and a current will flow in the external circuit that returns the electrons to the cathode. If, on the other hand, the plate is made negative with respect to the cathode the electron flow in the external circuit will cease due to the repulsion of the electronic stream within the tube back to the cathode. From this is derived a valuable property, namely, the ability of a vacuum tube to pass current in one direction only and hence to function as a *rectifier* or a device to convert alternating current into pulsating d.c.

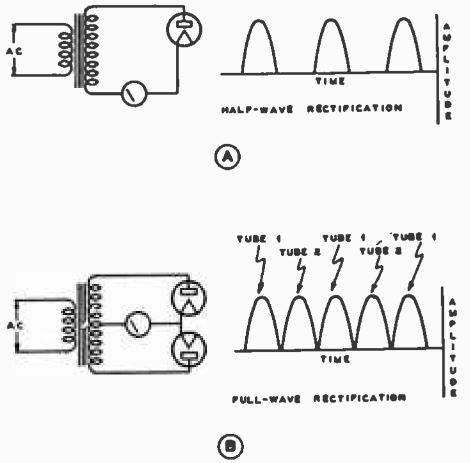


Figure 9.

Figure 9A shows a half-wave rectifier circuit. For convenience of explanation, a conventional power rectifier has been chosen although the same diagram and explanation would apply to diode rectification as employed in the detector circuits of many receivers.

When a sine-wave voltage is induced in the secondary of the transformer, the rectifier plate is made alternately positive and negative as the polarity of the alternating current changes. Electrons are attracted to the plate from the cathode when the plate is positive, and current then flows in the external circuit. On the succeeding half cycle, the plate becomes negative with respect to the cathode, and no current flows. Thus, there will be an interval before the succeeding half cycle occurs when the plate again becomes positive. Under these conditions, plate current once more begins to flow and there is another pulsation in the output circuit.

For the reason that one half of the complete wave is absent in the output, the result is what is known as *half-wave rectification*. The output power is the average value of these pulsations; it will, therefore, be of a low value because of the interval between pulsations.

In a *full-wave circuit* (figure 9B), the plate of one tube is positive when the other plate is negative; although the current changes its polarity, one of the plates is always positive. One tube, therefore, operates effectively on each half cycle, but the output current is in the same direction. In this type of circuit the rectification is complete and there is no gap between plate current pulsations. This output is known as *rectified a.c.* or *pulsating d.c.*

Mercury Vapor Rectifiers

If a two-element electron tube is evacuated and then filled with a gas such as mercury vapor, its characteristics and performance will differ radically from those of an ordinary high-vacuum diode tube.

The principle upon which the operation of a gas-filled rectifier depends is known as the phenomenon of gaseous ionization, which was discussed under *Fundamental Theory*. Investigation has shown that the electrons emitted by a hot cathode in a mercury-vapor tube are accelerated toward the anode (plate) with great velocity. These electrons move in the electrical field between the hot cathode and the anode. In this space they collide with the mercury-vapor molecules which are present.

If the moving electrons attain a velocity so great as to enable them to break through a potential difference of more than 10.4 volts (for mercury), they will literally knock the electrons out of the atoms with which they collide.

As more and more atoms are broken up by collision with electrons, the mercury vapor within the tube becomes *ion-*

ized and transmits a considerable amount of current. The ions are repelled from the anode when it is positive; they are then attracted to the cathode, thus tending to neutralize the negative space charge as long as saturation current is not drawn. This effect neutralizes the negative space charge to such a degree that the voltage drop across the tube is reduced to a very low and constant value. Furthermore, a considerable reduction in heating of the diode plate, as well as an improvement in the voltage regulation of the load current, is achieved. The efficiency of rectification is thereby increased because the voltage drop across any rectifier tube represents a waste of power.

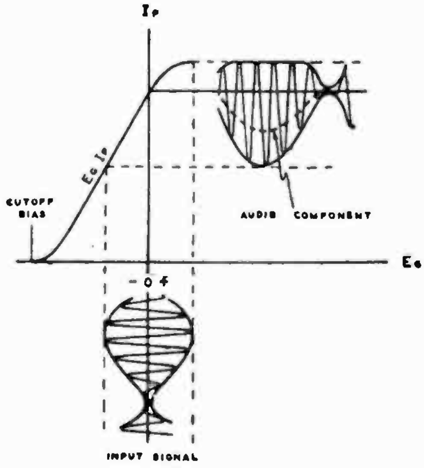
Detection or Demodulation

Detection is the process by which the audio component is separated from the modulated radio-frequency signal carrier at the receiver. Detection always involves either rectification or nonlinear amplification of an alternating current.

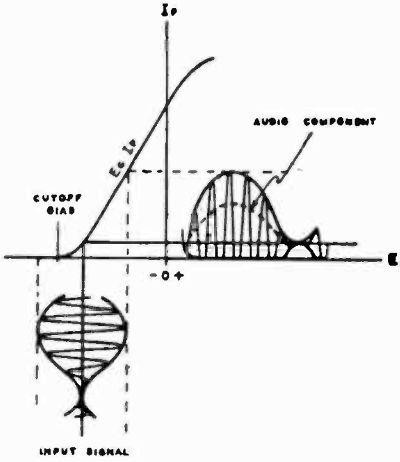
Two general types of amplifying detectors are used in radio circuits:

(1) *Plate Detector.* The plate detector or *bias detector* (sometimes called a *power detector*) amplifies the radio-frequency wave and then rectifies it and passes the resultant audio signal component to the succeeding audio amplifier. The detector operates on the lower bend in the plate current characteristic, because it is biased close to the cutoff point and therefore could be called a single-ended class B amplifier. The plate current is quite low in the absence of a signal and the audio component is evidenced by an increase in the average unmodulated plate current. See figure 10.

(2) *Grid Detector.* The grid detector differs from the plate detector in that it rectifies in the grid circuit and then amplifies the resultant audio signal. The only source of grid bias is the grid leak so that the plate current is maximum when no signal is present. This form of detector operates on the upper or saturated bend of its characteristic curve and the demodulated signal appears as an audio-frequency decrease in the average plate current. However, at *low* plate voltage, most of the rectification takes place as the result of the *curvature* in the grid characteristic. By proper choice of grid leak and plate voltage, distortion can be held to a reasonably small value. In extreme cases the distortion can reach a very high value, particularly when



A - GRID DETECTION



B - PLATE DETECTION

Figure 10.

Illustrating detector operation in upper- and lower-bend portion of the characteristic curve.

the carrier signal is modulated to a high percentage. In such cases the distortion can reach 25%.

The grid detector will absorb some power from the preceding stage because it draws grid current. It is significant to relate that the higher gain through the grid detector does not necessarily indicate that it is more sensitive. Detector sensitivity is a matter of *rectification efficiency* and amplification, not of amplification alone. Grid leak detectors are often used in regenerative detector circuits because smoother control of *regeneration* is possible than in other forms of plate and bias detectors.

(3) *Diode Detector.* In this type of detection the input r.f. signal is simply rectified by a diode and the modulation component appears as an alternating voltage across the diode load resistor. This type of detection, although it gives no gain and has a loading effect on the circuit that feeds it, is frequently used in high-quality receivers because of relatively distortionless demodulation or detection that is obtained. Diode detection is also frequently employed in superheterodynes because it is a simple process to take the negative voltage from the diode load resistor and use it as the a.v.c voltage. Figure 11A shows a conventional diode detector with provision for taking the diode load voltage for use as a.v.c bias.

(4) *Infinite-Impedance Detector.* Figure 11B illustrates this comparatively recently popularized type of detector circuit which has advantages over previous types where distortion-free detection is required. The circuit is essentially the same as that for plate or power-detection except that the output voltage is taken from the cathode circuit instead of from the plate. This gives the advantage that practically 100 per cent degenerative feedback is incorporated into the circuit with a consequent great reduction in harmonic distortion as compared to the simple plate detector. The circuit gives no loading to the circuit from which it obtains its voltage—hence the name, infinite-impedance detection. Also, due to the 100 per cent degenerative feedback, the circuit has a gain of one. Essentially the same output voltage will be obtained from this detector as will be obtained from a diode detector.

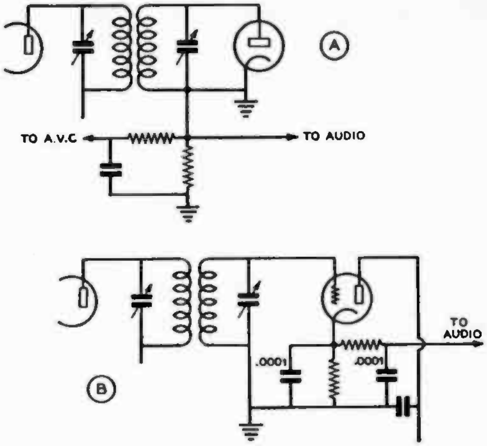


Figure 11.

Frequency Converters or Mixers

Another common usage of the vacuum tube is as a frequency changer or mixer tube. This is the operation performed by the first detector or mixer in a superheterodyne and consists of changing (most frequently) a particular high-frequency signal (bearing the desired modulation) to a fixed intermediate frequency. In this service the high-frequency signal and another signal from a local oscillator whose frequency is either lower or higher than the h.f. signal by an amount equal to the intermediate frequency (the frequency to which it is desired to convert) are fed to appropriate grids of the converter tube. The resultant intermodulation of the two signals in the converter tube produces one frequency which is the sum of the two, and another frequency which is equal to the difference between their frequencies. It is this latter frequency which is selected by the output circuit of the mixer tube and which is subsequently fed to the intermediate frequency amplifier.

Conversion Conductance

The relative efficiency of a converter tube in changing one frequency to another is called its conversion conductance or transconductance. Recent improvements in mixer tubes have allowed sizeable improvements to be made in the efficiency of mixer stages. With the latest types of mixer tubes it is possible to obtain nearly as much gain from a frequency changing stage as from an amplifier stage with its input and output circuits on the same frequency. Discussion of mixer characteristics will be found in the chapter, *Receiver Theory,* and under the section *Special Purpose Mixer Tubes* earlier in this chapter.

The Vacuum Tube as a Measuring Device

The characteristics of the vacuum tube make it very well suited for use as a measuring device in electrical circuits, especially when no power may be taken from the circuit under measurement. Vacuum tube voltmeters are the most common application of this principle. V.t. voltmeters of the peak-indicating and r.m.s. types will be found in the chapter *Test and Measurement Equipment.*

Particular types of vacuum tube voltmeters utilizing the action of an electron stream upon a fluorescent material to give a visual indication are the electron-ray or "magic eye" tubes, and the cathode-ray oscilloscope. In the electron-ray tube a small knife whose charge varies with the voltage under measurement (usually the amplified d.c. voltage of an a.v.c. circuit) deflects the electron stream to produce a varying angle of fluorescence on the visible screen at the end of the tube.

In the cathode-ray tube an electron gun consisting of cathode, grid, and accelerating anode or plate shoots a fine beam of electrons between two sets of deflecting plates separated by 90° to a fluorescent viewing screen at the end of the tube. One set of deflecting plates is most commonly set up so that it will deflect the stream of electrons back and forth in the horizontal plane. The other set of deflecting plates is oriented so that it will deflect the same stream up and down in the vertical plane. The practical design and application of the cathode-ray oscilloscope is covered in the *Test and Measurement Equipment* chapter.

FOUR

Radio Receiver Theory

A RADIO receiver is a device which reproduces, in the form of useful output, all the intelligence carried by an incoming radio wave. A necessary adjunct to the receiver is the antenna. However, the details of the function of the antenna are covered in another part of this book.

Common Receiver Terms

Before proceeding further into the subject of receiver theory, it is necessary to define several commonly-used receiver terms. These are selectivity, sensitivity, tuning, detection and fidelity.

Selectivity is the measure of the receiver's ability to discriminate between signals of different frequencies.

Sensitivity represents the receiver's ability to respond to radio-frequency voltages in its input circuit. Quantitatively, sensitivity is a measure of the smallest radio-frequency input voltage which will give a predetermined reference audio output.

Tuning is the process of resonating the receiver's radio-frequency circuits to frequencies within its range.

Detection is the process of reproducing the intelligence applied to the original r.f. signal. Since this process involves removing the modulation component from a radiotelephone carrier wave, it is often called *demodulation.*

Fidelity is a measure of the ability of the receiver to reproduce accurately the intelligence contained in the modulated radio wave applied to its input.

Basic Components

The basic parts of a simple radio receiver are the vacuum tube and the coupling circuits. The tube provides the amplification and detection, while the r.f. coupling circuits provide the selectivity and determine the frequency at which the receiver operates. Besides the r.f. coupling circuits, other coupling circuits in the receiver are used for supplying power to the electrodes of the tubes and for coupling the audio-frequency amplifiers, if used.

Radio-Frequency Coupling

Any radio wave which is intercepted by an antenna will induce a radio-frequency current in the antenna. This minute current can be made to energize a radio receiver by passing it through an *input coupling circuit.*

When the current from the antenna or feeder is caused to pass through a coil, such as L_1 in figure 1, a voltage is induced across the coil. It will be recalled from chapter 1 that this voltage across the coil is equal to the product of the current and the impedance of the coil. The impedance of a non-resonant coil such as L_1 is made up principally of its reactance. This reactance is a function of the coil dimensions and the frequency of the impressed current.

Coils L_1 and L_2 in figure 1 are said to be *inductively coupled,* as radio-frequency energy is transferred from one to

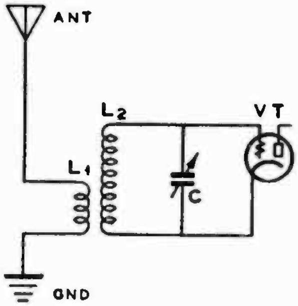


Figure 1.
INDUCTIVE COUPLING.
The antenna coil and the grid coil are inductively coupled together. Both coils are usually wound on the same form with the antenna coil at the lower end of the grid coil.

the other by virtue of the fact that the alternating inductive field around L_1 links and unlinks with the turns of L_2, thus inducing a voltage in L_2. The antenna may also be coupled to the receiver by *capacitive coupling*. An example of this type of coupling is shown in figure 2.

By means of capacitive coupling, the radio-frequency energy in the antenna may be coupled directly into the receiver's tuned circuit, L-C_2, without the use of an antenna-coupling coil. With antennas of ordinary lengths the capacity of C_1 is quite small. If the capacity of this condenser is made too large, too much coupling between the antenna and the tuned circuit will result and the current flowing through L will be reduced.

Resonant Circuits

The current flowing through L_2 of figure 1 is limited by the reactance of the coil. This reactance increases with frequency while the reactance of the variable condenser, C, which is connected across L_2, decreases with frequency. Thus, it may be seen that for any setting of C there is a frequency at which the *capacitive reactance* and the *inductive reactance are equal*. These two reactances are opposite in effect and neutralize each other at this frequency, resulting in a circuit having zero reactance and a condition of *resonance*.

At resonance the current flowing back and forth between L_2 and C is limited only by their resistances; since the resistance of modern condensers is very small, the current is actually limited by the resistance of the coil. The high current flowing through the coil causes a voltage across the coil (and consequently the condenser, since they are in parallel) equal to the product of the current and the impedance of the coil. As the impedance of the coil at resonance is high, the voltage across it is also high. Thus, it may be seen that at its resonant frequency the voltage across a tuned circuit may be very much higher than what might be expected from looking at the diagram and assuming that a simple transformer action took place between the primary and secondary.

BANDSPREAD

The frequency to which a receiver responds may be varied by changing the size of either the coils or the condensers in the tuning circuits, or both. In shortwave receivers a combination of both methods is usually employed, the coils being changed from one band to another and variable condensers being used to *tune* the receiver across each band. In

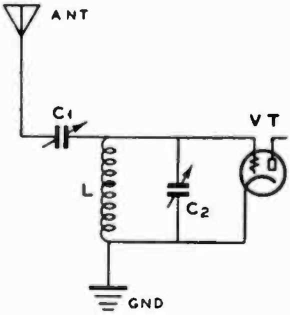


Figure 2.
CAPACITIVE COUPLING TO THE RECEIVER.
C_1 must not have too much capacity or the voltage across the coil will be reduced.

practical receivers, coils may be changed by one of two methods: A switch, controllable from the front panel, may be used to switch coils of different sizes into the tuning circuits or, alternatively, coils of different sizes may be plugged manually into the receiver, the connection into the tuning circuits being made by suitable plugs on the coils. Where there are several "plug-in" coils for each band they are sometimes arranged on a single mounting strip, allowing them all to be plugged in simultaneously.

Bandspread Tuning

In receivers using large tuning condensers to cover the short-wave spectrum with a minimum of coils, tuning is liable to be quite difficult owing to the large frequency range covered by a small rotation of the variable condensers. To alleviate this condition, some method of slowing down the tuning rate, or *bandspreading* must be used.

Quantitatively, bandspread is usually designated as being inversely proportional to the range covered. Thus, a *large* amount of bandspread indicates that a *small* frequency range is covered by the bandspread control. Conversely, a *small* amount of bandspread is taken to mean that a *large* frequency range is covered by the bandspread dial.

Bandspreading systems are of two general types: electrical and mechanical. Mechanical systems are exemplified by high-ratio dials in which the tuning condensers rotate much more slowly than the dial knob. In this system there is often a separate scale or pointer either connected or geared to the dial knob to facilitate accurate dial readings. However, there is a limit to the amount of mechanical bandspread which can be obtained in an inexpensive dial before the speed-reduction unit develops backlash, which makes tuning difficult. To overcome this problem most receivers employ a combination of both electrical and mechanical bandspread. In this system a moderate reduction in the tuning is obtained in the dial and the rest of the reduction obtained by *electrical bandspreading.*

Parallel Bandspread

Electrical bandspreading takes two general forms. In one, two tuning condensers are used across each coil, one of rather high capacity to cover a large tuning range and another of small capacity to cover a small range around the frequency to which the large condenser is set. These condensers are usually controlled by separate dials or knobs, the large condenser being known as the *bandsetting* condenser, and the smaller one being the bandspread condenser. Where there is more than one tuned circuit in the receiver, a bandsetting and a bandspread condenser are used across *each* coil and all the condensers serving in each capacity are mechanically connected together, or *ganged,* thus allowing a single dial to be used for each purpose even though there may be several tuned circuits.

Since the tuning range of a condenser is proportional to its ratio of minimum to maximum capacity, a wide variation in the amount of bandspreading is made possible by a proper choice of the two capacities. As the minimum capacity across the circuit is set, for the most part, by the capacity of the bandsetting condenser, the greater the capacity of the bandsetting condenser the greater will be the bandspread for a given size of bandspread condenser.

The bandspreading method described above is usually known as the *parallel* system. This system, as applied to a single tuned circuit, is diagrammed in figure 3. The large tuning, or bandsetting, condenser, C_1, usually has a maximum capacity of from 100 to 370 $\mu\mu$fd. C_2, the bandspread condenser, usually has a value of from 10 to 50 $\mu\mu$fd., depending upon the design of the receiver.

A special form of the parallel bandspread method is used in some manufactured tuning assemblies. In this system a single set of stationary plates (stator) in the tuning condenser is acted upon by two separate rotors, one of large capacity for bandsetting and the other of small capacity for bandspread. Each rotor is operated by a separate dial. This system allows the bandsetting and bandspread functions to be combined in a single tuning-condenser unit. A variation of this method is sometimes used in which the same dial is used for both bandsetting and bandspreading purposes, the change from one function to the other being accomplished by a "gear-shifting" mechanism built into the dial. The schematic representation of this type of bandspread system is shown in figure 4.

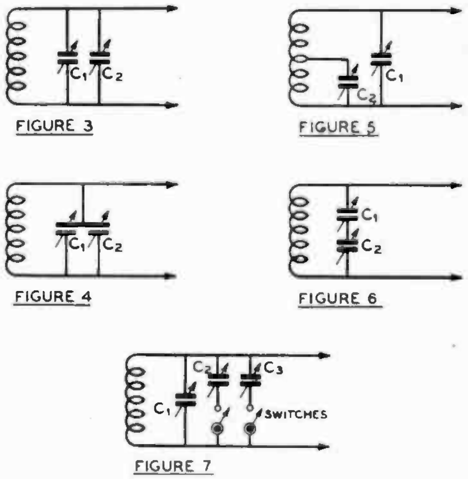
The parallel system of bandspreading has one major disadvantage, especially for amateur-band usage. This disadvantage lies in the fact that if the bandspreading condenser is made large enough to cover the lower-frequency amateur bands with optimum capacity being used across the coil in the bandsetting condenser, an extremely large bandsetting condenser is needed to give an equal amount of bandspread on the high-frequency bands. The high capacity across the coils reduces the voltage gain of the tuned circuits on the high-frequency bands, where it is most needed.

Tapped-Coil System

To allow equal bandspread on the amateur bands and still not use extremely high bandsetting capacities on the higher frequencies, the variation of the parallel system shown in figure 5 is often employed. As the bandspread condenser is connected across part of the coil, this method is usually known as the *tapped coil* system.

The theory upon which the tapped-coil system operates is quite simple. The effectiveness of the bandspread condenser in tuning the coil depends upon the proportion of the coil included across the bandspread condenser terminals. As the number of turns between the bandspread condenser terminals is decreased the amount of bandspread increases.

In most amateur-band receivers employing the tapped-coil system of bandspreading a separate bandsetting condenser is permanently connected across each coil. These condensers are either mounted within the coils, in the plug-in-coil system, or alongside the coils in the bandswitching system.



FIVE DIFFERENT BANDSPREAD CIRCUITS.
The operation of each of the circuits is described in the text.

The tapped-coil bandspread method is quite widely used in modern amateur-band receivers, especially in home constructed sets. Its principal advantage is that it allows equal bandspread, to any degree desired, over several amateur bands. Another advantage is that it facilitates accurate tracking in ganged tuning circuits; the taps are slid along the coils until the various circuits track identically.

The bandspread condenser, C_2, may have a maximum capacity of from 25 to 50 $\mu\mu$fd. for amateur band usage, while the bandsetting condenser, C_1, should have a maximum capacity of 30 to 150 $\mu\mu$fd. for amateur bands from 10 to 160 meters. Although it is possible to use almost any combination of capacities at C_1 and C_2, too little capacity at C_1 is liable to lead to cross modulation and image interference, while too great a capacity at C_2 will cause uneven bandspread, the high-frequency end of the tuning range being more crowded than the low-frequency end.

Series System

Another bandspread system is shown in figure 6. This system, which was widely used in the past, and is still employed to some extent, is known as *series bandspread*. In this system the bandspread condenser, C_2, usually has a capacity of 100 to 150 μμfd., while the bandsetting condenser, C_1, may have a capacity of 25 to 50 μμfd. The principle upon which the circuit operates is that while the *minimum* capacity across the coil varies but little for any setting of the bandsetting condenser, the *maximum* capacity available may be varied considerably.

Condenser Switching System

In figure 7 is illustrated another method of equalizing the degree of bandspread over a wide range of frequencies. C_1 is the large 350-μμfd. tuning condenser; two bandspread condensers C_2 and C_3, of 50 μμfd. and 15 μμfd. respectively, are switched across the large condenser for bandspreading the short-wave bands. The 50-μμfd. condenser is suitable for bandspread tuning in the range from 75 to 200 meters, and the smaller condenser is suitable from 10 to 75 meters. The disadvantage of this circuit lies in the switching arrangement, which may require relatively long connecting leads; the minimum capacity of the circuit would then be rather high, and the lumped inductance low at the higher frequencies.

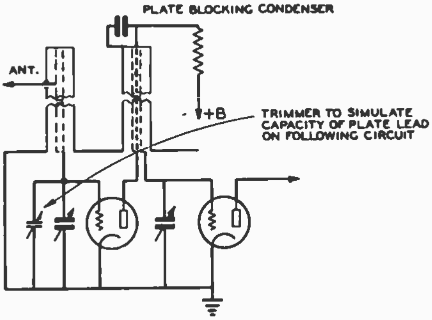


Figure 8.

CONCENTRIC TANK CIRCUITS AS USED IN ULTRA-HIGH-FREQUENCY RECEIVERS.

Concentric tanks are best at very high frequencies as they have a much higher impedance at these frequencies.

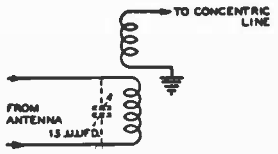


Figure 9.

CIRCUIT FOR COUPLING A BALANCED ANTENNA TO A CONCENTRIC TANK CIRCUIT.

For 56 Mc. the coils are 5 turns, 1⅜-in. in diameter and wound to a length of ⅝ inch. It may be necessary to adjust them somewhat for maximum signal strength.

Linear Tank Circuits

In receivers operating in the ultra-high-frequency ranges of 56 Mc. and above it becomes increasingly difficult, as the frequency is raised, to construct conventional coil-and-condenser tuning circuits having high impedance and low losses. To overcome this difficulty, *linear tank circuits* are often employed. These tanks may consist either of open-wire lines or concentric circuits. The concentric type is somewhat better for receiver applications as it is self-shielded and at the same time permits a somewhat higher impedance to be obtained.

An example of an ultra-high-frequency r.f. stage using concentric-line tank circuits is shown in figure 8. Coupling between stages is provided by running the plate lead of one stage through the hollow inner (grid) conductor of the following stage. Figure 9 shows a suitable method of coupling a balanced, two-wire antenna into the concentric grid circuit of the r.f. stage. While there are many ratios of inner-to-outer-conductor radius that will give satisfactory performance for receiver tank circuits, the most practical ratio, where the size of the receiver must be kept within reasonable limits, has been found to be about 1-4. The chart of figure 10 shows the capacity required to resonate different length lines of a 3.86 radius ratio (½-inch and 2-inch outside diameter pipes) at 56 and 60 Mc. The tuning condenser maximum and mini-

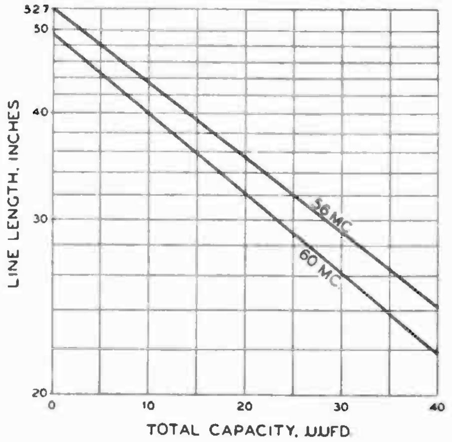


Figure 10.
GRAPH SHOWING CAPACITY NECESSARY TO RESONATE CONCENTRIC LINES.
The graph shows the amount of capacity needed to resonate concentric lines with a 3.866 ratio of conductor sizes at both ends of the 5-meter band. As explained in the text, the graph may be used for other bands.

mum capacities required for full band coverage may be determined directly from the chart. For instance: a line 32 inches long will require 20 $\mu\mu$fd. at 60 Mc. and 25 $\mu\mu$fd. at 56 Mc. This means that the total minimum capacity across the tank circuit, including that of the tuning condenser when "wide open" and all tube and stray capacities must be 20 $\mu\mu$fd., while the maximum capacity across the circuit with the tuning condenser closed should be 25 $\mu\mu$fd. The length used should be that of the inner conductor, even though it may extend below the chassis. A general idea of the appearance of a concentric-line receiver for 56-60 Mc. may be obtained from figure 11.

Line lengths and capacities for the 2½ and 1¼ meter bands may be determined from the chart by multiplying the frequency by either 2 or 4 and dividing the figures for both length and capacity by the same factor.

Vacuum-Tube Amplifiers

A radio-frequency amplifier tube can be connected between tuned circuits in order to increase the *sensitivity* of the receiver. The amplification derived from the vacuum tube depends upon the type of circuit in which it is used; if the plate load impedance can be made very high, the gain may be as much as 200 or 300 times that of the signal impressed across the grid circuit. Normal values of gain in the broadcast band are in the vicinity of 100 times. A gain of 30 per r.f. stage is considered excellent for short-wave receivers which have a range of from 30 to 100 meters. Radio-frequency amplifiers for the very short wavelengths, such as from 5 to 20 meters, seldom provide a gain of more than 10 times because of the difficulty in obtaining high load impedances, and the shunt effect of the rather high input capacities of most screen-grid tubes.

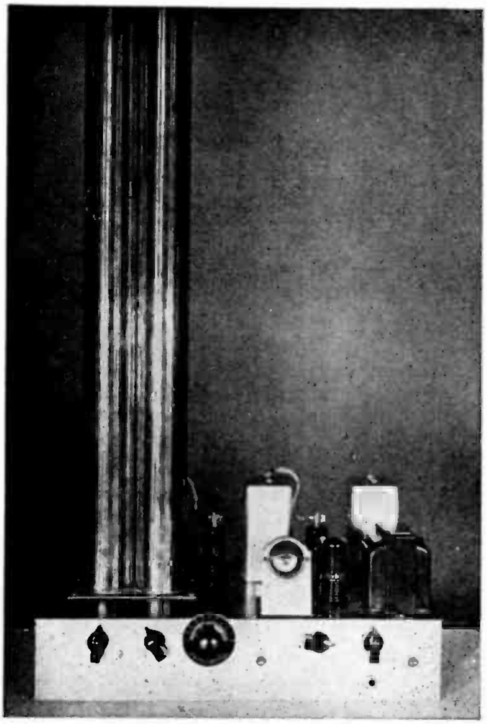


Figure 11.
SUPERHETERODYNE FOR 56 MC. USING CONCENTRIC TANK CIRCUITS.
The acorn tubes used in the high-frequency stages are located under the chassis.

Beside acting as radio-frequency amplifiers, vacuum tubes are also used in receivers as detectors, audio-frequency amplifiers, mixers in superhetrodynes, tuning indicators, and rectifiers. The operation of the tubes in these applications has been described in *chapter 3* and will be covered more or less in detail in a later portion of this chapter.

Receiver Tubes

The tube manufacturers have been lavish in their production of tubes for use in radio receivers. Many similar tubes are made in different forms, such as metal tubes, glass tubes with standard bases, glass tubes with octal bases similar to those used on metal tubes, glass tubes with tubular envelopes, glass tubes encased in metal shells and fitted with octal bases and tubes with similar characteristics but differing in their heater or filament voltage and current ratings. Some tubes are designed for dry-battery filament supply, others for automobile service and another group for operation from an a.c. source.

In general, there are certain distinct classes of tubes for particular purposes. Screen-grid tubes were primarily designed for radio-frequency amplifiers, yet they are often employed for regenerative detectors, mixers and high-gain voltage audio amplifiers. General purpose triode tubes are designed for oscillators, detectors and audio amplifiers. Power triodes, tetrodes and pentodes are designed for obtaining as much power output as possible in the output audio amplifier stage of a radio receiver. Diodes, are designed for power supply rectifiers, radio detectors, automatic volume control circuits and noise suppression circuits. In addition to these general types of tubes, there are a great many others designed for some particular service, such as oscillator-mixer operation in a superheterodyne receiver.

All vacuum tubes require a source of power for the filament and other electrodes. Various components in a radio receiver are for the purpose of supplying direct-current energy to the electrodes of the tubes, such as the plate and screen circuits. In nearly all circuits, the control grid of the vacuum tube is biased negatively with respect to the cathode, for proper amplifier action. This bias is obtained in several ways, such as from a self-biasing resistor in series with the cathode, fixed bias from the power supply or grid leak bias for some oscillators and detectors.

Various by-pass and coupling condensers are found in different portions of the circuits throughout a radio receiver. By-pass condensers provide a low impedance for r.f. or audio frequencies around such components as resistors and choke coils. Coupling condensers provide a means of connection between plate and grid circuits in which the d.c. voltage components are of widely different values. The coupling condenser offers an infinite impedance to the d.c. voltages, and a relatively low impedance to the r.f. or a.f. voltages.

Screen-grid tubes have a higher plate impedance than triodes and, therefore, require a much higher value of plate load impedance in order to obtain the greatest possible amount of amplification in the audio or radio circuits. Screen-grid tubes are normally used in all r.f. and i.f. amplifiers because the control grid is electrostatically screened from the plate circuit. Lack of this screening would cause self-oscillation in the amplifier; when triodes are used in radio-frequency amplifiers, the grid-to-plate capacities must be neutralized. The r.f. amplification from a triode amplifier in a radio receiver is so much less than can be obtained from a screen-grid tube amplifier that triodes are no longer used for this purpose.

Circuit Capacity

In the sections on *Tuned Circuits* and *Bandspread Tuning* mention was made of "stray" or *circuit capacity*. This capacity, in the usual sense, is defined as the capacity remaining across a coil when all the tuning, bandspread, and padding condensers across the circuit are at their minimum capacity setting. Circuit capacity can be attributed to two general sources. One source, which is fixed for any particular type of tube, is that due to the input capacitance of the tube. This capacity is listed in most tube tables and characteristic sheets. Strictly speaking, the tube input capacitance is not a fixed value, since its effective value varies somewhat with plate load impedance, grid bias, frequency, etc. However, in all except the extremely high-transconductance tubes the published measured input capacitance is quite close to the effective value. In the high-transconductance types however, the effective capacitance does vary considerably from the published figures, under different operating conditions.

The second source of circuit capacity, which is more easily controllable, is that contributed by the minimum capacity of the variable condensers across the circuit and that due to capacity between the wiring and ground. In well-designed high-frequency receivers every effort is made to keep this portion of the circuit capacity at a minimum, since a large capacity reduces the tuning range available with a given coil and prevents a good L/C ratio from being obtained.

Typical value of circuit capacity may run from 10 to 75 $\mu\mu$fd. in high-frequency receivers, the first figure representing concentric-line receivers with acorn tubes and extremely small tuning condensers and the latter representing all-wave sets with bandswitching and large tuning condensers and conventional tubes.

Types of Receivers

There are numerous types of receivers suitable for high-frequency reception. However most of them fall under one of the following general classifications:

(1) Regenerative detector with or without audio and with or without radio-frequency amplifiers.
(2) Superregenerative receiver.
(3) Superheterodyne receiver.

The regenerative receiver has been quite popular in high-frequency work for many years. It combines high sensitivity, simplicity, low cost, good signal-to-noise ratio and reliability. Its principal disadvantage, however, and the one which has caused it to assume a secondary role in the high-frequency receiver picture, is its lack of selectivity when subjected to large signal inputs. For uncongested localities, where interference problems are not great, the regenerative receiver can give performance comparable with the most costly of receivers.

Simple Detector

Probably the simplest receiver of all is a regenerative detector without either audio or radio-frequency amplification. A typical receiver of this type is diagrammed in figure 12. This *grid-leak* detector operates as follows: In the absence of a signal in the input circuit and with the proper voltages applied to the filament and plate, the plate current assumes a value near the upper bend of the tube's characteristic curve. When a signal voltage is applied across the input circuit the plates on the coil side of the grid condenser, C, become positive (lose some of their electrons) each half-cycle of the signal voltage. When this side of the grid condenser goes positive, electrons from the filament flow to the grid and into the plates on the grid side of C, the resulting excess of electrons trapped on the grid causing it to assume a negative potential and reducing the plate current. To prevent the grid from becoming more and more negative as electrons accumulate on the condenser, a high-resistance grid leak, R, is connected across the condenser. This resistor allows the

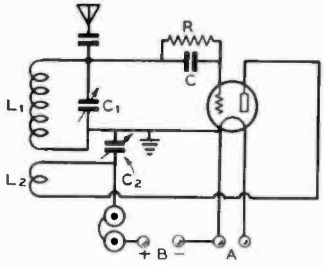


Figure 12.
REGENERATIVE DETECTOR CIRCUIT.
A regenerative detector makes the simplest high-frequency receiver. In a good location this type of receiver will give amazingly good results.

negative charge on the grid to become cumulative only during the number of r.f. cycles that constitute one-half an audio cycle, thus allowing the plate current to follow the modulation on the impressed signal. This type of *grid-leak detector* gives high audio output, since rectification takes place in the grid circuit and the amplifying properties of the tube are utilized. Unfortunately, however, this type of detector is prone to give rather high distortion when signals having a large percentage of modulation are impressed on it. The grid-leak detector is not limited to triodes; either tetrodes or pentodes may be used, these generally having greater sensitivity than the triodes.

For the reception of c.w. (constant-wave telegraphy) signals, it is necessary to provide some means of securing a heterodyne, or "beat note" with the incoming signal. In the autodyne detector this is done by coupling some of the radio-frequency energy in the plate circuit back into the grid circuit and allowing the tube to oscillate weakly. The feedback or *tickler,* coil, L_2, is closely coupled to the grid coil and thus provides the feedback necessary to make the stage oscillate. Since the detector is most sensitive on the edge of oscillation, a variable condenser, C_2, may be used as a variable plate by-pass to adjust the detector for its most sensitive condition. This condenser is called a "throttle condenser," or regeneration control.

With the detector *regenerative,* that is, with feedback taking place, but not enough to cause oscillation, it is also extremely sensitive. When the circuit is adjusted to operate in this manner, modulated signals may be received with considerably greater strength than when the detector is in a non-regenerative condition.

Alternative Detector Circuits

The circuit shown in figure 12 is by no means the only one which will give satisfactory results as a regenerative detector. There are several methods by which regeneration may be obtained, and also several alternative methods of controlling the regeneration. In tubes with an indirectly-heated cathode, regeneration may be obtained by tapping the cathode onto the grid coil a few turns up from the ground end or by returning the cathode to ground through a coil coupled to the grid winding. With tetrode or pentode tubes, feedback is sometimes provided by connecting the screen, rather than the plate, to the tickler coil.

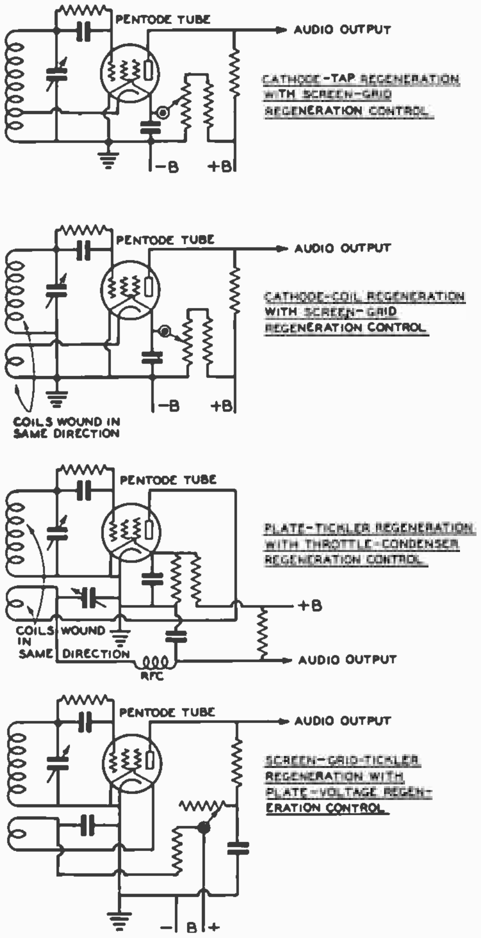


Figure 13.
POPULAR REGENERATIVE DETECTOR CIRCUITS.
Showing some of the more popular regenerative detector arrangements. Values of one to three megohms for grid leaks are common. The grid-condenser may be .0001 µfd. and the screen by-pass 0.1 µfd.

Alternative methods of controlling regeneration consist of providing means for varying the voltage on one of the tube elements, usually the plate or screen. Examples of some of the possible variations in regeneration and control methods are shown in figure 13. Representative receivers employing some of these circuits will be found in *chapter 6*.

Radio-Frequency Amplifiers

To increase the sensitivity or selectivity of a receiver, one or more *radio-frequency amplifier* stages are often used. A typical radio-frequency (r.f.) amplifier connected ahead of a regenerative detector is shown in figure 14. A pentode tube is used in the r.f. stage with a tuned grid circuit and inductive coupling from the antenna and to the detector. Capacitive coupling could be used in both instances, but in the case of the coupling between stages, a high-impedance radio-frequency choke would have to be connected to the plate of the r.f. stage to allow plate voltage to be applied to the tube. A capacity-coupling system which allows the r.f. choke to be dispensed with is shown in figure 15. This circuit is often used at ultra-high frequencies where a high-impedance resonant circuit in the plate of the r.f. tube is desired in order to obtain greater amplification.

As previously described, the tuning condensers on the r.f. stage are usually ganged with those on the detector to provide single-dial control. However, when the r.f. stage is separate from the receiver and the tuning controls not ganged it is commonly known as a *preselector*. A preselector may be added to any receiver but it is most often used with the superheterodyne type.

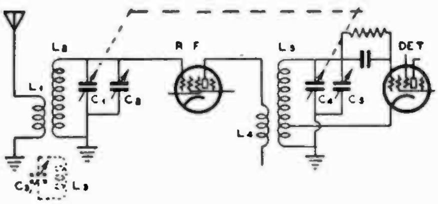


Figure 14.

SKELETON DIAGRAM OF R.F. AMPLIFIER AND REGENERATIVE DETECTOR.

The use of a radio-frequency amplifier ahead of the regenerative detector increases the receiver's sensitivity and selectivity.

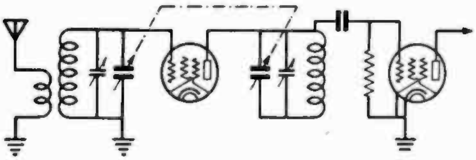


Figure 15.

CAPACITY COUPLING BETWEEN R.F. AND DETECTOR STAGES.

A coupling circuit of this type is sometimes used at ultra-high frequencies when it is desired to obtain a high-impedance plate load for the r.f. tube.

Regenerative R.F. Stages

To increase the amplification and selectivity of the r.f. stage, either when in the form of a preselector or when as an integral part of the receiver, it may be made regenerative. The regenerative r.f. amplifier increases amplification and selectivity in a manner similar to that of the regenerative detector. The regenerative r.f. amplifier is never allowed to oscillate, however; the greatest amplification is obtained with the circuit operating just below the point of oscillation. Figure 16 shows a regenerative r.f. stage of the type generally used on the higher frequencies.

A minor disadvantage to the regenerative r.f. stage is the need for an additional control for regeneration. A more important disadvantage is that, due to the high degree of selectivity obtainable with the regenerative stage, it is usually impossible to secure accurate enough tracking between its tuning circuit and the other tuning circuits in the receiver to make single-dial control feasible. Where single-dial control is desired, a small "trimmer" condenser is usually provided across the main r.f.-stage tuning condenser. By making this condenser operable from the front panel, it is possible to compensate manually for slight inaccuracies in the tracking. A further discussion of regenerative r.f. stages will be found under the section on superhetero-

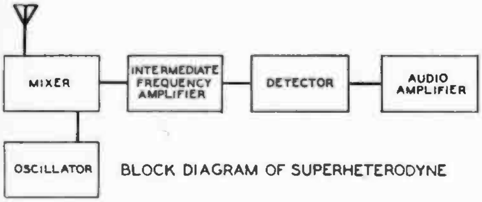


Figure 16.
THE ESSENTIAL PARTS OF A SUPERHETERODYNE RECEIVER.
There are several possible variations to this arrangement. Occasionally the i.f.-amplifier stages are omitted in simple superheterodynes. R.f.-amplifier stages are quite often used ahead of the mixer.

dyne receivers, in which connection they are most often used.

Audio Amplifiers

Nearly all radio receivers employ some kind of *audio amplification*. The audio amplifier stage or stages are usually of the class A type, although small class B stages are used in some receivers. The operation of both of these types of amplifier was described in *chapter 3*. The purpose of the audio amplifier is to bring the relatively weak signal from the detector up to a strength sufficient to operate a pair of headphones or a loud speaker. Either triodes, pentodes, or beam tetrodes may be used, the pentodes and beam tetrodes usually giving greater output. In some receivers it is possible to operate the headphones directly from the detector, without audio amplification. In such receivers a single audio stage with a beam tetrode or pentode tube is ordinarily used to drive the loud speaker. Several representative audio amplifier arrangements will be found in the following chapter.

THE SUPERREGENERATIVE RECEIVER

A special form of the regenerative receiver known as the *superregenerator* is quite popular for use at ultra-high frequencies when it is desired to keep cost and weight at a minimum. The superregenerator is essentially a regenerative receiver with a means provided to throw the detector rapidly in and out of oscillation. The frequency at which the detector is made to go in and out of oscillation varies in different receivers but is usually between 20,000 and 100,000 times a second. As a consequence of having the detector go in and out of oscillation at such a rapid rate, a loud hiss is present in the audio output when no signal is being received. This hiss diminishes in proportion to the strength of the signal being received, loud signals eliminating the hiss entirely.

Detector Operation

There are two systems in common use for causing the detector to break in and out of oscillation rapidly. In one a separate *interruption-frequency* oscillator is arranged so as to vary the plate voltage rapidly on one of the detector tube elements (usually the plate, sometimes the screen) at the high rate necessary. The interruption-frequency oscillator commonly uses a conventional tickler-feedback circuit with coils appropriate for the frequency at which it operates.

The second, and simplest, type of superregenerative detector circuit is arranged so as to produce its own interruption frequency oscillation, without the aid of a separate tube. The detector tube damps, or "quenches," itself out of signal-frequency oscillation at a high rate by virtue of the use of a high value of grid leak and proper size plate-blocking and grid condensers. In this type of "self-quenched" detector the grid leak is usually returned to the positive side of the power supply (through the coil) rather than to the cathode.

Both types of superregenerative detectors act as small transmitters and radiate broad, rough signals unless they are well shielded and preceded by an r.f. stage. For this reason they are not too highly recommended for use on frequencies below 60 Mc. However, there are occasionally cases where their use is justified on the 56-to-60 Mc. band. The superregenerative receiver tunes very broadly, receiving a band about 100 kc. wide. For this reason it has found wide use for the reception of unstable, modulated oscillators at ultra-high frequencies.

THE SUPERHETERODYNE

The *superheterodyne* type receiver is the most widely used form of receiver today. Because of its prominence in all fields of radio reception, every radio experimenter, whether he contemplates building a superheterodyne or not, should be thoroughly familiar with its principle of operation.

Superheterodyne Principle

In the superheterodyne a radio-frequency circuit is tuned to the frequency of the incoming signal and the signal across this circuit applied to a vacuum-tube mixer stage. In the mixer stage the signal is mixed with a steady signal generated in the receiver, with the result that a signal bearing all the modulation applied to the original *but of a frequency equal to the difference between the local oscillator and incoming signal frequencies* appears in the mixer output circuit. The output from the mixer stage is fed into a fixed-tune *intermediate-frequency amplifier,* where it is amplified and detected in the usual manner and passed on to the audio amplifier. Figure 16 shows a block diagram of the fundamental superheterodyne arrangement.

Advantages of the Superheterodyne

Practically all of the advantages of superheterodyne reception are directly attributable to the use of the fixed-tune intermediate-frequency (i.f.) amplifier. Since all signals are converted to the intermediate frequency, this section of the receiver may be designed for optimum selectivity and amplification without going into the extremely complicated tunable bandpass arrangements which would be necessary if the signal-frequency tuning circuits were designed to have a comparable degree of selectivity. High amplification is easily obtained in the intermediate-frequency amplifier, since it operates at a relatively low frequency, where conventional pentode-type tubes give a great deal of voltage gain. A typical i.f.-amplifier stage is shown in figure 17. Here it may be seen that both the grid and plate circuits are tuned. Tuning both circuits in this way is advantageous in two ways: it increases the selectivity, and it allows the tubes to work into a high-impedance resonant plate load, a very desirable condition where high gain is desired. The coil-and-condenser combinations used for coupling between i.f. stages are known as *i.f. transformers.* These will be more fully discussed later in this chapter.

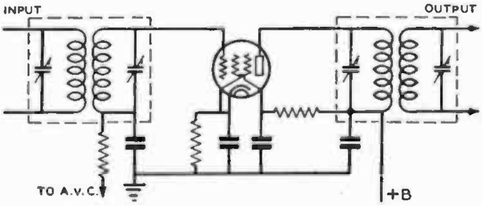


Figure 17.
TYPICAL INTERMEDIATE - FREQUENCY AMPLIFIER STAGE.
Pentodes such as the 58 or 6K7 are usually used as i.f.-amplifier tubes. For high-gain i.f. stages, the 1851, 1852 or 1853 types may be employed.

The choice of a frequency for the i.f. amplifier involves several considerations. One of these considerations is in the matter of selectivity; as a general rule, the lower the intermediate frequency the better the selectivity. On the other hand, a rather high intermediate frequency is desirable from the standpoint of *image* elimination. Images are a peculiarity common to all superheterodyne receivers, and for this reason they are given a detailed discussion later in this chapter.

While intermediate frequencies as low as 30 kc. were common at one time, and frequencies as high as 10,000 kc. are used in some specialized forms of receivers, most present-day communications superheterodynes nearly always use intermediate frequencies around either 456 kc. or 1600 kc. Two other frequencies which are encountered in broadcast receivers are 175 kc. and 262 kc.

Arithmetical Selectivity

Besides allowing the use of fixed-tune band-pass amplifier stages, the superheterodyne has an overwhelming advantage over the T.R.F. type of receiver because of what is commonly known as *arithmetical selectivity.*

This can best be illustrated by considering two receivers, one of the t.r.f. type and one of the superheterodyne type, both attempting to receive a desired signal at 10,000 kc. and eliminate a strong interfering signal at 10,010 kc. In the t.r.f. receiver, separating these two signals in the tuning circuits is practically impossible, since they differ in frequency by only 0.1 per cent. However, in a superheterodyne with an intermediate frequency of, for example, 1000 kc., the desired signal will be converted to a frequency of 1000 kc. and the interfering signal will be converted to a frequency of 1010 kc., both signals appearing at the input of the i.f. amplifier. In this case the two signals may be separated much more readily since they differ by 1 per cent, or ten times as much as in the first case.

Mixers

The heart of the superheterodyne is its *mixer.* No matter how much signal is applied to the mixer, if the signal is not converted and passed on to the i.f. amplifier it is lost. The tube manufacturers have released a large variety of special tubes for mixer applications and these, as well as improved circuits with older type tubes, have resulted in highly efficient mixer arrangements in present-day receivers.

Figure 18 shows several representative mixer-oscillator circuits. At A is illustrated control-grid *injection* from an electron-coupled oscillator to the mixer. The mixer tube for this type of circuit is usually a remote-cut-off pentode of the 57—6J7 type. The coupling condenser, C, between the oscillator and mixer is quite small, usually 1 or 2 $\mu\mu$fd.

This same circuit may be used with the oscillator output being taken from the oscillator grid or cathode. The only disadvantage to this method is that interlocking, or "pulling," between the mixer and oscillator tuning controls is liable to take place. A rather high value of cathode resistor (10,000 to 50,000 ohms) is used with this circuit.

Injection of oscillator voltage into mixer elements other than the control grid is illustrated by figures 18B, C, D and E. The circuit of 18B shows injection into the suppressor grid of the mixer tube. The suppressor is biased negatively by connecting it directly to the grid of the oscillator.

An alternative method of obtaining bias for the suppressor, and one which is less prone to cause interlocking between the oscillator and mixer is shown in figure 18C. In this circuit the suppressor bias is obtained by allowing the rectified suppressor-grid current to flow through a 50,000- or 100,000-ohm resistor to ground. The coupling condenser, C, for use with this circuit may be 50 or 100 $\mu\mu$fd., depending upon the frequency. As in the case of control-grid injection, the output from the oscillator may be taken from the cathode instead of the grid end of the coil, if sufficient oscillator output is available. Mixer cathode resistors having values between 500 and 5000 ohms are ordinarily used with these circuits.

The mixer circuit shown in figure 18D is similar in appearance to that of 18B. The difference in the two lies in the type of tube used as a mixer. The 6L7 shown in 18D is especially designed for mixer service. It has a separate, shielded *injector grid,* by means of which voltage from the oscillator may be injected. This circuit permits the same variations as the suppressor-injection system in regard to the method of connection into the oscillator circuit. The 6L7 requires rather high screen voltage and draws considerable screen current, and for these reasons the screen-dropping resistor is usually made around 10,000 or 15,000 ohms, which is considerably less than the value used with most other mixer tubes.

Figure 18E shows injection into the mixer screen grid. When connected in

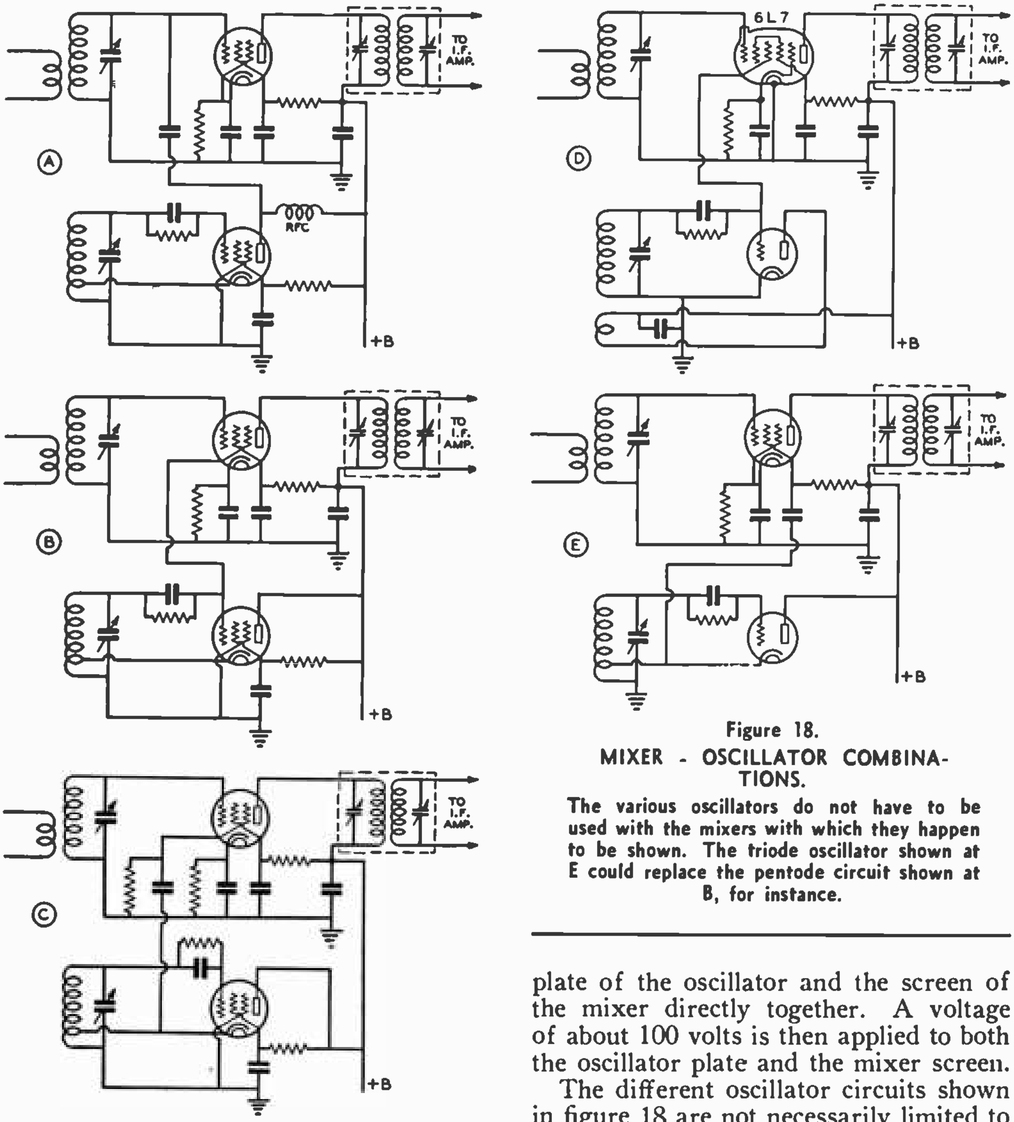


Figure 18.
MIXER - OSCILLATOR COMBINATIONS.
The various oscillators do not have to be used with the mixers with which they happen to be shown. The triode oscillator shown at E could replace the pentode circuit shown at B, for instance.

the manner shown, a rather large (.01-to-0.1 μfd.) coupling condenser may be used. This circuit is liable to cause rather bad pulling at high frequencies as there is no electrostatic shielding within the mixer tube between the screen grid and the control grid. A variation of this circuit in which the pulling effect is reduced considerably consists of using an electron-coupled oscillator circuit similar to that shown in 18A and connecting the plate of the oscillator and the screen of the mixer directly together. A voltage of about 100 volts is then applied to both the oscillator plate and the mixer screen.

The different oscillator circuits shown in figure 18 are not necessarily limited to use with the mixers with which they happen to be shown. Almost any oscillator arrangement may be used with any mixer circuit. Examples of some of the possible combinations will be found in the *Receiver Construction* chapter.

Combination Tubes

There is a series of *pentagrid converter* tubes available in which the functions of the oscillator and mixer are combined in a single tube. Typical of these tubes are the 6A7, 6A8, and 6SA7. The term *pentagrid* has been applied to these tubes because they have 5 grids, one of the extra grids being used as grid and the other as an anode for the oscillator section of the circuit. Suitable circuits for use with these tubes are shown in figure 19A, and 19B.

Another set of combination tubes known as *triode-heptodes* and *triode-hexodes* is also available for use as combination mixers and oscillators. These tubes are exemplified by the 6J8G and the 6K8; they get their name from the fact that they contain two separate sets of elements—a triode and a heptode in one case, and a triode and a hexode in the other. Representative circuits for both types of tube are shown at 19C and 19D.

Some of the combination mixer-oscillator tubes make exceptionally good mixers when their oscillator section is left unused and the oscillator-section grid is connected to a separate oscillator. The 6K8, 6J8G and 6SA7 perform particularly well when used in this manner. A circuit of this type for use with a 6K8 is shown in figure 20. The points marked "X" in figure 19 show the proper place to inject r.f. from a separate oscillator with the other combination type converter tubes. When the 6A7 and 6A8 types are used with a separate oscillator the unused oscillator anode-grid is connected directly to the screen.

Mixer Noise and Image Interference

Mixer noise and *images* are inherent faults common to all superheterodynes and, since difficulties arising from both types of trouble may be eliminated by the same remedy, they will be discussed together.

Mixer noise is a direct consequence of the process of frequency conversion. It is caused by shot noise within the mixer

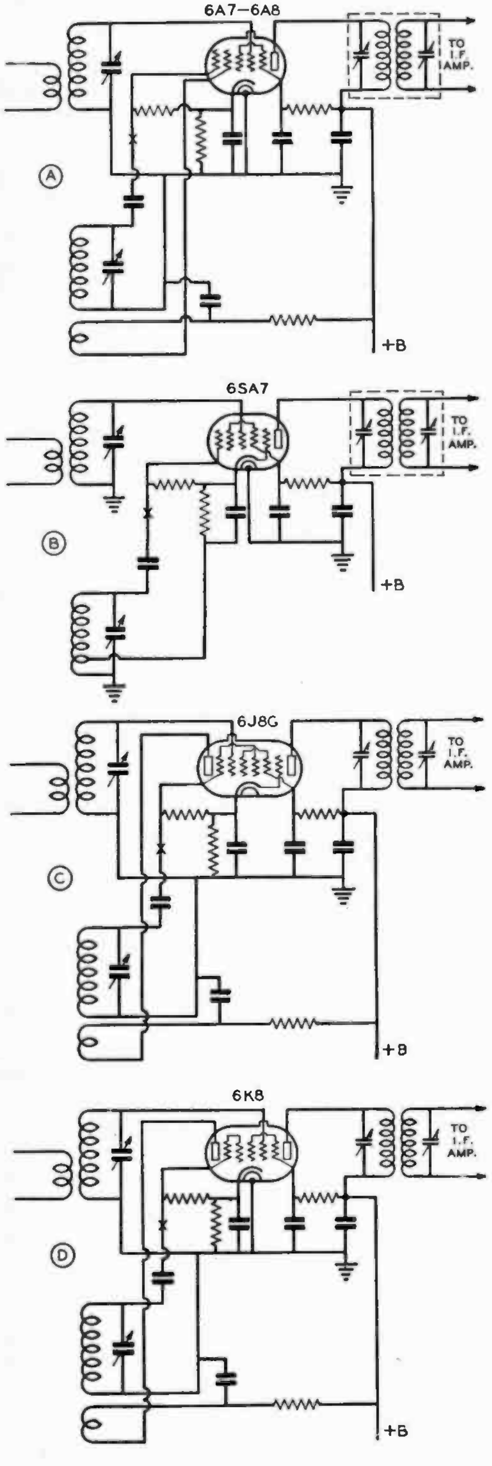


Figure 19.
CIRCUITS FOR COMBINED MIXER-OSCILLATOR TUBES.
A and B are for "pentagrid" tubes and C and D for "triode-heptode" and "triode-hexode" tubes.

tube in the same manner as tube hiss in ordinary amplifier stages. Mixer noise, however, is considerably stronger than tube hiss in an equivalent r.f. stage. While this noise cannot be eliminated, its effects can be greatly minimized by placing sufficient signal-frequency amplification ahead of the mixer, so that the noise is small in proportion to the signal. Increasing the gain after the mixer will be of little advantage in eliminating mixer noise; greater selectivity after the mixer will help to a certain extent but cannot be carried too far since this type of selectivity decreases the limits of bandpass and reduces the strength of the high-frequency components on modulated signals.

Images are also a result of frequency conversion. They are a result of the fact that there are two signal frequencies which will combine with a single oscillator frequency to produce the same difference frequency. For example: a superheterodyne with its oscillator operating on a higher frequency than the signal, which is common practice in present superheterodynes, is tuned to receive a signal at 14,100 kc. Assuming an i.f.-amplifier frequency of 450 kc., the mixer input circuit will be tuned to 14,100 kc. and the oscillator to 14,100 plus 450, or 14,550 kc. Now, a strong signal at the oscillator plus the intermediate frequency (14,550 plus 450, or 15,000 kc.) will also give a difference frequency of 450 kc. in the mixer output and will be received just as though it were actually on 14,100 kc., the frequency of the desired signal. The only way that the *image* could be eliminated in this particular case would be to make the selectivity of the mixer input circuit and any circuits preceding it great enough so that the 15,000-kc. signal would be eliminated with these circuits tuned to 14,100 kc.

For any particular intermediate frequency, image interference troubles become increasingly greater as the frequency to which the signal-frequency portion of the receiver is tuned is increased. This is due to the fact that the percentage difference between the desired frequency and the image frequency decreases as the receiver is tuned to a higher frequency. The ratio of strength between a signal at the image frequency and a signal at the frequency to which the receiver is tuned required to give equal output is known as the *image ratio.* The higher this ratio, the better the receiver in regard to image-interference troubles.

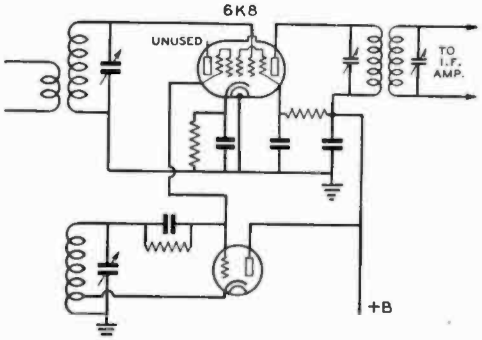


Figure 20.
USING A SEPARATE OSCILLATOR WITH A DUAL-PURPOSE CONVERTER TUBE.

A separate oscillator may also be connected into the mixer circuits shown in figure 19 at the points marked "X."

With but a single tuned circuit between the mixer grid and the antenna, and with 400-500 kc. i.f. amplifiers image ratios of one hundred and over are easily obtainable up to frequencies around 5000 kc. Above this frequency greater selectivity in the mixer grid circuit (through the use of regeneration) or additional tuned circuits between the mixer and the antenna are necessary if a good image ratio is to be maintained. An image is always *twice* the intermediate frequency away from the desired signal.

Since the necessary tuned circuits between the mixer and the antenna can be combined with tubes to form r.f. amplifier stages, the reduction of the effects of mixer noise and the increasing of the image ratio can be accomplished in a single section of the receiver. When incorporated in the receiver this section is known simply as an *r.f. amplifier;* when it is a separate unit with a separate dial it is known as a *preselector.* Either one or two stages may be used in the preselector or r.f. amplifier. Some single-stage preselectors and a few two-stage units use regeneration to obtain still greater amplification and selectivity.

Another method of reducing image-interference troubles is through the use of higher i.f. frequencies, resulting in a greater separation between the signal frequency and the image frequency. I.f. amplifiers operating on frequencies of 1500-1600 kc. are quite common in receivers operating up to 30,000 kc. For reception at still higher frequencies, intermediate frequencies as high as 10,000 kc. are sometimes employed.

Double Conversion

To give both good image ratio at the higher frequencies and good selectivity in the i.f. amplifier, a system known as *double conversion* is sometimes employed. In this system the incoming signal is first converted to a rather high intermediate frequency, such as 1600 kc., and then amplified and again converted, this time to a much lower frequency, such as 175 kc. The first i.f. frequency supplies the necessary wide separation between the image and the desired signal while the second one supplies the bulk of the i.f. selectivity. An example of a receiver employing this system will be found in *chapter 6.*

Regenerative Preselectors

R.f. amplifiers for wave-lengths down to 30 meters can be made to operate efficiently in a nonregenerative condition. Amplification and selectivity are ample over this range. For higher frequencies, on the other hand (wavelengths below 30 meters), *controlled regeneration* in the r.f. amplifier is often desirable for the purpose of increasing the gain and selectivity.

The input impedance of the grid circuit of a radio-frequency amplifier consists of a very high capacitive reactance which becomes part of the tuning capacity for longer wavelengths. However, in very short wave receivers the input reactance of a screen-grid tube may drop to very low values, such as a few thousand ohms. The input impedance then drops to such a low value that very little amplification can be secured from the complete r.f. amplifier stage.

A small amount of r.f. feedback can be introduced to compensate for this tube loss. Regeneration can be carried to the point of actually creating the effect of negative resistance in the tuned circuit, and thereby balancing the resistance introduced across the tuned circuit by the relatively low parallel tube resistance. Excessive regeneration will result in too much negative resistance, which will cause the r.f. amplifier to oscillate. Operation should always be below the point of self-oscillation.

As previously discussed, a disadvantage of the regenerative r.f. amplifier is the need for an additional regeneration control, and the difficulty of aligning this circuit with the following tuned r.f. stages. Resonant effects of antenna systems usually must be taken into account; a variable antenna coupling device can be used to compensate for this effect. Another disadvantage is the increase in hiss, or internal noise, in the r.f. amplifier.

The reason for using regeneration at the higher frequencies and not at the medium and low frequencies can be explained as follows: The signal to noise ratio (output signal) of the average r.f. amplifier is reduced slightly by the incorporation of regeneration, but the signal to noise ratio of the *receiver as a whole* is improved at the very high frequencies because of the extra gain provided ahead of the first detector, this extra gain tending to knock down the conversion and thermal agitation hiss in the first detector and the i.f. amplifier stages by allowing one to run them at reduced gain for a given receiver output.

Input Resistance

The input resistance of tubes used as r.f. amplifiers varies considerably with frequency. At broadcast frequencies the input resistance of most tubes is high enough so that it is not bothersome. As the frequency is increased, however, the input resistance becomes lower, and at frequencies above 25 Mc. it can become

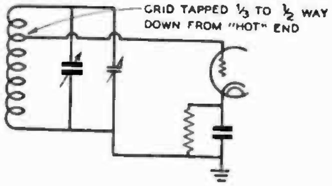


Figure 21.
CIRCUIT USED TO REDUCE GRID-LOADING EFFECTS.
Tapping the grid down on the coil in this manner increases gain and selectivity of high-transconductance tubes at high frequencies.

so low as to reduce greatly the voltage across the tuned circuit and broaden the resonance curve, resulting in a decrease in gain and a lower image ratio. These effects are particularly pronounced in the high-transconductance tubes such as the 1851 and 1852.

The difficulties presented by input-resistance effects may be partially obviated by tapping the grid down on the coil, as shown in figure 21. This circuit is commonly employed with high-transconductance tubes when operating on the 28-to-30 Mc. amateur band, and nearly always with such tubes on the 56-to-60 Mc. band. Acorn tubes, due to their smaller dimensions and lower capacities, are considerably better than the conventional types at ultra-high frequencies and it usually will not be found necessary to tap their grids down on the tuned circuit.

Bandpass Circuits

All i.f. amplifiers employ bandpass circuits of some sort. A bandpass circuit is exactly what the name implies—a circuit for passing a band of frequencies. Bandpass arrangements can be designed for almost any degree of selectivity, the type used in any particular application depending upon the use to which the i.f. amplifier is to be put.

Bandpass circuits consist essentially of two or more tuned circuits and some method of coupling the tuned circuits together. Some representative arrangements are shown in figure 22. The circuit shown at A is the conventional i.f. transformer with the mutual coupling, M, between the tuned circuits being provided by inductive coupling from one coil to the other. As the coupling is increased, the selectivity curve becomes less peaked, and when a condition of over-coupling is reached the top of the curve flattens out. When the coupling is increased still more, a dip occurs in the top of the selectivity curve. The windings for this type of i.f. transformer, as well as most others, nearly always consist of small, flat universal-wound pies mounted either on a piece of dowel to provide an air core or on powdered-iron impregnated bakelite for "iron core" i.f. transformers. The iron-core transformers generally have somewhat more gain

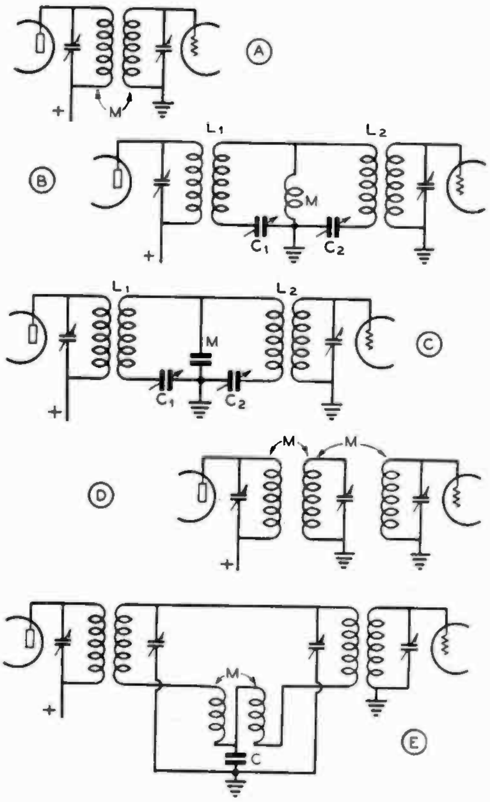


Figure 22.
BAND-PASS CIRCUITS FOR USE IN I.F. AMPLIFIERS.
The operation of the different circuits is discussed in the text.

and better selectivity than equivalent air-core units between 175 and 1500 kc.

The circuits shown at B and C are quite similar. Their only difference is the type of mutual coupling used, an inductance being used at B and a capacitance at C. The operation of both circuits is similar. Three resonant circuits are formed by the components. In B, for example, one resonant circuit is formed by L_1, C_1, C_2, and L_2 all in series. The frequency of this resonant circuit is just the same as that of a single one of the coils and condensers, since the coils and condensers are similar in both sides of the circuit and the resonant frequency of the two condensers and the two coils all in series is the same as that of a single coil and condenser. The second resonant frequency of the complete circuit is determined by the characteristics of each half of the circuit containing the mutual coupling device. In B, this second frequency will be lower than the first since the resonant frequency of L_1, C_1 and the inductance, M, or L_2, C_2 and M is lower than that of a single coil and condenser, due to the inductance of M being added to the circuit. The opposite effect takes place at C, where the common coupling impedance is a condenser. Thus at C the second resonant frequency is higher than the first. In either case, however, the circuit has two resonant frequencies, resulting in a flat-topped selectivity curve. The width of the top of the curve is controlled by the reactance of the mutual coupling component. As this reactance is increased (inductance made greater, capacity made smaller) the two resonant frequencies become farther apart and the curve is broadened.

The circuit of figure 22D is often used where a fairly high degree of bandpass action is required and the number of i.f. transformers used must be kept at a minimum. In this circuit there is inductive coupling between the center coil and each of the outer coils. The result of this arrangement is that the center coil acts as a sharply tuned coupler between the other two. A signal somewhat off the resonant frequency of the transformer will not induce as much voltage in the center coil as will a signal of the correct frequency. When a smaller voltage is induced in the center coil it in turn transfers a still smaller voltage to the output coil. In other words the coupling of the three coils increases as the resonant frequency is approached and remains nearly constant over a small range and then decreases again as the resonant band is passed.

Another very satisfactory bandpass arrangement which gives a very straight-sided, flat-topped curve is the negative-mutual arrangement shown at E. Energy is transferred between the input and output circuits in this arrangement by both the negative-mutual coils, M, and the common capacitive reactance, C. The negative-mutual coils are interwound on the same form and connected "backward," as shown.

Crystal Filters

The selectivity of an intermediate-frequency amplifier can be greatly increased by means of a quartz crystal filter. This results in a better signal to noise ratio, and is a very satisfactory means for obtaining a high degree of selectivity in the i.f. amplifier. The quartz crystal is placed in the i.f. amplifier circuit in such a way that it acts as a very sharply resonant filter which will pass only an extremely narrow band of frequencies. A simple crystal filter circuit is shown in figure 23.

The crystal functions as a series-resonant circuit having a very high Q. The capacity across the crystal holder is neutralized by means of the phasing con-

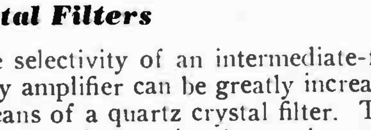


Figure 23.
SIMPLE CRYSTAL-FILTER CIRCUIT.
A quartz-crystal filter such as this will increase the selectivity of the intermediate-frequency amplifier.

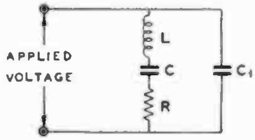


Figure 24.

EQUIVALENT CRYSTAL CIRCUIT.

The crystal is equivalent to a large inductance in series with a small capacitance and resistance.

denser and center-tapped tuning condenser or center-tapped input coil. The phasing condenser can also be made to change the selectivity characteristic of the filter circuit, and therefore this control always should be located on the front panel of the radio receiver.

By placing the phasing condenser in the circuit so that the voltage across it is out of phase with that across the crystal, the parallel resonance can be shifted above or below the series crystal resonance. Thus, the phasing condenser can be adjusted so that the parallel resonance causes a sharp dip in the response curve at some desired point, such as 2 kc. from the desired signal peak. This effect can be utilized to eliminate completely the unwanted sideband 1 kc. away from zero beat for c.w. reception. The b.f.o. then provides a true single signal effect, that is, a single beat frequency note. This effectively increases the number of c.w. channels that can be used in any short-wave band.

The circuit in figure 24 will illustrate the principle of operation of a quartz crystal filter. The quartz crystal may be compared to the equivalent electrical circuit shown, where C_1 is the capacity across the quartz plate when not vibrating, R is the resistance equivalent to the frictional effects of the vibrating crystal, L the inductance corresponding to the inertia and C the capacity corresponding to the elasticity. On one side of resonance, the circuit has capacitive reactance, due to the elastic forces which control the crystal vibrations, while on the other side of resonance the reactance is inductive because of the effects of inertia. The crystal vibrates freely at resonance, its amplitude being limited by the frictional effects at resonance. L and C are equal and opposite in reactance, the impedance is very low, and the resonant frequency is the same as the mechanical vibration mode.

A typical 451-kc. quartz crystal showed an equivalent inductance of 3.5 henrys and a series capacity of less than 0.1 $\mu\mu$fd. The effective Q may run as high as 10,000, which results in an extremely sharp resonant curve, not obtainable with ordinary condensers and coils. At frequencies slightly off-resonance, the series impedance is extremely high due to the minute series capacity C and enormous inductance L.

Other typical crystal filter circuits are shown in figures 25, 26, 27 and 28.

The ideal response curve for an i.f. amplifier in either a phone or c.w. receiver would be *flat-topped* and *straight-sided.* The pass band would be somewhat wider for phone, however, than for c.w. An ideal c.w. curve would have a 300- or 400-cycle flat top, while for phone the flat top for good intelligibility and maximum freedom from QRM would be 3000 or 4000 cycles wide. The phone *fidelity* would be impaired with this degree of selectivity because of the chopping off of the higher frequency sidebands, but the intelligibility would still be quite good in spite of the narrow pass band. The narrow pass band has the advantage of allowing one to discriminate between two stations quite close together in frequency without interference.

The type of series crystal filter commonly used in superheterodynes gives a

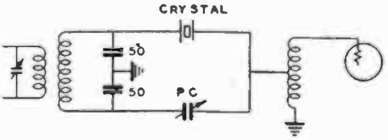


Figure 25.

A POPULAR CRYSTAL-FILTER ARRANGEMENT.

In this circuit a tapped output coil is used to provide a good impedance match between the crystal and the following grid.

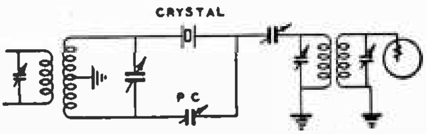


Figure 26.

ANOTHER POPULAR CRYSTAL-FILTER CIRCUIT.

The output coupling condenser in this circuit is usually a small (3-30 μμfd.) trimmer. A balanced input circuit may either be obtained by a center-tapped coil, as shown, or through the use of two condensers as shown in figure 25.

very narrow response curve at 456 or 465 kc. when set for maximum selectivity. Fortunately, however, the response curve can be altered by suitable circuits to make radiotelephone reception possible if some loss of sidebands can be tolerated. For c.w. reception, the maximum selectivity of the crystal will be found useful in many cases.

Variable-Selectivity Crystal Filters

There are several circuits for broadening the response characteristic of crystal filters. Two of these methods are shown in figures 27 and 28. Both methods consist of a circuit arrangement for introducing a resistance in series with the crystal, thereby lowering its Q and reducing the selectivity. In the circuit of figure 27 the selectivity is minimum with the crystal input circuit tuned to resonance, since at resonance the input circuit is a pure resistance effectively in series with the voltage applied to the crystal. As the input circuit is detuned from resonance, however, the resistive component of the input impedance decreases and the selectivity becomes greater. In this circuit, as in figure 25, the output from the crystal filter is tapped down on the i.f.-stage grid winding to provide a better match and lower the impedance in series with the crystal.

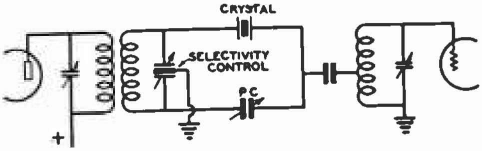


Figure 27.

VARIABLE-SELECTIVITY CRYSTAL CIRCUIT.

In this circuit the selectivity is minimum when the input circuit is tuned to resonance.

The circuit shown in figure 28 also achieves variable selectivity by adding an impedance in series with the crystal circuit. In this case the variable impedance is in series with the crystal output circuit. The impedance of the output tuned circuit is varied by varying the Q. As the Q is reduced (by adding resistance in series with the coil) the impedance decreases and the selectivity becomes greater.

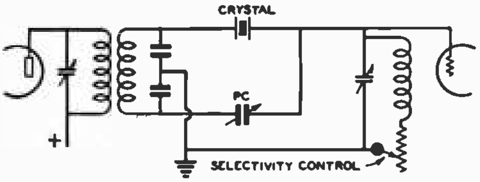


Figure 28.

A WIDE-RANGE VARIABLE-SELECTIVITY CRYSTAL CIRCUIT.

Variable selectivity is obtained by increasing or decreasing the Q of the output circuit.

1600-Kc. Crystal Filters

Since the selectivity of a series crystal resonator varies approximately directly with frequency, crystal filters for use with i.f. amplifiers in the 1500- to 1600-kc. range are approximately three times as broad as their maximum selectivity setting as 465-kc. crystal circuits. This is no great disadvantage, as a well-designed 1600-kc. filter may be made to have 300-cycle selectivity at its maximum setting. For radiotelephone reception the 1600-kc. filter actually is advantageous, because its minimum selectivity permits a much wider band than a 465-kc. unit. The wider available pass band allows the crystal to be left in the circuit at all times and the selectivity merely varied to suit the kind of recep-

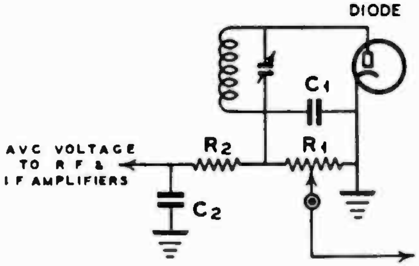


Figure 29.
TYPICAL DIODE A.V.C. CIRCUIT.
This circuit will be found in many superheterodynes. The diode also acts as a detector, audio voltage appearing across the volume control, R_1.

tion desired. Variable-selectivity circuits of the type shown in figure 27 require special consideration when used with 1600-kc. crystals, however. This is due to the fact that the capacity across the crystal holder, and consequently the capacity of the phasing condenser, is much higher, due to the thinner crystal required at 1600 kc.

As the phasing condenser and the crystal are actually in series across the input circuit and selectivity control, any change in setting of the phasing condenser will alter the selectivity. This difficulty may be eliminated by using a special form of phasing condenser which acts as a capacity potentiometer and maintains equal capacity across the input circuit and at the same time varies the capacity in the phasing branch.

Second Detectors

Second detectors for use in superheterodynes are usually of the diode, plate, or infinite impedance types, which were described in detail in *Chapter 3*. Occasionally, grid-leak detectors are used in receivers using one i.f. stage or none at all, when the second detector is regenerative. In terms of audio output, the various detectors line up as follows: 1st, grid-leak; 2nd, power; 3rd, infinite impedance; 4th, diode. The difference between the output of the diode and infinite-impedance types is very small, with the infinite-impedance having just a slight edge.

Diodes are the most popular second detectors because they allow a simple method of obtaining automatic volume control to be used. Diodes load the tuned circuit to which they are connected, however, and thus reduce the selectivity slightly. Special i.f. transformers are used for the purpose of providing a low-impedance input circuit to the diode detector.

Automatic Volume Control

An elementary circuit of an automatic volume control (a.v.c.) system is shown in figure 29. A diode tube is used as a rectifier of the carrier signal. The radio- (or intermediate) frequency circuit to the diode is completed through the small condenser C_1, which is too low in value to by-pass audio frequencies. The carrier signal is detected or rectified, and the resulting current flows through the diode circuit and the resistance R_1. This rectified current develops a voltage across R_1, which is more negative at the ungrounded end.

A simple R-C (resistance-capacity) filter in the form of R_2-C_2 may be connected to the diode circuit in order to utilize the d.c. voltage for automatic volume control purposes. The filter irons out the audio frequencies and also acts as a decoupling filter. The negative voltage developed across R_1 and C_2 has a value directly proportional to the incoming carrier signal. This voltage is used to bias the control grids of some of the r.f. and i.f. amplifier stages. An increased negative bias will reduce the amplification of the radio receiver so that a strong carrier, such as from a local broadcast station, furnishes approximately the same audio-frequency output signal as would be obtained from a distant broadcast station. Automatic volume control has the further advantage of maintaining the audio signal at a fairly constant level, even though the signal from a distant station may be fading or varying in amplitude.

A great many different circuits are used for obtaining a.v.c., and it is obviously impossible to show them all here. Essentially, most of these circuits consist

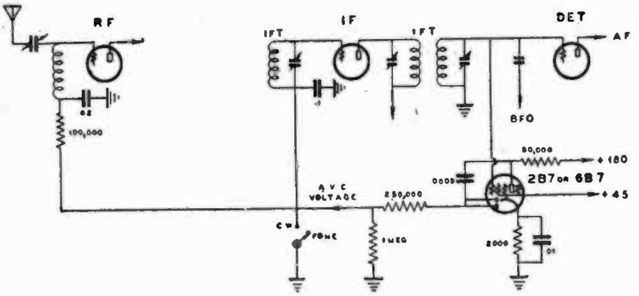


Figure 30.
A.V.C. CIRCUIT FOR ANY SUPERHETERODYNE.
This circuit may be added to a receiver not equipped with a.v.c. The 2B7 or 6B7 acts as an a.v.c. amplifier and diode rectifier.

of some kind of rectifier for rectifying the signal and using it for bias on the preceding stages or else some sort of an amplifier biased near the cutoff point which draws more current through a plate resistance when a signal is applied, the drop across the plate resistance being used in one of several possible ways to bias the amplifier stages.

Figure 30 shows a typical automatic volume control circuit which can be applied to almost any superheterodyne receiver.

The resistors and condensers in the various i.f. and r.f. grid-return circuits constitute a time-delay filter. The time constant of the a.v.c. circuit may be reduced by using smaller condensers or resistors or increased by using larger ones.

Signal-Strength Indicators

A visual means for determining whether or not the receiver is properly tuned, as well as an indication of the relative signal strength, are both provided by means of *tuning indicators* of the meter or vacuum-tube types. Direct current milliammeters can be connected in the plate return circuit of an r.f. amplifier as shown in figure 31 so that the change in plate current, due to the a.v.c. voltage which is supplied to that tube, will indicate proper tuning or *resonance.* Sometimes these d.c. meters are built in such a manner as to produce a shadow of varying width. Vacuum-tube tuning indicators are designed so that an electron-ray eye changes its relative size when the input circuit of the tube is connected across part of the d.c. component of the automatic volume control circuit. The basic circuit for this type of indicator is illustrated in figure 32.

Unfortunately, when a meter is used in the plate circuit of a stage for the purpose of indicating signal strength, the meter reads backward with respect to strength. This is caused by increased a.v.c. bias on stronger signals resulting in lowered plate current through the meter. For this reason special meters which indicate zero at the right-hand end of the scale are often used for signal strength indicators in this type of circuit. Alternatively, the meter may be mounted upside down so that the needle moves toward the right with increased signal strength.

A circuit which allows an ordinary meter to be used, and which gives con-

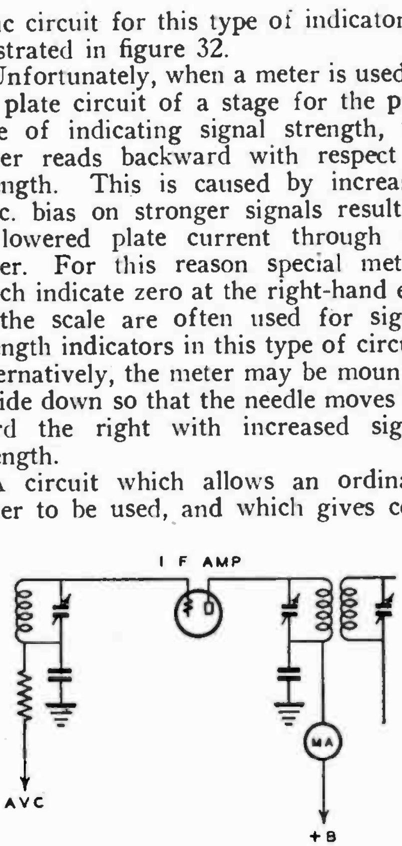


Figure 31.

A LOW-RANGE MILLIAMMETER MAY BE USED AS A TUNING OR SIGNAL-STRENGTH INDICATOR.
The plate current to an i.f. stage varies as the a.v.c. bias changes. A 0-10 d.c. milliammeter will serve in most cases. The meter reads "backward" in this circuit, strong signals causing the current to decrease more than weak ones

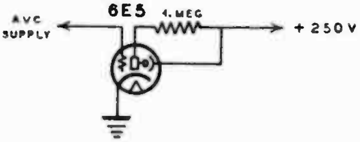


Figure 32.
ELECTRON-RAY TUNING INDICATOR.
Other "eye" tubes such as the 6N5, 6U5 and 6G5 may also be used in this circuit.

ventional right-hand movement of the needle with increased signal strength is shown in figure 33. The plate (or plate and screen) current to the stages receiving a.v.c. bias is fed through one-half of a bridge network. The meter, M, is usually a 0-1 milliammeter. The resistor values shown are average ones; it may be necessary to change them slightly, depending upon the number of stages drawing current through the network. Using a lower value at R will give greater "swing" for a given signal strength, while larger values will reduce the swing. The variable 1000-ohm resistor is used to set the meter for minimum indication when no signal is being received.

Beat-Frequency Oscillators

Beat frequency oscillators, usually called the *b.f.o.*, are a necessary adjunct for reception of c.w. telegraph signals on superheterodynes. The oscillator is coupled into the second detector circuit and supplies a weak signal of nearly the same frequency as that of the desired signal from the output of the i.f. amplifier. If the i.f. amplifier is tuned to 465 kc., for example, the b.f.o. is tuned to approximately 464 or 466 kc. in order to produce a 1000-cycle beat note in the output of the second detector of the superheterodyne. The carrier signal would otherwise be inaudible. The b.f.o. is not used for voice reception, except as an aid in searching for weak stations.

The b.f.o. input to the second detector need only be sufficient to give a good beat note on an average signal. Too much coupling into the second detector will give an excessively high hiss level, masking weak signals by the high noise background.

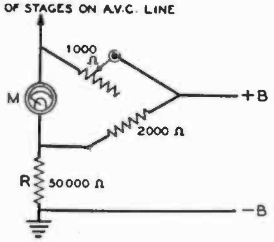


Figure 33.
FORWARD-READING SIGNAL METER CIRCUIT.
The meter, M, is usually a 0-1 d.c. milliammeter in this circuit.

A method of adjusting the b.f.o. output to correspond with the strength of received signals is shown in figure 34. A variable b.f.o. output control of this sort is a useful adjunct to any superheterodyne, since it allows sufficient b.f.o. output to be obtained to give a "beat" with strong signals and at the same time permits the b.f.o. output, and consequently the hiss, to be reduced when attempting to receive weak signals. The circuit shown is somewhat better than those in which one of the electrode voltages on the b.f.o. tube is changed, as the latter usually change the frequency of the b.f.o. at the same time they change the strength, making it necessary to reset the trimmer each time the output is adjusted.

In nearly all receivers in which both a.v.c. and a b.f.o. are used it is necessary to disconnect the a.v.c. circuit and manu-

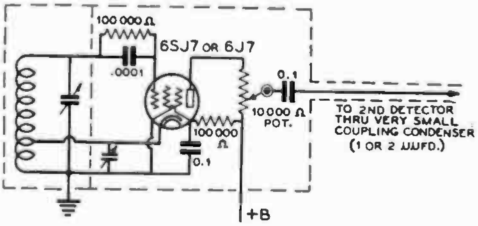


Figure 34.
VARIABLE-OUTPUT B.F.O. CIRCUIT.
Being able to vary the output of the b.f.o. is sometimes helpful when receiving weak signals.

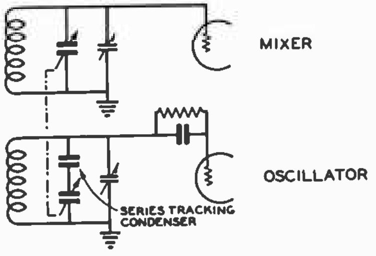


Figure 35.
SHOWING THE LOCATION OF THE SERIES TRACKING CONDENSER IN A SUPERHETERODYNE.
The series condenser allows the oscillator to tune at a slower rate than the mixer.

ally control the gain when the b.f.o. is turned on. This is because the b.f.o. acts exactly like a strong signal and puts a.v.c. bias on the stages on the a.v.c. line, thereby lowering the gain of the receiver.

Tracking in Superheterodynes

Because the detector (and r.f. stages, if any) and the oscillator operate on different frequencies in superheterodynes, in some cases it is necessary to make special provisions to allow the oscillator to track with the other tuned circuits when similar tuning condensers are used. The usual method of obtaining good tracking is to operate the oscillator on the high-frequency side of the mixer and use a series "tracking condenser" to slow down the tuning rate of the oscillator. The oscillator tuning rate must be slower because it covers a smaller range than does the mixer when both ranges are expressed as a percentage of frequency. At frequencies above 7000 k.c. and with ordinary i.f. frequencies, the difference in percentage between the two tuning ranges is so small that it may be disregarded in receivers designed to cover only a small range, such as an amateur band. A mixer and oscillator tuning arrangement in which a series tracking condenser is provided is shown in figure 35. The value of the tracking condenser varies considerably with different intermediate frequencies and tuning ranges, capacities as low as .0001 μfd. being used at the lower tuning-range frequencies, and values up to .01 μfd. being used at the higher frequencies.

Noise Suppression

The problem of noise suppression confronts the listener who is located in such places where interference from power lines, electrical appliances and automobile ignition systems is troublesome. This noise is often of such intensity as to swamp out signals from desired stations.

There are three principal methods for reducing this noise:

(1) A.c. line filters at the source of interference if the noise is created by an electrical appliance.
(2) Noise-balancing circuits for the reduction of power-leak interference.
(3) Noise-limiting circuits for the reduction, in the receiver itself, of interference of the type caused by automobile ignition systems.

Line Filters

Numerous household appliances, such as electric mixers, heating pads, vacuum sweepers, refrigerators, oil burners, sewing machines, doorbells, etc., create an interference of an intermittent nature. The insertion of a line filter near the source of interference often will effect a complete cure. Filters for small appliances can consist of a 0.1-μfd. condenser connected across the 110-volt a.c. line. Two condensers in series across the line, with the midpoint connected to ground, can be used in conjunction with ultra-violet ray machines, refrigerators, oil burner furnaces and other more stubborn offenders. In severe cases of interference, additional filters in the form of heavy-duty r.f. choke coils must be connected in series with the 110-volt a.c. line on both sides of the line.

Noise-Balancing Systems

Power line noise interference can be greatly reduced by the installation of a *noise-balancing* circuit ahead of the receiver, as shown in figure 36. The noise-balancing circuit adds the noise components from a separate noise antenna in such a manner that this noise antenna

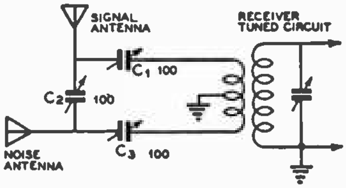


Figure 36.
JONES NOISE - BALANCING CIRCUIT.
This type of circuit reduces intensity of power leak and similar interference.

will buck the noise picked up by the regular receiving antenna. The noise antenna can consist of a connection to one side of the a.c. line, in some cases, while at other times an additional wire, 20 to 50 feet in length, can be run parallel to the a.c. house supply line. The noise antenna should pick up as much noise as possible in comparison with the amount of signal pickup. The regular receiving antenna should be a good-sized out-door antenna, so that the signal to noise ratio will be as high as possible. When the noise components are balanced out in the circuit ahead of the receiver, the signals will not be appreciably attenuated.

This type of noise balancing is not a simple process; it requires a bit of experimentation in order to obtain good results. However when proper adjustments have been made, it is possible to reduce the power leak noise from 3 to 5 R points without reducing the signal strength more than one R point, and in some cases there will be no reduction in signal strength whatsoever. This means that fairly weak signals can be received through terrific power leak interference. Hash type interference from electrical appliances can be reduced to a very low value by means of the same circuits.

The coil should be center-tapped and connected to the receiver ground connection in most cases. The pickup coil consists of four turns of hookup wire 2" in diameter which can be slipped over the first r.f. tuned coil in most radio receivers. A two-turn coil is more appropriate for 10- and 20-meter operation, though the four-turn coil is suitable if care is taken in adjusting the condensers to avoid 10-meter resonance (unless very loose inductive coupling is used).

Adjustment of C_1 will generally allow a noise balance to be obtained when varying C_2 and C_3 in nearly any location. One antenna, then the other, can be removed to check for noise in the receiver. When properly balanced, the usual power line buzz can be balanced down nearly to zero without attenuating the desired signal more than 50%. This may result in the reception of an intelligible distant signal through extremely bad power line noise. Sometimes an incorrect adjustment will result in balancing out the signal as well as the noise. A good high antenna for signal reception will ordinarily overcome this effect.

With this circuit some readjustment is necessary from band to band in the short-wave spectrum; noise-balancing systems require a good deal of patience and experimenting at each particular receiving location.

Noise-Limiting Circuits

Several different noise-limiting circuits have become popular. These circuits are beneficial in overcoming automobile ignition interference. They operate on the principle that each individual noise pulse is of very short duration, yet of extremely high amplitude. The popping or clicking type of noise from electrical ignition systems may produce a signal ten to twenty times as great as the incoming radio signal.

As the duration of this type of noise peak is short, the receiver can be made inoperative during the noise peak without the human ear detecting the total loss of signal. Some noise limiters, or eliminators, actually *punch a hole* in the signal, while others merely *limit* the maximum peak signal which reaches the headphones or loudspeaker.

The noise peak is of such short duration that it would not be objectionable except for the fact that it produces an overloading effect on the receiver, which increases its time constant. A sharp voltage peak will give a kick to the diaphragm of the headphones or speaker, and the momentum or inertia keeps the diaphragm in motion until the dampening of the diaphragm stops it. This movement produces a popping sound which may completely obliterate the desired signal. If the noise peak can be limited to an amplitude equal to that of the desired signal, the resulting interference is practically negligible, except in extreme cases.

A.F. Peak Limiters

Remarkably good noise suppression can be obtained in the audio amplifier of a radio receiver by using a delayed push-pull diode suppressor. Any twin diode tube can be used, though the type 84 high vacuum full-wave rectifier tube seems to be the most effective.

The circuit in figure 37 can be used to describe the operation of this general type of noise suppressor or limiter. Each diode works on opposite noise voltages; that is, both sides of the noise voltage (+ and − portions of the a.c. components) are applied to diodes which short-circuit the load whenever the applied voltage is greater than the delay voltage. The delay bias voltage prevents diode current from flowing for low-level audio voltages, and so the noise circuit has no effect on the desired signals except during the short interval of noise peaks. This interval is usually so short that the human ear will not notice a drop in signal during the small time that the load (headphones) is short-circuited by the diodes.

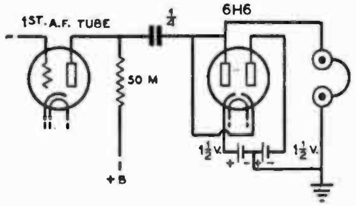


Figure 37.
A.F. PEAK LIMITER CIRCUIT.
This type of noise limiter is helpful in reducing short-duration noise pulses, such as automobile ignition interference.

Delay bias voltage of 1½ volts from a small flashlight cell will allow any signal voltage to operate the headphones which has a peak of less than about 1½ volts. Noise peaks often have values of from 5 to 20 times as great as the desired signal; so these peaks operate the diodes, causing current to flow and a sudden drop in impedance across the headphones.

Diodes have nearly infinite impedance when no diode current is flowing; however, as soon as current starts, the impedance will drop to a very few hundred ohms, which tends to damp out or short circuit the audio output. The final result is that the noise level from automobile ignition is limited to values no greater than the desired signal. This is low enough to cause no trouble in understanding the voice or c.w. signals.

It is necessary to use a push-pull diode circuit because the noise peaks are of an a.c. nature and are not symmetrical with respect to the zero a.c. voltage reference level. The negative peaks may be greater than the positive peaks, depending on the bias and overload characteristics of the audio amplifier tube. If a single diode is used, only the positive (or negative) peaks could be suppressed. In figure 37 the two bias dry-cells are arranged to place a negative bias on each diode plate of 1½ volts. A positive noise voltage peak at the plate of the audio amplifier tube will overcome this negative bias on the top diode plate and cause diode current to flow and lower the impedance. A negative noise voltage peak will overcome the positive bias on the other diode cathode and cause this diode to act as a noise suppressor. A positive bias on the cathode is the same as a negative bias on the diode plate. The 6H6 has two separate cathodes and plates, hence lends itself readily to the simple circuit illustrated in figure 37.

These circuits are very effective for noise elimination because they tend to punch a hole in the signal for the duration of a strong noise voltage peak. A peak that will cause a loudspeaker or headphones to rattle with a loud pop will be reduced to a faint pop by the noise-suppression system. The delay bias pre-

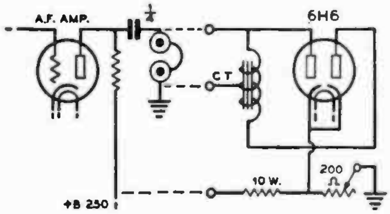


Figure 38.
ADJUSTABLE NOISE-LIMITING CIRCUIT.

In this circuit the bias on the limiting diodes may be adjusted for different noise levels. The center-tapped choke may be the primary of a small pentode output transformer.

vents any attenuation of the desired signal as long as the signal voltage is less than the bias.

With this type of noise limiter it is possible to adjust the audio or sensitivity gain controls so that the auto ignition QRM seems to drop out, leaving only the desired signal with a small amount of distortion. Lower gain settings will allow some noise to get through but will eliminate audio distortion on voice or music reception. At high levels the speech or music peaks will be attenuated whenever they exceed the d.c. delay bias voltage. Faint ignition rattle will always be audible in the background with any noise-suppressor circuit since some noise peaks are too small to operate the systems, yet are still audible as a weak rattle or series of pops in the headphones.

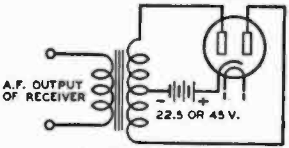
Figures 38 and 39 show two noise-limiter circuits which can be used as separate units for connection to any receiver. The unit shown in figure 38 can be connected across any headphone output as long as there is no d.c. current flowing through the latter. A blocking condenser can be connected in series with it if necessary, though better noise suppression results when the blocking condenser is in series with the plate lead to the headphones. Delay bias is obtained from the plus B supply through a 15,000-ohm 10-watt resistor and a 200-ohm wire-wound variable resistor. The cathode or cathodes are made a volt or so positive with respect to ground and minus B connection.

The diode plates are connected through a center-tapped low resistance choke to ground as far as bias voltage is concerned. Any push-pull to voice coil output transformer can be used for the center-tapped choke in figure 38. The secondary can be left open. The delay bias is adjustable from 0 up to about 3 volts and once set for some noise level, can be left in that position.

The unit illustrated in figure 39 can be connected across any audio amplifier stage, even the output stage which drives a loudspeaker. Any bias from 1½ to 90 volts or more can be connected in series with the center tap and 84 tube cathode. The higher values of delay bias would be needed for high output levels from the loudspeaker. Generally, 22½- to 45-volts bias will allow enough delay to allow moderate room volume reception of the desired voice signals without leveling off and distortion. As low a delay bias should be used as possible without distortion, in order to obtain effective noise suppression.

Noise Silencers for Connection Into I. F. Amplifier Circuits

Several noise-silencing or limiting circuits have been developed for connection into the i.f. or detector portions of a superheterodyne receiver. Tests conducted with a great many of these circuits have indicated that the one shown in figure 40 is among the most practical and desirable for use in amateur communications receivers. The noise-silencing ac-



SMALL CLASS B OUTPUT TRANS.
1:1 OR 2:1 RATIO
(PRIMARY & SECONDARY REVERSED)

Figure 39.
NOISE LIMITER FOR USE WITH LOUDSPEAKER.

The high bias on this noise limiter allows it to be used across high-level audio stages.

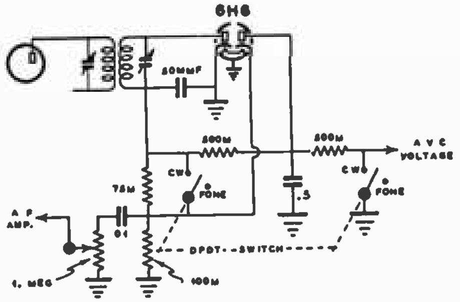


Figure 40.
AUTOMATIC NOISE SILENCER, DETECTOR AND A.V.C. SYSTEM.
This circuit places a low resistance across the audio output when noise peaks occur.

tion is entirely automatic and does not require readjustment for each incoming signal.

A double-diode, such as a 6H6, or two separate tubes are necessary for second detector and noise-suppression tubes. One diode acts as a second detector and a.v.c. tube, the other being connected across it as a noise-suppression tube. The principle of operation is as follows: The incoming carrier signal will build up a certain value of a.v.c. voltage across the 75,000- and 100,000-ohm resistors in the detector diode. The plate of the noise diode is connected across these two resistors, as well as the cathode of the noise diode. The plate of the noise diode will remain at the average potential developed by the a.v.c. voltage due to the carrier signal. The time constant of the ½-megohm resistor and ½-μfd. condenser in the noise diode plate circuit will not follow the short pulse period of a noise signal. This noise pulse will act upon the cathode of the noise diode due to the very short time constant in that circuit. The noise peak causes the cathode to be more negative than the plate, so that the noise diode conducts current and drops to a very low impedance value. This effectively short-circuits the audio-frequency output for the duration of the noise pulse. Thus, it can be seen that this noise silencer will operate very effectively on noise pulses of short time duration, such as ignition noise, without destroying the intelligibility of the desired signal. However, in the case of a power leak which produces a more or less constant noise voltage, the signal would be blocked out for so great a time that it would be unintelligible.

The noise silencer shown in figure 40 can be used for either phone or c.w. reception, but is most effective for the latter. The noise diode for phone reception must be set so that it will not operate for noise pulses of an amplitude less than twice that of the incoming carrier signal; for c.w., the device can be made to operate for any noise pulse of greater intensity than the c.w. carrier. The changeover from phone to c.w. is accomplished by short-circuiting the 75,000-ohm resistor. This operation can be accomplished by means of a single-pole single-throw switch, or, if desired, by a double-pole single-throw switch, in which case the automatic volume control can simultaneously be cut off for c.w. reception.

Practical applications of various modifications of the noise limiters described in this chapter will be found in the following chapter on receiver construction.

A more detailed and comprehensive discussion of noise balancing and noise limiting systems will be found in the RADIO *Noise Reduction Handbook.*

RECEIVER ADJUSTMENT

Good results can only be obtained from a radio receiver when it is properly aligned and adjusted. The most practical technique for making these adjustments is given in the following discussion.

The simplest type of regenerative receiver requires little adjustment other than those necessary to insure correct tuning and smooth regeneration over some desired range. Receivers of the tuned radio-frequency type and superheterodynes require precise alignment to obtain the highest possible degree of selectivity and sensitivity.

Test Instruments

A very small number of instruments will suffice to check and align any multitube receiver, the most important of these testing units being a modulated oscillator and a d.c. and a.c. voltmeter. The meters are essential in checking the voltage applied at *each* circuit point from the power supply. If the a.c. voltmeter is of the oxide-rectifier type, it can be used, in addition, as an output meter when connected across the receiver output when tuning to a modulated signal. If the signal is a steady tone, such as from a test oscillator, the output meter will indicate the value of the detected signal. In this manner, lineup adjustments may be visually noted on the meter rather than by increases or decreases of sound intensity as detected by ear.

Tuned R. F. Receiver Alignment

The alignment procedure in a multistage r.f. receiver is exactly the same as aligning a single stage. If the detector is regenerative, each preceding stage is successively aligned while keeping the detector circuit tuned to the test signal, the latter being a station signal or one locally generated by a test oscillator loosely coupled to the antenna lead. During these adjustments, the r.f. amplifier gain control is adjusted for maximum sensitivity, assuming that the r.f. amplifier is stable and does not oscillate. Oscillation is indicative of improper by-passing or shielding. Often a sensitive receiver can be roughly aligned by tuning for maximum noise pickup, such as parasitic oscillations originating from static or electrical machinery.

SUPERHETERODYNE ALIGNMENT

Aligning a superhet is a detailed task requiring a great amount of care and patience. It should never be undertaken without a thorough understanding of the involved job to be done and then only when there is abundant time to devote to the operation. There are no short cuts; every circuit must be adjusted individually and accurately if the receiver is to give peak performance. The precision of each adjustment is dependent upon the accuracy with which the preceding one was made.

Superhet alignment requires (1) a good signal generator (modulated oscillator) covering the radio and intermediate frequencies and equipped with an attenuator and B-plus switch; (2) the necessary socket wrenches, screwdrivers, or "neutralizing tools" to adjust the various i.f. and r.f. trimmer condensers, and (3) some convenient type of tuning indicator, such as a copper-oxide or electronic voltmeter.

Throughout the alignment process, unless specifically stated otherwise, the a.f. and r.f. gain controls must be set for maximum output, the beat oscillator switched off, the R-meter cut out, the crystal filter set for minimum selectivity and the a.v.c. turned off. If no provision is made for a.v.c. switching, the signal generator output must be reduced to the proper level by means of the attenuator. When the signal output of the receiver is excessive, either the attenuator or the a.f. gain control may be turned down, but never the r.f. gain control.

I.F. Alignment

After the receiver has been given a rigid electrical and mechanical inspection and any faults which may have been found in wiring or the selection and assembly of parts corrected, the i.f. amplifier may be aligned as the first step in the checking operations.

The coils for the r.f. (if any), first detector and high-frequency oscillator stages must be in place. It is immaterial which coils are inserted, since they will serve during the i.f. alignment only to prevent open-grid oscillation. However, in order to save a changeover operation, it is suggested that those covering the lowest-frequency band be used, since they will be the first ones tackled in the front-end alignment.

With the signal generator set for a modulated signal on the frequency at which the i.f. amplifier is to operate, clip the output leads from the generator to the last i.f. stage; "hot" end to the control grid, "cold" end to the receiver ground. Adjust both trimmer condensers in the last i.f. transformer (C_5 and C_6 in figure 42) to resonance as indicated by signal peak in the headphones or speaker and maximum deflection of the output meter.

Each i.f. stage is adjusted in the same manner, moving the hot lead, stage by stage, back toward the front end of the receiver and backing off the attenuator as the signal strength increases in each new position. The last adjustment will be made to the first i.f. transformer with the hot lead connected to the control grid of the first detector. Occasionally, it is necessary to disconnect the 1st detector grid lead from the coil, grounding it through a 1,000- or 5,000-ohm grid leak and coupling the signal generator through a small capacitance to the grid.

When the last i.f. adjustment has been completed, it is good practice to go back through the i.f. channel, re-peaking all of the transformers. It is imperative that this recheck be made in sets which do not include a crystal filter and where necessarily the simple alignment of the i.f. amplifier to the generator is final.

I. F. With Crystal Filter

There are several ways of aligning an i.f. channel which contains a crystal-filter circuit. However, the following method is one which has been found to give satisfactory results in every case:

If the i.f. channel is known to be far out of alignment or if the initial alignment of a new receiver is being attempted, the crystal itself should first be used to control the frequency of a test oscillator. The circuit shown in figure 41 can be used. A winding from an i.f. transformer can be used for the plate inductance. If none is handy, a b.f.o. coil can be used as shown in the diagram. In either case, it is necessary to disconnect the trimmer across the winding unless it has sufficient maximum capacity to be used in place of the 350-$\mu\mu$fd. tuning condenser indicated in the diagram.

A milliammeter inserted in the plate circuit will indicate oscillation, the plate current dipping as the condenser tunes the inductance to the resonant frequency of the crystal. Some crystals will require additional grid-plate capacity for oscillation; if so, a 30-$\mu\mu$fd. mica trimmer may be connected from plate to grid of the oscillator tube. The oscillator is then used as a line-up oscillator as described in the preceding section by using a.c. for plate supply instead of batteries. The a.c. plate supply gives a modulated signal suitable for the lining-up process.

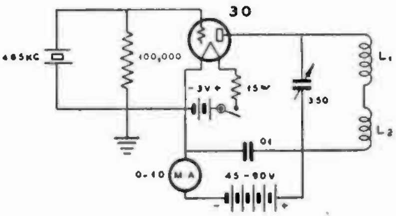


Figure 41.

TEST OSCILLATOR CIRCUIT.
This oscillator can be used for rough alignment of receivers using a crystal filter.

The crystal should then be replaced in the receiver and the phasing condenser set at the "phased" setting, if this is known. If the proper setting of the phasing condenser is unknown it can be set at half capacity for the preliminary line-up. Next, a signal generator should be connected across the mixer grid and ground and, with the receiver's a.v.c. circuit operating and the beat oscillator turned "off," the signal generator slowly tuned across the i.f. amplifier frequency.

As the generator is tuned through the crystal frequency, the receiver's signal strength meter will give a sudden kick. Should the receiver not be provided with a signal-strength meter, a vacuum-tube voltmeter, such as shown in *chapter 18*, can be connected across the a.v.c. line; if the receiver has neither a.v.c. nor a tuning meter, the vacuum-tube voltmeter may be connected between the second detector grid and ground. In any case a kick of either the tuning meter or the vacuum-tube voltmeter will indicate crystal resonance. It is quite probable that more than one resonance point will be found if the receiver is far out of alignment. The additional points of resonance are spurious crystal peaks; the strongest peak should be chosen and the signal generator left tuned to this frequency.

The phasing condenser should next be adjusted for *minimum* hiss or noise in the receiver output and the selectivity control, if any is provided, set for maximum selectivity. From this point on, the alignment of the i.f. amplifier follows conventional practice, except that the a.v.c. circuit is used as an alignment indicator, each circuit being adjusted for maximum output. If the receiver is of the type having no a.v.c. or tuning indicator, and the vacuum-tube voltmeter must be connected across the second-detector grid circuit, it will be necessary to remove the vacuum-tube voltmeter and make the final adjustment on the last i.f. transformer by ear after the other transformers have been aligned.

B. F. O. Adjustment

Adjusting the beat oscillator is relatively simple. It is only necessary to tune the receiver to resonance with any signal, as indicated by the tuning indicator, and then turn on the b.f.o. and set its trimmer (or trimmers) to produce the desired beat note. Setting the beat oscillator in this way will result in the beat note being stronger on one "side" of the signal than on the other, which is what is desired for maximum selectivity. The b.f.o. should *not* be set to "zero beat" with the receiver tuned to resonance with the signal as this will cause an equally strong beat to be obtained on both sides or resonance.

Front-End Alignment

Before the front-end alignment is begun, inspect the tuning condenser sections for good "fitting." All the plates must be made perfectly parallel throughout the tuning range if the set is to possess uniform sensitivity throughout the tuning ranges and if ganging operations are to be facilitated.

Alignment of the front end begins with the high-frequency oscillator. Insert the lowest frequency coils (160- or 80-meter range in ham receivers) and set the main tuning dial to the point where it is desired to have the highest frequency in the band fall. Couple the signal generator to the antenna input and provide an unmodulated signal on the high-frequency band limit of the low-frequency band. (2000 or 4000 kc. as the case may be.)

Next adjust the parallel trimmer of the h.f. oscillator coil (C_5, figure 43) slowly from maximum capacity until the generator signal is picked up. Two separate signals will be encountered; one at the high-capacity (low-frequency) setting of the trimmer, the other near the low-capacity (high-frequency) setting. The desired signal is the highest frequency one, since the h.f. oscillator is to be operated at a higher frequency than the incoming signal. The lower frequency signal represents the image setting. This is occasioned by the fact that two settings of the h.f. oscillator will provide signals which will beat with the incoming signal to produce a third signal on the intermediate frequency. The frequency of the first setting is numerically equal to the intermediate frequency plus the frequency of the incoming signal; the other to the intermediate frequency minus the signal frequency. When one or more efficient r.f. stages are employed ahead of the first detector, the image will usually be attenuated sufficiently to make it readily distinguishable from the real signal.

When the h.f. oscillator has been set to the high-frequency signal, the generator is switched off by opening its B-plus switch and the other stages, starting with the 1st detector, are peaked at the same setting of the tuning dial by adjusting the parallel trimmers (as C_2, figure 43) for peak in the background noise. If the receiver has no r.f. stages, the background noise due to thermal agitation in the front-end tubes may not be loud enough for the purpose, and a modulated signal will be necessary for detector trimmer adjustments. The trimmer is then set for signal peak.

In setting the detector and r.f. trimmers it is possible, as in the case of the h.f. oscillator, to select the image setting. The real signal is the low-frequency (high-capacity) one in this case, since the detector and r.f. stages are to operate at a lower frequency than the h.f. oscillator.

If the adjustments have been made by means of set noise, the unmodulated signal is again supplied and the h.f. oscillator setting rechecked. There should not be enough interaction between the h.f. oscillator and other front-end stages on 160, 80 and 40 meters to shift the oscillator setting when making detector or r.f. adjustments. Interlocking is violent on some receivers on 10 and 20 meters, however, and the recheck is apt to show that the signal has been displaced several dial divisions during the detector-r.f. adjustments. If the signal is found to be displaced, it is necessary to reset the h.f. oscillator and detector-r.f. circuits and in turn to recheck the oscillator, repeating the process until the outfit settles down.

After the front-end circuits have been set at the high-frequency end of the band, the generator is adjusted for an unmodulated signal on the lowest frequency in the band and the receiver is tuned to locate this signal. With "all-wave" type receivers it is a matter of good fortune when this signal is tuned in at the desired point on the dial. Almost invariably it will be located many dial divisions above or below the proper reading, sometimes off the low end of the dial entirely. In receivers designed only for the amateur bands, the band edges will usually be properly located.

If the signal is below the desired point, the capacitance of the series padder (C_3, figure 43) must be increased. Conversely, if it is above the desired point, the capacitance must be decreased. Whichever the case, the signal must be carried to the other side of the desired point (by cut-and-try adjustment of C_3), a distance equal to the same number of dial divisions by which it is already displaced and then retuned at the proper dial setting by adjusting C_5.

For example, suppose the 4000-kc. end of the 80-meter band has been set and 3500, which should fall on 10 on the dial, is found at 15. The signal is five divisions higher than desired, so the capacitance of C_3 is decreased progressively until 3500 is tuned in at 5, or five divisions on the opposite side of the desired dial reading. Then with the dial set at 10, 3500 is retuned by adjusting C_5.

Whenever any adjustment is made to any circuit at the low-frequency end of the band, it is necessary to readjust the circuit at the high-frequency end. So, after making the low-frequency band-setting adjustment explained in the foregoing, it is necessary to reset C_5 to the high-frequency signal with the set tuned to the high-frequency band limit. It will then be necessary to return to the low-frequency end, repeating the adjustments to series and parallel padder condensers there, repeating the process until the high- and low-frequency band limits coincide with the desired points on the dial.

After the h.f. oscillator has been set according to the foregoing directions, the generator is switched off and the detector-r.f. sections checked for tracking as follows. If the circuits contain only parallel trimmers (as C_2, figure 43) and these have, of course, already been set at the high-frequency end of the band, the set is tuned to the low-frequency end of the band and each circuit checked by pulling out and pressing in the outside plates of the individual tuning condenser sections, noting in which direction the plates must be moved in order to bring up the background noise or modulated signal to a sharply defined peak. If the plates must be moved only slightly, they are bent permanently to give the required separation. Drastic bending is to be avoided, however. If more than one eighth of an inch bend is required in any section, the corresponding coil should be pruned as indicated rather than produce an unsightly bend in the condenser plate. If increasing the capacitance of the condenser (pushing the plates together) brings up the peak, the inductance of

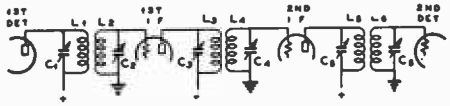


Figure 42.

REPRESENTATIVE I.F.-AMPLIFIER CIRCUIT.

the coil must be increased. Decreasing the capacitance (pulling plates apart) indicates that the inductance of the coil must be decreased. These operations are purely cut and try and require a great deal of patience.

If the only low-frequency adjustment has been gentle plate-bending, readjustment at the high-frequency end is not necessary. But if the coil inductance has been altered, the corresponding parallel trimmer must be readjusted at the high-frequency end of the band.

Even though the high-frequency oscillator and the detector and r.f. stages have been set at both ends, intermediate points throughout the tuning range may be considerably out of gang. Both oscillator and detector-f.f. sections must be checked at several points throughout the tuning range of the condenser, bending the plates as the test indicates. When bending the outside plates in the vicinity of the band limits, care must be exercised to prevent shifting the high- and low-frequency settings made previously. If the band-limit signal positions are inadvertently shifted, bending the condenser plates outward will recover a signal that has wandered up the dial; bending the plates inward will recover one that has gone down the dial. This bending must be done at dial settings for the band limits.

If the detector and r.f. stages contain series padders, arranged as the oscillator section in figure 43, they are adjusted with the parallel padders as explained in the section on h.f. oscillator adjustments. It must be borne in mind, however, that the series padded adjustments merely set the bandwidth, and plates must still be bent to insure tracking at the intermediate points throughout the range.

Perfect Tracking

Perfect tracking is evidenced by a uniform level in the background noise as the set is tuned through any waveband. If the end plates of any condenser section are bent gently in either direction in a well-tracked front end, the background noise level should decrease.

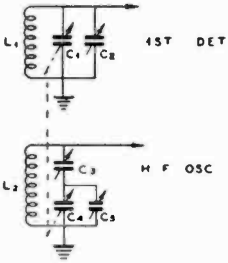


Figure 43.
SUPERHETERODYNE MIXER AND OSCILLATOR TUNING CIRCUITS.
In some cases the series padder, C_3, is not used. An example of that type of circuit is shown in figure 45.

Condenser plates are bent only on the lowest frequency coil range. With the other coils, band limits are set in the same manner and tracking tests made by gently testing with the condenser end plates, but the indicated adjustments are made to corresponding coils rather than to condensers. How well the higher frequency coils can be made to fall in line by careful pruning of their inductance values depends upon the efficacy of the ganging job on the lowest frequency range.

A. V. C. Checking

The automatic volume control system is checked by picking up a modulated signal with a.v.c. switched off and running the r.f. gain control to a point where the receiver blocks. Switching on the a.v.c. should relieve this blocking.

Multiband Receivers

Individual coils in multiband receivers with coil switching arrangements or plug-in coils must have small trimmer condensers shunted across the inductive circuits, as shown in figure 44. This allows fairly accurate alignment in each band by following the procedure previously outlined. In assembling a superheterodyne, the labor of checking is rather long and tedious since each coil must have *exactly* the correct inductance because bending the main tuning condenser plates would unbalance or misalign all other coils.

Unfortunately, in receivers incorporating coil switching arrangements, it is practically impossible to obtain *accurate* circuit alignment on *all* coils. Many commercially built receivers use two stages of r.f. ahead of the first detector, tuned rather broadly in order to overcome this

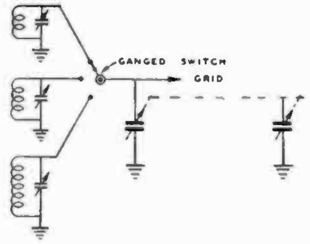


Figure 44.

TYPE OF TUNED CIRCUIT USED WITH COIL-SWITCHING RECEIVERS.

Separate trimmer condensers are used across each coil so that the proper L/C ratio may be maintained on each band.

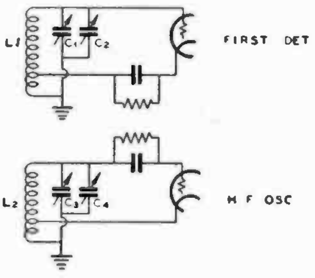


Figure 45.

REGENERATIVE TUNING ARRANGEMENT.

When the receiver covers only a narrow band, the oscillator series padding condenser may be dispensed with.

defect and obtain better signal to noise and image ratios.

The foregoing applies to the *all-wave* communications receivers and not to bandswitching or plug-in coil receivers designed to cover only the relatively narrow amateur bands; tracking is not such a problem in the latter type receivers.

If either the r.f. stage or first detector is regenerative, it must track closely with the h.f. oscillator. This type of circuit is shown in figure 45 where C_1 and C_3 are approximately 25-$\mu\mu$fd. ganged tuning condensers on the main tuning dial, and C_2 and C_4 are bandsetting condensers of 100 to 140 $\mu\mu$fd. In this instance, C_2 can be used as a panel-operated trimmer condenser to hold the circuits exactly in line at high degrees of regeneration. The series padding condenser C_3 of figure 43 is not required in this class of receiver due to the very narrow band tuning range of C_1 and C_3. The coil turns on L_1 and L_2 can be adjusted so that at random settings of C_2 and C_4 they will give practically perfect alignment. Varying the coil turns and spacing between turns will insure good tracking throughout all the amateur bands with the possible exception of the 160-meter band. This form of receiver invariably uses plug-in coils which first must be adjusted properly, the turns then being cemented in place.

Notes

When lining up a receiver which has automatic volume control (a.v.c.), it is considered good practice to keep the test oscillator signal near the threshold sensitivity at all times to give the effect of a very weak signal relative to the audio amplifier output with the audio gain control on maximum setting.

In checking over a receiver, certain troubles are often difficult to locate. By making voltage or continuity tests, blown-out condensers, or burned-out resistors, coils or transformers may usually be located. Oscillators are usually checked by means of a d.c. voltmeter connected from ground to screen or plate-return circuits. Short-circuiting the tuning condenser plates usually should produce a change in voltmeter reading. A vacuum-tube-type voltmeter is very handy for the purpose of measuring the correct amount of oscillator r.f. voltage supplied to the first detector circuit. The proper value of the r.f. voltage is approximately one volt less than the fixed grid bias on the first detector when the voltage is introduced into either the grid or the cathode circuit.

Incorrect voltages, poor resistors or leaky by-pass or blocking condensers will ruin the audio tone of the receiver. Defective tubes can be checked in a tube tester. Loud-speaker rattle is not always a defect in the voice coil or spider support, or metallic filings in its air gap; more often the distortion is caused by overloading the audio amplifier. An i.f. amplifier can also impair splendid tone due to a defective tube or overloading.

FIVE

Radio Receiver Tube Characteristics

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TYPES OOA TO 1F5G, INCLUSIVE

Characteristics for Types 1A7-GT, 1D8-GT are shown on Page 127

TYPE	NAME	DIMENSIONS SOCKET CONNECTIONS		CATHODE TYPE AND RATING			USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY	GRID BIAS ■	SCREEN SUPPLY	SCREEN CURRENT	PLATE CURRENT	A-C PLATE RESISTANCE	TRANSCONDUCTANCE (GRID-PLATE)	AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT	POWER OUTPUT	TYPE
		DIMEN.	S. C.	C. T.	VOLTS	AMP.		VOLTS	VOLTS	VOLTS	MA.	MA.	OHMS	µMHOS		OHMS	WATTS	
00-A	DETECTOR TRIODE	D12	4D	D.C. F	5.0	0.25	GRID-LEAK DETECTOR	45	Grid Return to (−) Filament			1.5	30000	666	20	—	—	00-A
01-A	DETECTOR★ AMPLIFIER	D12	4D	D.C. F	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
0A4-G	GAS-TRIODE	D3	G-4V	Cold	—	—	RELAY SERVICE	Peak Cathode Current, 100 max. ma. D-C Cathode Current, 25 max. ma. Starter-Anode Drop, 60 approx. volts. Anode Drop, 70 approx. volts.										0A4-G
0Z4	FULL-WAVE GAS RECTIFIER	B3	4R	Cold	—	—	RECTIFIER	Starting-Supply Voltage per Plate, 300 min. peak volts. Peak Plate Current, 200 max. ma. D-C Output Current, 75 max., 30 min. ma. D-C Output Voltage, 300 max. volts.										0Z4
0Z4-G	FULL-WAVE GAS RECTIFIER	B1	G-4R ◆	Cold	—	—	RECTIFIER											0Z4-G
1A4-P	SUPER-CONTROL R-F AMPLIFIER PENTODE	D9	4M	D.C. F	2.0	0.06	AMPLIFIER	For other characteristics, refer to Type 1D5-GP.										1A4-P
1A5-G	POWER AMPLIFIER PENTODE	D1	G-6X	D.C. F	1.4	0.05	CLASS A AMPLIFIER	85 90	− 4.5 − 4.5	85 90	0.7 0.8	3.5 4.0	300000 300000	800 850	240 255	25000 25000	0.100 0.115	1A5-G
1A6	PENTAGRID CONVERTER ○	D9	6L	D.C. F	2.0	0.06	CONVERTER	For other characteristics, refer to Type 1D7-G.										1A6
1A7-G	PENTAGRID CONVERTER ○	D8	G-7Z	D.C. F	1.4	0.05	CONVERTER	90	0	45♣	0.6	0.55	600000	Anode-Grid (#2): 90 max. volts, 1.2 ma. Oscillator-Grid (#1) Resistor, 0.2 meg. Conversion Conductance, 250 micromhos.				1A7-G
1B4-P	R-F AMPLIFIER PENTODE	D9	4M	D.C. F	2.0	0.06	AMPLIFIER	For other characteristics, refer to Type 1E5-GP.										1B4-P
1B5/25S	DUPLEX-DIODE TRIODE	D5	6M	D.C. F	2.0	0.06	TRIODE UNIT AS AMPLIFIER	For other characteristics, refer to Type 1H6-G.										1B5/25S
1C5-G	POWER AMPLIFIER PENTODE	D1	G-6X	D.C. F	1.4	0.10	CLASS A AMPLIFIER	83 90	− 7.0 − 7.5	83 90	1.6 1.6	7.0 7.5	110000 115000	1500 1550	165 180	9000 8000	0.20 0.24	1C5-G
1C6	PENTAGRID CONVERTER ○	D9	6L	D.C. F	2.0	0.12	CONVERTER	For other characteristics, refer to Type 1C7-G.										1C6
1C7-G	PENTAGRID CONVERTER○	D8	G-7Z	D.C. F	2.0	0.12	CONVERTER	135 180	− 3.0 min.	67.5 67.5	2.0 2.0	1.3 1.5	550000 750000	Anode-Grid (#2): 180■ max. volts, 3.3 ma. Oscillator-Grid (#1) Resistor ■. Conversion Conductance, 325 micromhos.				1C7-G
1D5-GP	SUPER-CONTROL R-F AMPLIFIER PENTODE	D8	G-5Y	D.C. F	2.0	0.06	CLASS A AMPLIFIER	90 180	− 3.0 min.	67.5 67.5	0.9 0.8	2.2 2.3	600000 1000000	720 750	425 750	—	—	1D5-GP
1D7-G	PENTAGRID CONVERTER○	D8	G-7Z	D.C. F	2.0	0.06	CONVERTER	135 180	− 3.0 min.	67.5 67.5	2.5 2.4	1.2 1.3	400000 500000	Anode-Grid (#2): 180■ max. volts, 2.3 ma. Oscillator-Grid (#1) Resistor■. Conversion Conductance, 300 micromhos.				1D7-G
1E5-GP	R-F AMPLIFIER PENTODE	D8	G-5Y	D.C. F	2.0	0.06	CLASS A AMPLIFIER	90 180	− 3.0 − 3.0	67.5 67.5	0.7 0.6	1.6 1.7	1000000 1500000	600 650	550 1000	—	—	1E5-GP
1E7-G	TWIN PENTODE POWER AMPLIFIER	D3	G-8C	D.C. F	2.0	0.24	CLASS A AMPLIFIER	135	− 7.5	135	—	Power Output is for one tube at stated plate-to-plate load.				24000	0.65	1E7-G
1F4	POWER AMPLIFIER PENTODE	D12	5K	D.C. F	2.0	0.12	AMPLIFIER	For other characteristics, refer to Type 1F5-G.										1F4
1F5-G	POWER AMPLIFIER PENTODE	D10	G-6X	D.C. F	2.0	0.12	CLASS A AMPLIFIER	90 135	− 3.0 − 4.5	90 135	1.3 2.6	4.0 8.0	240000 200000	1400 1700	340 340	20000 16000	0.12 0.34	1F5-G

1F6	DUPLEX-DIODE PENTODE	D9	6W	D.C. F	2.0	0.06	PENTODE UNIT AS AMPLIFIER	For other characteristics, refer to Type 1F7-GV.								1F6
1F7-GV	DUPLEX-DIODE PENTODE	D8	G-7AD	D.C. F	2.0	0.06	PENTODE UNIT AS R-F AMPLIFIER	180	− 1.5	67.5	0.6	2.0	1000000	550	650	—	—	1F7-GV
							PENTODE UNIT AS A-F AMPLIFIER	135✖	− 2.0	Screen Supply, 135 volts applied through 0.8-megohm resistor. Grid Resistor,** 1.0 megohm. Voltage Gain, 46.							
1G5-G	POWER AMPLIFIER PENTODE	D10	G-6X	D.C. F	2.0	0.12	CLASS A AMPLIFIER	90 135	− 6.0 −13.5	90 135	2.5 2.5	8.5 8.7	133000 160000	1500 1550	200 250	8500 9000	0.25 0.55	1G5-G
1G6-G	TWIN TRIODE AMPLIFIER	D1	G-7AB	D.C. F	1.4	0.10	CLASS B AMPLIFIER	90	0	—	—	Power Output is for one tube at stated plate-to-plate load.				12000	0.45	1G6-G
1H4-G	DETECTOR★ AMPLIFIER	D3	G-5S	D.C. F	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	—	—	1H4-G
							CLASS B AMPLIFIER	157.5	−15.0	—	—	1.0♠	—	—	—	8000	2.1†	
1H5-G	DIODE HIGH-MU TRIODE	D6	G-5Z	D.C. F	1.4	0.05	TRIODE UNIT AS CLASS A AMPLIFIER	90	0	—	—	0.14	240000	275	65	—	—	1H5-G
1H6-G	DUPLEX-DIODE TRIODE	D3	G-7AA	D.C. F	2.0	0.06	TRIODE UNIT AS CLASS A AMPLIFIER	135	− 3.0	—	—	0.8	35000	575	20	—	—	1H6-G
1J6-G	TWIN TRIODE AMPLIFIER	D3	G-7AB	D.C. F	2.0	0.24	CLASS B AMPLIFIER	135 135	0 − 3.0	—	—	Power Output is for one tube at stated plate-to-plate load.				10000 10000	2.1 1.9	1J6-G
1N5-G	R-F AMPLIFIER PENTODE	D6	G-5Y	D.C. F	1.4	0.05	CLASS A AMPLIFIER	90	0	90	0.3	1.2	1500000	750	1160	—	—	1N5-G
1-v	HALF-WAVE RECTIFIER	D5	4G	H	6.3	0.3	Maximum A-C Plate Voltage........350 Volts, RMS Maximum D-C Output Current........50 Milliamperes											1-v
2A3	POWER AMPLIFIER TRIODE	E3	4D	F	2.5	2.5	CLASS A AMPLIFIER	250	−45.0	—	—	60.0	800	5250	4.2	2500	3.5	2A3
							PUSH-PULL CLASS AB$_1$ AMPLIFIER	300 300	Self-bias, 780 ohms♠ −62 volts, fixed bias			80.0♠ 80.0♠	—	—	—	5000 3000	10.0† 15.0†	
2A5	POWER AMPLIFIER PENTODE	D12	6B	H	2.5	1.75	AMPLIFIER	For other characteristics, refer to Type 6F6.										2A5
2A6	DUPLEX-DIODE HIGH-MU TRIODE	D9	6G	H	2.5	0.8	TRIODE UNIT AS AMPLIFIER	For other characteristics, refer to Type 6SQ7.										2A6
2A7	PENTAGRID CONVERTER □	D9	7C	H	2.5	0.8	CONVERTER	For other characteristics, refer to Type 6A7.										2A7
2B7	DUPLEX-DIODE PENTODE	D8	7D	H	2.5	0.8	PENTODE UNIT AS AMPLIFIER	For other characteristics, refer to Type 6B8-G.										2B7
5T4	FULL-WAVE RECTIFIER	D7	5T	F	5.0	2.0	A-C Voltage per Plate (Volts RMS)........ 450 550 D-C Output Current (Maximum Ma.)........ 250 250 The 550-volt rating applies to filter circuits having an input choke of at least 10 henries.											5T4
5U4-G	FULL-WAVE RECTIFIER	E2	G-5T‡	F	5.0	3.0	Maximum A-C Voltage per Plate........500 Volts, RMS Maximum D-C Output Current........250 Milliamperes											5U4-G
5V4-G	FULL-WAVE RECTIFIER	D10	G-5L‡	H	5.0	2.0	Maximum A-C Voltage per Plate........400 Volts, RMS Maximum D-C Output Current........200 Milliamperes											5V4-G
5W4	FULL-WAVE RECTIFIER	C2	5T	F	5.0	1.5	A-C Voltage per Plate (Volts, RMS)........350 400 D-C Output Current (Maximum Ma.)........110 90											5W4
5X4-G	FULL-WAVE RECTIFIER	E2	G-5Q	F	5.0	3.0	For other ratings, refer to Type 5U4-G.											5X4-G
5Y3-G	FULL-WAVE RECTIFIER	D10	G-5T‡	F	5.0	2.0	Maximum A-C Voltage per Plate........400 Volts, RMS Maximum D-C Output Current........125 Milliamperes											5Y3-G
5Y4-G	FULL-WAVE RECTIFIER	D10	G-5Q	F	5.0	2.0	A-C Voltage per Plate (Volts RMS)........ 350 400 550 D-C Output Current (Maximum Ma.)........ 125 110 135 The 550-volt rating applies to filter circuits having an input choke of at least 20 henries.											5Y4-G
5Z3	FULL-WAVE RECTIFIER	E3	4C	F	5.0	3.0	For other ratings, refer to Type 5U4-G.											5Z3

TYPES 1F6 TO 5Z3, INCLUSIVE

Characteristics for Types 1G4-G, 1H5-GT, 1N5GT, 1Q5GT, 1T5-GT are shown on Page 127

TYPES 5Z4 TO 6C5, INCLUSIVE

Characteristics for Types 6AB7/1853, 6AC7/1852, 6AG7, 6B5 are shown on Page 127

TYPE	NAME	DIMENSIONS SOCKET CONNECTIONS		CATHODE TYPE AND RATING			USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID BIAS ■ VOLTS	SCREEN SUPPLY VOLTS	SCREEN CURRENT MA.	PLATE CURRENT MA.	A-C PLATE RESISTANCE OHMS	TRANSCONDUCTANCE (GRID-PLATE) µMHOS	AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
		DIMEN.	S.C.	C.T.	VOLTS	AMP.												
5Z4	FULL-WAVE RECTIFIER	C2	5L	H	5.0	2.0	Maximum A-C Voltage per Plate.........400 Volts, RMS Maximum D-C Output Current.........125 Milliamperes											5Z4
6A4/LA	POWER AMPLIFIER PENTODE	D12	5B	F	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/LA
6A6	TWIN TRIODE AMPLIFIER	D12	7B	H	6.3	0.8	AMPLIFIER	For other characteristics, refer to Type 6N7.										6A6
6A7	PENTAGRID CONVERTER ○	D9	7C	H	6.3	0.3	CONVERTER	100 250	−1.5 min. −3.0 min.	50 100	1.3 2.7	1.1 3.5	600000 360000	Anode-Grid (#2): 250● max. volts, 4.0 ma. Oscillator-Grid (#1) Resistor ●. Conversion Conductance, 520 micromhos.				6A7
6A8	PENTAGRID CONVERTER ○	C1	8A	H	6.3	0.3	CONVERTER	100 250	−1.5 min. −3.0 min.	50 100	1.5 3.2	1.2 3.3	600000 360000	Anode-Grid (#2): 250● max. volts, 4.0 ma. Oscillator-Grid (#1) Resistor ●. Conversion Conductance, 500 micromhos.				6A8
6A8-G	PENTAGRID CONVERTER ○	D8	G-8A‡	H	6.3	0.3	CONVERTER	100 250	− 1.5 min. − 3.0 min.	50 100	1.3 2.7	1.1 3.5	600000 360000	Anode-Grid (#2): 250● max. volts. 4.0 ma. Oscillator-Grid (#1) Resistor ●. Conversion Conductance, 550 micromhos.				6A8-G
6A8-GT	PENTAGRID CONVERTER ○	C3	G-8A‡	H	6.3	0.3	CONVERTER	For other characteristics, refer to Type 6A8.										6A8-GT
6AC5-G	HIGH-MU POWER AMPLIFIER TRIODE	D3	G-6Q‡	H	6.3	0.4	CLASS B AMPLIFIER	250	0	—	—	5.0♠	—	—	—	10000	8.0†	6AC5-G
							DYNAMIC-COUPLED AMPLIFIER WITH TYPE 76 DRIVER	250	Bias for both 6AC5-G and 76 is developed in coupling circuit. Average Plate Current of Driver = 5.5 milliamperes. Average Plate Current of 6AC5-G = 32 milliamperes.							7000	3.7	
6AF6-G	ELECTRON-RAY TUBE Twin Indicator Type	B2	G-7AG	H	6.3	0.15	VISUAL INDICATOR	Target Voltage, 100 volts. Control-Electrode Voltage, 0 volts; Shadow Angle, 100°; Target Current, 0.9 ma. Control-Electrode Voltage, 60 volts; Angle, 0°.										6AF6-G
								Target Voltage, 135 volts. Control-Electrode Voltage, 0 volts; Shadow Angle, 100°; Target Current, 1.5 ma. Control-Electrode Voltage, 81 volts; Angle, 0°.										
6B6-G	DUPLEX-DIODE HIGH-MU TRIODE	D8	G-7V‡	H	6.3	0.3	TRIODE UNIT AS CLASS A AMPLIFIER	250	− 2.0	—	—	1.0	91000	1100	100	—	—	6B6-G
6B7	DUPLEX-DIODE PENTODE	D9	7D	H	6.3	0.3	PENTODE UNIT AS AMPLIFIER	For other characteristics, refer to Type 6B8-G.										6B7
6B8	DUPLEX-DIODE PENTODE	C1	8E	H	6.3	0.3	PENTODE UNIT AS R-F AMPLIFIER	250	− 3.0	125	2.3	10.0	600000	1325	800	—	—	6B8
							PENTODE UNIT AS A-F AMPLIFIER	90✠ 300✠	Self-bias, 3500 ohms. Screen Resistor = 1.1 meg. Self-bias, 1600 ohms. Screen Resistor = 1.2 meg.					Grid Resistor,** 0.5 megohm.		Gain per stage = 55 Gain per stage = 79		
6B8-G	DUPLEX-DIODE PENTODE	D8	G-8E‡	H	6.3	0.3	PENTODE UNIT AS 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	—	—	6B8-G
							PENTODE UNIT AS A-F AMPLIFIER	90✠ 300✠	Self-bias, 3500 ohms. Screen Resistor = 1.1 meg. Self-bias, 1600 ohms. Screen Resistor = 1.2 meg.					Grid Resistor,** 0.5 megohm.		Gain per stage = 55 Gain per stage = 79		
6C5	DETECTOR★ AMPLIFIER TRIODE	B3	6Q	H	6.3	0.3	CLASS A AMPLIFIER	250	− 8.0	—	—	8.0	10000	2000	20	—	—	6C5
								90♥ 300♥	Self-bias, 6400 ohms. Self-bias, 5300 ohms.					Grid Resistor,** 0.25 megohm		Gain per stage = 11 Gain per stage = 13		
							BIAS DETECTOR	250	−17.0 approx. Plate current to be adjusted to 0.2 milliampere with no signal.									

6C5-G	DETECTOR★ AMPLIFIER TRIODE	D3	G-6Q::	H	6.3	0.3	AMPLIFIER DETECTOR	For other characteristics, refer to Type 6C5.										6C5-G
6C6	TRIPLE-GRID DETECTOR AMPLIFIER	D13	6F	H	6.3	0.3	AMPLIFIER DETECTOR	For other characteristics, refer to Type 6J7.										6C6
6C8-G	TWIN TRIODE AMPLIFIER	D8	G-8G	H	6.3	0.3	EACH UNIT AS AMPLIFIER	250	− 4.5	—	—	3.2	22500	1600	36	—	—	6C8-G
6D6	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	D13	6F	H	6.3	0.3	AMPLIFIER MIXER	For other characteristics, refer to Type 6U7-G.										6D6
6D8-G	PENTAGRID CONVERTER□	D8	G-8A:	H	6.3	0.15	CONVERTER	135 250	− 3.0 min.	67.5 100	— —	— —	400000 320000	Anode-Grid (#2): 250● max. volts. Oscillator-Grid (#1) Resistor ●. Conversion Conductance, 500 micromhos.				6D8-G
6E5	ELECTRON-RAY TUBE	D5	6R	H	6.3	0.3	VISUAL INDICATOR	Plate & Target Supply = 100 volts. Triode Plate Resistor = 0.5 meg. Target Current = 1.0 ma. Grid Bias, −3.3 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.19 ma.										6E5
								Plate & Target Supply = 250 volts. Triode Plate Resistor = 1.0 meg. Target Current = 4.0 ma. Grid Bias, −8.0 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.24 ma.										
6F5	HIGH-MU TRIODE	C1	5M	H	6,3	0.3	AMPLIFIER	For other characteristics, refer to Type 6SF5.										6F5
6F5-G	HIGH-MU TRIODE	D8	G-5M::	H	6.3	0.3	AMPLIFIER	For other characteristics, refer to Type 6SF5.										6F5-G
6F6	POWER AMPLIFIER PENTODE	C2	7S	H	6.3	0.7	PENTODE CLASS A AMPLIFIER	250 315	−16.5 −22.0	250 315	6.5 8.0	34.0 42.0	80000 75000	2500 2650	200 200	7000 7000	3.0 5.0	6F6
							TRIODE□ CLASS A AMPLIFIER	250	−20.0	—	—	31.0	2600	2600	6.8	4000	0.85	
							PENTODE PUSH-PULL CLASS A AMPLIFIER	315 315	Self-bias −22.0	315 315	16.0♠ 16.0♠	84.0♠ 84.0♠	Self-Bias Resistor, 220 ohms♠ —	 —	 —	10000 10000	13.0† 13.0†	
							PENTODE PUSH-PULL CLASS AB₁ AMPLIFIER	375 375	Self-bias −26.0	250 250	8.0♠ 5.0♠	54.0♠ 34.0♠	Self-Bias Resistor, 340 ohms♠ —	 —	 —	10000 10000	19.0† 19.0†	
							TRIODE PUSH-PULL□ CLASS AB₁ AMPLIFIER	350 350	Self-bias −38.0	—	—	50.0♠ 45.0♠	Self-Bias Resistor, 730 ohms♠ —	 —	 —	10000 6000	14.0† 18.0†	
6F6-G	POWER AMPLIFIER PENTODE	D10	G-7S:	H	6.3	0.7	AMPLIFIER	For other characteristics, refer to Type 6F6.										6F6-G
6F7	TRIODE-PENTODE	D9	7E	H	6.3	0.3	TRIODE UNIT AS CLASS A AMPLIFIER	100	− 3.0	—	—	3.5	16000	500	8	—	—	6F7
							PENTODE UNIT AS CLASS A AMPLIFIER	100 250	− 3.0 min.	100 100	1.6 1.5	6.3 6.5	290000 850000	1050 1100	300 900	—	—	
							PENTODE UNIT AS MIXER	250	−10.0	100	0.6	2.8	Oscillator Peak Volts = 7.0. Conversion Conductance = 300 micromhos.					
6F8-G	TWIN TRIODE AMPLIFIER	D8	G-8G	H	6.3	0.6	EACH UNIT AS AMPLIFIER	250	− 8.0	—	—	9.0	7700	2600	20	—	—	6F8-G
6G6-G	POWER AMPLIFIER PENTODE	D3	G-7S:	H	6.3	0.15	CLASS A AMPLIFIER	135 180	− 6.0 − 9.0	135 180	2.0 2.5	11.5 15.0	170000 175000	2100 2300	360 400	12000 10000	0.6 1.1	6G6-G
6H6	TWIN DIODE	A1	7Q	H	6.3	0.3	DETECTOR RECTIFIER	Maximum A-C Voltage per Plate........100 Volts, RMS Maximum D-C Output Current........4 Milliamperes										6H6
6H6-G	TWIN DIODE	D3	G-7Q::	H	6.3	0.3	DETECTOR RECTIFIER	For other ratings, refer to Type 6H6.										6H6-G
6J5	DETECTOR AMPLIFIER TRIODE	B3	6Q	H	6.3	0.3	CLASS A AMPLIFIER	250	− 8.0	—	—	9.0	7700	2600	20	—	—	6J5
6J5-G	DETECTOR AMPLIFIER TRIODE	D3	G-6Q:	H	6.3	0.3	AMPLIFIER	For other characteristics, refer to Type 6J5.										6J5-G

TYPES 6C5-G TO 6J5G, INCLUSIVE

Characteristics for Types 6F5-GT, 6J5GT are shown on Page 128

TYPES 6J7 TO 6L7, INCLUSIVE

Characteristics for Types 6J7GT, 6K6-GT are shown on Page 128

TYPE	NAME	DIMENSIONS SOCKET CONNECTIONS		CATHODE TYPE AND RATING			USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID BIAS ■ VOLTS	SCREEN SUPPLY VOLTS	SCREEN CURRENT MA.	PLATE CURRENT MA.	A-C PLATE RESISTANCE OHMS	TRANSCONDUCTANCE (GRID-PLATE) μMHOS	AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
		DIMEN.	S. C.	C. T.	VOLTS	AMP.												
6J7	TRIPLE-GRID DETECTOR AMPLIFIER	C1	7R	H	6.3	0.3	CLASS A R-F AMPLIFIER	100 250	− 3.0 − 3.0	100 100	0.5 0.5	2.0 2.0	1000000 1.5 +§	1185 1225	1185 1500+	—	—	6J7
							CLASS A A-F AMPLIFIER	90 ✖ 300 ✖	Self-bias, 2600 ohms. Screen Resistor = 1.2 meg. Self-bias, 1200 ohms. Screen Resistor = 1.2 meg.					Grid Resistor,** 0.5 megohm.		Gain per stage = 85 Gain per stage = 140		
							BIAS DETECTOR	250	− 4.3	100	Cathode current 0.43 ma.		—	Plate Resistor, 500000 ohms. Grid Resistor,** 250000 ohms.				
6J7-G	TRIPLE-GRID DETECTOR AMPLIFIER	D8	G-7R‡‡	H	6.3	0.3	AMPLIFIER DETECTOR	For other characteristics, refer to Type 6J7.										6J7-G
6K5-G	HIGH-MU TRIODE	D8	G-5U	H	6.3	0.3	CLASS A AMPLIFIER	100 250	− 1.5 − 3.0	— —	— —	0.35 1.1	78000 50000	900 1400	70 70	— —	— —	6K5-G
6K6-G	POWER AMPLIFIER PENTODE	D3	G-7S‡	H	6.3	0.4	CLASS A AMPLIFIER	100 250	− 7.0 −18.0	100 250	1.6 5.5	9.0 32.0	103500 68000	1450 2200	150 150	12000 7600	0.33 3.40	6K6-G
6K7	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	C1	7R	H	6.3	0.3	CLASS A AMPLIFIER	90 250	− 3.0 min.	90 125	1.3 2.6	5.4 10.5	315000 600000	1275 1650	400 990	—	—	6K7
							MIXER IN SUPERHETERODYNE	250	−10.0	100	—	—	Oscillator Peak Volts = 7.0					
6K7-G	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	D8	G-7R‡	H	6.3	0.3	AMPLIFIER MIXER	For other characteristics, refer to Type 6K7.										6K7-G
6K7-GT	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	C3	G-7R‡	H	6.3	0.3	CLASS A AMPLIFIER	100 250	− 3.0 min.	100 100	1.6 1.7	6.5 7.0	250000 800000	1325 1450	350 1160	—	—	6K7-GT
6K8	TRIODE-HEXODE CONVERTER	C1	8K	H	6.3	0.3	TRIODE UNIT AS OSCILLATOR	100	Triode-Grid Resistor■			3.8	Triode-Grid & Hexode-Grid Current, 0.15 ma.					6K8
							HEXODE UNIT AS MIXER	100 250	− 3.0 min.	100 100	6.2 6.0	2.3 2.5	400000 600000	Conversion Conductance, 325 micromhos. Conversion Conductance, 350 micromhos.				
6L5-G	DETECTOR AMPLIFIER TRIODE	D3	G-6Q‡	H	6.3	0.15	CLASS A AMPLIFIER	135 250	− 5.0 − 9.0	— —	— —	3.5 8.0	11300 9000	1500 1900	17 17	—	—	6L5-G
6L6	BEAM POWER AMPLIFIER	D7	7AC	H	6.3	0.9	SINGLE-TUBE CLASS A_1 AMPLIFIER	250 250	−14.0 Self-bias	250 250	5.0 5.4	72.0 75.0	— Self-Bias Resistor, 170 ohms.	—	—	2500 2500	6.5 6.5	6L6
							PUSH-PULL CLASS A_1 AMPLIFIER	250 250	−16.0 Self-bias	250 250	10.0♠ 10.0♠	120.0♠ 120.0♠	— Self-Bias Resistor, 125 ohms.♠	—	—	5000 5000	14.5† 13.8†	
							PUSH-PULL CLASS AB_1 AMPLIFIER	400 400	−25.0 Self-bias	300 300	6.0♠ 7.0♠	102.0♠ 112.0♠	— Self-Bias Resistor, 200 ohms.♠	—	—	6600 6600	34.0† 32.0†	
							PUSH-PULL CLASS AB_2 AMPLIFIER	400 400	−20.0 −25.0	250 300	4.0♠ 6.0♠	88.0♠ 102.0♠	—	—	—	6000 3800	40.0† 60.0†	
6L6-G	BEAM POWER AMPLIFIER	E2	G-7AC‡	H	6.3	0.9	AMPLIFIER	For other characteristics, refer to Type 6L6.										6L6-G
6L7	PENTAGRID MIXER A AMPLIFIER	C1	7T	H	6.3	0.3	MIXER IN SUPERHETERODYNE	250	− 3.0	100	7.1	2.4	Oscillator-Grid (#3) Bias, −10 volts. Grid #3 Peak Swing, 12 volts minimum. Conversion Conductance, 350 micromhos.					6L7
							CLASS A AMPLIFIER	250	− 3.0 min.◀	100	6.5	5.3	800000	1100	880	—	—	

6L7-G	PENTAGRID MIXERA AMPLIFIER	D8	G-7T:	H	6.3	0.3	MIXER AMPLIFIER	For other characteristics, refer to Type 6L7.										6L7-G
6N5	ELECTRON-RAY TUBE	D5	6R	H	6.3	0.15	VISUAL INDICATOR	Plate & Target Supply = 135 volts. Triode Plate Resistor = 0.25 meg. Target Current = 2.0 ma. Grid Bias, − 12.0 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.5 ma.										6N5
6N7	TWIN TRIODE AMPLIFIER	C2	8B	H	6.3	0.8	CLASS A AMPLIFIER (As Driver)°	250 294	− 5.0 − 6.0	——	——	6.0 7.0	11300 11000	3100 3200	35 35	20000 or more	exceeds 0.4	6N7
							CLASS B AMPLIFIER	250 300	0 0	——	——	Power Output is for one tube at stated plate-to-plate load.				8000 10000	8.0 10.0	
6N7-G	TWIN TRIODE AMPLIFIER	D10	G-8B:	H	6.3	0.8	AMPLIFIER	For other characteristics, refer to Type 6N7.										6N7-G
6Q7	DUPLEX-DIODE HIGH-MU TRIODE	C1	7V	H	6.3	0.3	TRIODE UNIT AS CLASS A AMPLIFIER	100 250	− 1.5 − 3.0	——	——	0.35 1.1	87500 58000	800 1200	70 70	——	——	6Q7
								90✖ 300✖	Self-bias, 7600 ohms. Self-bias, 3000 ohms.	Grid Resistor,** 0.5 megohm.						Gain per stage = 32 Gain per stage = 45		
6Q7-G	DUPLEX-DIODE HIGH-MU TRIODE	D8	G-7V:	H	6.3	0.3	TRIODE UNIT AS AMPLIFIER	For other characteristics, refer to Type 6Q7.										6Q7-G
6Q7-GT	DUPLEX-DIODE HIGH-MU TRIODE	C3	G-7V:	H	6.3	0.3	TRIODE UNIT AS CLASS A AMPLIFIER	100 250	0 − 3.0	——	——	2.3 1.1	43000 58000	1400 1200	60 70	——	——	6Q7-GT
6R7	DUPLEX-DIODE TRIODE	C1	7V	H	6.3	0.3	TRIODE UNIT AS CLASS A AMPLIFIER	250	− 9.0	——	——	9.5	8500	1900	16	——	——	6R7
								90♥ 300♥	Self-bias, 4400 ohms. Self-bias, 3800 ohms.	Grid Resistor,** 0.25 megohm.						Gain per stage = 10 Gain per stage = 10		
6R7-G	DUPLEX-DIODE TRIODE	D8	G-7V:	H	6.3	0.3	TRIODE UNIT AS AMPLIFIER	For other characteristics, refer to Type 6R7.										6R7-G
6S7	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	C1	7R	H	6.3	0.15	CLASS A AMPLIFIER	135 250	− 3.0 min.	67.5 100	0.9 2.0	3.7 8.5	—— 1000000	1250 1750	—— 1750	——	——	6S7
6S7-G	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	D8	G-7R:	H	6.3	0.15	AMPLIFIER	For other characteristics, refer to Type 6S7.										6S7-G
6SA7	PENTAGRID CONVERTER▲	B3	8R	H	6.3	0.3	MIXER	100 250	− 2.0 − 2.0	100 100	8.0 8.0	3.2 3.4	500000 800000	Grid #1 Resistor, 20000 ohms. Conversion Conductance, 450 micromhos.				6SA7
6SC7	TWIN TRIODE AMPLIFIER	B3	8S	H	6.3	0.3	EACH UNIT AS AMPLIFIER	250	− 2.0	——	——	2.0	53000	1325	70	——	——	6SC7
6SF5	HIGH-MU TRIODE	B3	6AB	H	6.3	0.3	CLASS A AMPLIFIER	250	− 2.0	——	——	0.9	66000	1500	100	——	——	6SF5
								90✖ 300✖	Self-bias, 8800 ohms. Self-bias, 3200 ohms.	Grid Resistor,** 0.5 megohm.						Gain per stage = 43 Gain per stage = 63		
6SJ7	TRIPLE-GRID DETECTOR AMPLIFIER	B3	8N	H	6.3	0.3	CLASS A AMPLIFIER	100 250	− 3.0 − 3.0	100 100	0.9 0.8	2.9 3.0	700000 1500000	1575 1650	1100 2500	——	——	6SJ7
								90✖ 300✖	Self-bias, 1700 ohms. Self-bias, 860 ohms.	Grid Resistor,** 0.5 megohm.						Gain per stage = 93 Gain per stage = 167		
6SK7	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	B3	8N	H	6.3	0.3	CLASS A AMPLIFIER	100 250	− 3.0 min.	100 100	2.6 2.4	8.9 9.2	250000 800000	1900 2000	475 1600	——	——	6SK7
6SQ7	DUPLEX-DIODE HIGH-MU TRIODE	B3	8Q	H	6.3	0.3	TRIODE UNIT AS CLASS A AMPLIFIER	250	− 2.0	——	——	0.8	91000	1100	100	——	——	6SQ7
								90✖ 300✖	Self-bias, 11000 ohms. Self-bias, 3900 ohms.	Grid Resistor, ** 0.5 megohm.						Gain per stage = 40 Gain per stage = 53		
6T7-G	DUPLEX-DIODE HIGH-MU TRIODE	D8	G-7V:	H	6.3	0.15	TRIODE UNIT AS CLASS A AMPLIFIER	135 250	− 1.5 − 3.0	——	——	0.9 1.2	65000 62000	1000 1050	65 65	——	——	6T7-G

TYPES 6L7-G TO 6T7-G, INCLUSIVE

Characteristics for Types 6N6-G, 6P5-G are shown on Page 128

TYPES 6U5 TO 12SJ7, INCLUSIVE

Characteristics for Types 6V6-GT, 12J7-GT are shown on Page 128

TYPE	NAME	DIMENSIONS SOCKET CONNECTIONS		CATHODE TYPE AND RATING			USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID BIAS ■ VOLTS	SCREEN SUPPLY VOLTS	SCREEN CURRENT MA.	PLATE CURRENT MA.	A-C PLATE RESISTANCE OHMS	TRANSCONDUCTANCE (GRID-PLATE) MHOS	AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
		DIMEN.	S. C.	C. T.	VOLTS	AMP.												
6U5/6G5	ELECTRON-RAY TUBE	D4	6R	H	6.3	0.3	VISUAL INDICATOR	Plate & Target Supply = 100 volts. Triode Plate Resistor = 0.5 meg. Target Current = 1.0 ma. Grid Bias, −8 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.19 ma.										6U5/6G5
								Plate & Target Supply = 250 volts. Triode Plate Resistor = 1.0 meg. Target Current = 4.0 ma. Grid Bias, −22 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.24 ma.										
6U7-G	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	D8	G-7R‡	H	6.3	0.3	CLASS A AMPLIFIER	100 250	− 3.0 min.	100 100	2.2 2.0	8.0 8.2	250000 800000	1500 1600	375 1280	——	——	6U7-G
							MIXER IN SUPERHETERODYNE	100 250	−10.0 −10.0	100 100	——	——	Oscillator Peak Volts = 7.0					
6V6	BEAM POWER AMPLIFIER	C2	7AC	H	6.3	0.45	SINGLE-TUBE CLASS A1 AMPLIFIER	180 250	− 8.5 −12.5	180 250	3.0 4.5	29.0 45.0	—— ——	—— ——	—— ——	5500 5000	2.00 4.25	6V6
							PUSH-PULL CLASS AB1 AMPLIFIER	250 300	−15.0 −20.0	250 300	5.0♠ 5.0♠	70.0♠ 78.0♠	—— ——	—— ——	—— ——	10000 8000	8.5† 13.0†	
6V6-G	BEAM POWER AMPLIFIER	D10	G-7AC‡	H	6.3	0.45	AMPLIFIER	For other characteristics, refer to Type 6V6.										6V6-G
6W7-G	TRIPLE-GRID DETECTOR AMPLIFIER	D8	G-7R‡	H	6.3	0.15	CLASS A AMPLIFIER	250	− 3.0	100	0.5	2.0	1500000	1225	1850	——	——	6W7-G
6X5	FULL-WAVE RECTIFIER	C2	6S	H	6.3	0.6	Maximum A-C Voltage per Plate.......350 Volts, RMS Maximum D-C Output Current....... 75 Milliamperes											6X5
6X5-G	FULL-WAVE RECTIFIER	D3	G-6S‡	H	6.3	0.6	For other ratings, refer to Type 6X5.											6X5-G
6Y6-G	BEAM POWER AMPLIFIER	D10	G-7AC‡	H	6.3	1.25	SINGLE-TUBE CLASS A1 AMPLIFIER	135 200	−13.5 −14.0	135 135	3.0 2.2	58.0 60.0	—— ——	—— ——	—— ——	2000 2600	3.6 6.0	6Y6-G
6Z7-G	TWIN TRIODE AMPLIFIER	D3	G-8B‡	H	6.3	0.3	CLASS B AMPLIFIER	135 180	0 0	——	——	Power Output is for one tube at stated plate-to-plate load.				9000 12000	2.5 4.2	6Z7-G
6ZY5-G	FULL-WAVE RECTIFIER	D3	G-6S‡	H	6.3	0.3	Maximum A-C Voltage per Plate.......350 Volts, RMS Maximum D-C Output Current....... 35 Milliamperes											6ZY5-G
10	POWER AMPLIFIER TRIODE	E4	4D	F	7.5	1.25	CLASS A AMPLIFIER	350 425	−32.0 −40.0	——	——	16.0 18.0	5150 5000	1550 1600	8.0 8.0	11000 10200	0.9 1.6	10
11 12	DETECTOR★ AMPLIFIER TRIODE	D2 D11	4F 4D	D.C. F	1.1	0.25	CLASS A AMPLIFIER	90 135	− 4.5 −10.5	——	——	2.5 3.0	15500 15000	425 440	6.6 6.6	——	——	11 12
12A8-GT	PENTAGRID CONVERTER●	C3	G-8A‡	H	12.6	0.15	CONVERTER	For other characteristics, refer to Type 6A8.										12A8-GT
12C8	DUPLEX-DIODE PENTODE	C1	8E	H	12.6	0.15	PENTODE UNIT AS AMPLIFIER	For other characteristics, refer to Type 6B8.										12C8
12K7-GT	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	C3	G-7R‡	H	12.6	0.15	AMPLIFIER	For other characteristics, refer to Type 6K7-GT.										12K7-GT
12Q7-GT	DUPLEX-DIODE HIGH-MU TRIODE	C3	G-7V‡	H	12.6	0.15	TRIODE UNIT AS AMPLIFIER	For other characteristics, refer to Type 6Q7-GT.										12Q7-GT
12SA7	PENTAGRID CONVERTER▲	B3	8R	H	12.6	0.15	MIXER	For other characteristics, refer to Type 6SA7.										12SA7
12SC7	TWIN TRIODE AMPLIFIER	B3	8S	H	12.6	0.15	AMPLIFIER	For other characteristics, refer to Type 6SC7.										12SC7
12SJ7	TRIPLE-GRID DETECTOR AMPLIFIER	B3	8N	H	12.6	0.15	AMPLIFIER	For other characteristics, refer to Type 6SJ7.										12SJ7

12SK7	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	B3	8N	H	12.6	0.15	AMPLIFIER	For other characteristics, refer to Type 6SK7.										**12SK7**
12SQ7	DUPLEX-DIODE HIGH-MU TRIODE	B3	8Q	H	12.6	0.15	TRIODE UNIT AS AMPLIFIER	For other characteristics, refer to Type 6SQ7.										**12SQ7**
12Z3	HALF-WAVE RECTIFIER	D5	4G	H	12.6	0.3	Maximum A-C Plate Voltage .... 250 Volts, RMS Maximum D-C Output Current .... 60 Milliamperes											**12Z3**
15	R-F AMPLIFIER PENTODE	D9	5F	D.C. H	2.0	0.22	CLASS A AMPLIFIER	67.5 135	− 1.5 − 1.5	67.5 67.5	0.3 0.3	1.85 1.85	630000 800000	710 750	450 600	——	——	**15**
19	TWIN TRIODE AMPLIFIER	D5	6C	D.C. F	2.0	0.26	AMPLIFIER	For other characteristics, refer to Type 1J6-G.										**19**
20	POWER AMPLIFIER TRIODE	D2	4D	D.C. F	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	R-F AMPLIFIER TETRODE	E1	4K	D.C. F	3.3	0.132	SCREEN-GRID R-F AMPLIFIER	135 135	− 1.5 − 1.5	45 67.5	0.6* 1.3*	1.7 3.7	725000 325000	375 500	270 160	——	——	**22**
24-A	R-F AMPLIFIER TETRODE	E1	5E	H	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 approx.	20 to 45	——	Plate current to be adjusted to 0.1 milliampere with no signal.						
25A6	POWER AMPLIFIER PENTODE	C2	7S	H	25.0	0.3	CLASS A AMPLIFIER	95 180	−15.0 −20.0	95 135	4.0 7.5	20.0 38.0	45000 40000	2000 2500	90 100	4500 5000	0.9 2.75	**25A6**
25A6-G	POWER AMPLIFIER PENTODE	D10	G-7S‡	H	25.0	0.3	AMPLIFIER	For other characteristics, refer to Type 25A6.										**25A6-G**
25A7-G	RECTIFIER-PENTODE	D10	8F	H	25.0	0.3	PENTODE UNIT AS CLASS A AMPLIFIER	100	−15.0	100	4.0	20.5	50000	1800	90	4500	0.77	**25A7-G**
							HALF-WAVE RECTIFIER	Maximum A-C Voltage .... 125 Volts, RMS Maximum D-C Output Current .... 75 Milliamperes										
25B6-G	POWER AMPLIFIER PENTODE	D10	G-7S‡	H	25.0	0.3	CLASS A AMPLIFIER	95 135	−15.0 −22.0	95 135	1.5 2.5	41.0 61.0	—— ——	4600 5000	75 75	2000 1700	1.9 4.3	**25B6-G**
25L6	BEAM POWER AMPLIFIER	C2	7AC	H	25.0	0.3	SINGLE-TUBE CLASS A_1 AMPLIFIER	110 110	− 7.5 − 7.5	110 110	4.0 4.0	49.0 49.0	10000 10000	8200 8200	82 82	1500 2000	2.1 2.2	**25L6**
25L6-G	BEAM POWER AMPLIFIER	D10	G-7AC‡	H	25.0	0.3	AMPLIFIER	For other characteristics, refer to Type 25L6.										**25L6-G**
25L6-GT	BEAM POWER AMPLIFIER	C3	G-7AC‡	H	25.0	0.3	AMPLIFIER	For other characteristics, refer to Type 25L6.										**25L6-GT**
25Z5	RECTIFIER-DOUBLER	D5	6E	H	25.0	0.3	VOLTAGE DOUBLER	Maximum A-C Voltage per Plate .... 125 Volts, RMS Maximum D-C Output Current .... 100 Milliamperes										**25Z5**
							HALF-WAVE RECTIFIER	Maximum A-C Voltage per Plate¶ .... 250 Volts, RMS Maximum D-C Output Current per Plate .... 85 Milliamperes										
25Z6	RECTIFIER-DOUBLER	C2	7Q	H	25.0	0.3	VOLTAGE DOUBLER	Maximum A-C Voltage per Plate .... 125 Volts, RMS Maximum D-C Output Current .... 85 Milliamperes										**25Z6**
							HALF-WAVE RECTIFIER	Maximum A-C Voltage per Plate¶ .... 250 Volts, RMS Maximum D-C Output Current per Plate .... 85 Milliamperes										
25Z6-G	RECTIFIER-DOUBLER	D3	G-7Q‡	H	25.0	0.3	RECTIFIER-DOUBLER	For other ratings, refer to Type 25Z6.										**25Z6-G**
25Z6-GT	RECTIFIER-DOUBLER	C3	G-7Q‡	H	25.0	0.3	VOLTAGE DOUBLER	Maximum A-C Voltage per Plate .... 125 Volts, RMS Maximum D-C Output Current .... 85 Milliamperes										**25Z6-GT**
							HALF-WAVE RECTIFIER	Maximum A-C Voltage per Plate .... 125 Volts, RMS Maximum D-C Output Current per Plate .... 85 Milliamperes										
26	AMPLIFIER TRIODE	D12	4D	F	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**

TYPES 12SK7 TO 26, INCLUSIVE

Characteristics for Types 1851, 1852/6AC7, 1853/6AB7, 35Z5, 50L6-GT are shown on Page 128

TYPES 27 TO 42, INCLUSIVE

TYPE	NAME	DIMENSIONS SOCKET CONNECTIONS		CATHODE TYPE AND RATING			USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID BIAS ■ VOLTS	SCREEN SUPPLY VOLTS	SCREEN CURRENT MA.	PLATE CURRENT MA.	A-C PLATE RESISTANCE OHMS	TRANSCONDUCTANCE (GRID-PLATE) µMHOS	AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
		DIMEN.	S. C.	C. T.	VOLTS	AMP.												
27	DETECTOR★ AMPLIFIER TRIODE	D5	5A	H	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 approx.	—	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
30	DETECTOR★ AMPLIFIER TRIODE	D5	4D	F	2.0	0.06	AMPLIFIER	For other characteristics, refer to Type 1H4-G.										30
31	POWER AMPLIFIER TRIODE	D5	4D	F	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	R-F AMPLIFIER TETRODE	E1	4K	F	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 approx.	67.5	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
33	POWER AMPLIFIER PENTODE	D12	5K	F	2.0	0.26	CLASS A AMPLIFIER	180	−18.0	180	5.0	22.0	55000	1700	90	6000	1.4	33
34	SUPER-CONTROL R-F AMPLIFIER PENTODE	E1	4M	D.C. F	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
35	SUPER-CONTROL R-F AMPLIFIER TETRODE	E1	5E	H	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
35L6-GT	BEAM POWER AMPLIFIER	C3	G-7AC‡	H	35.0	0.15	SINGLE-TUBE CLASS A AMPLIFIER	110	− 7.5	110	3.0	40.0	13800	5800	80	2500	1.5	35L6-GT
35Z4-GT	HALF-WAVE RECTIFIER	C3	G-5AA	H	35.0	0.15	A-C Plate Voltage (Volts, RMS) D-C Output Current (Maximum Ma.)							125 100	250♦ 100			35Z4-GT
36	R-F AMPLIFIER TETRODE	D9	5E	H	6.3	0.3	SCREEN-GRID R-F AMPLIFIER	100 250	− 1.5 − 3.0	55 90	— 1.7•	1.8 3.2	550000 550000	850 1080	470 595	—	—	36
							BIAS DETECTOR	100● 250●	− 5.0 − 8.0	55 90	—	Grid-bias values are approximate. Plate current to be adjusted to 0.1 milliampere with no signal.						
37	DETECTOR★ AMPLIFIER TRIODE	D5	5A	H	6.3	0.3	CLASS A AMPLIFIER	90 250	− 6.0 −18.0	—	—	2.5 7.5	11500 8400	800 1100	9.2 9.2	—	—	37
							BIAS DETECTOR	90 250	−10.0 −28.0	—	—	Grid-bias values are approximate. Plate current to be adjusted to 0.2 milliampere with no signal.						
38	POWER AMPLIFIER PENTODE	D9	5F	H	6.3	0.3	CLASS A AMPLIFIER	100 250	− 9.0 −25.0	100 250	1.2 3.8	7.0 22.0	• 140000 100000	875 1200	120 120	15000 10000	0.27 2.50	38
39/44	SUPER-CONTROL R-F AMPLIFIER PENTODE	D9	5F	H	6.3	0.3	CLASS A AMPLIFIER	90 250	− 3.0 min.	90 90	1.6 1.4	5.6 5.8	375000 1000000	960 1050	360 1050	—	—	39/44
40	VOLTAGE AMPLIFIER TRIODE	D12	4D	D.C. F	5.0	0.25	CLASS A AMPLIFIER	135✖ 180✖	− 1.5 − 3.0	—	—	0.2 0.2	150000 150000	200 200	30 30	—	—	40
41	POWER AMPLIFIER PENTODE	D5	6B	H	6.3	0.4	AMPLIFIER	For other characteristics, refer to Type 6K6-G.										41
42	POWER AMPLIFIER PENTODE	D12	6B	H	6.3	0.7	AMPLIFIER	For other characteristics, refer to Type 6F6.										42

43	POWER AMPLIFIER PENTODE	D12	6B	H	25.0	0.3	AMPLIFIER	For other characteristics, refer to Type 25A6.										43
45	POWER AMPLIFIER TRIODE	D12	4D	F	2.5	1.5	CLASS A AMPLIFIER	180 275	−31.5 −56.0	—	—	31.0 36.0	1650 1700	2125 2050	3.5 3.5	2700 4600	0.82 2.00	45
							PUSH-PULL CLASS AB$_2$ AMPLIFIER	275 275	Self-bias, 775 ohms♠ −68.0 volts, fixed bias			36.0♠ 28.0♠	—	—	—	5060 3200	12.0† 18.0†	
46	DUAL-GRID POWER AMPLIFIER	E3	5C	F	2.5	1.75	CLASS A AMPLIFIER □	250	−33.0	—	—	22.0	2380	2350	5.6	6400	1.25	46
							CLASS B AMPLIFIER◆	300 400	0 0	—	—	8.0♠ 12.0♠	—	—	—	5200 5800	16.0† 20.0†	
47	POWER AMPLIFIER PENTODE	E3	5B	F	2.5	1.75	CLASS A AMPLIFIER	250	−16.5	250	6.0	31.0	60000	2500	150	7000	2.7	47
48	POWER AMPLIFIER TETRODE	E3	6A	D.C. H	30.0	0.4	TETRODE 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
							TETRODE PUSH-PULL CLASS A AMPLIFIER	125	−20.0	100	—	100.0♠	—	—	—	3000	5.0†	
49	DUAL-GRID POWER AMPLIFIER	D12	5C	D.C. F	2.0	0.12	CLASS A AMPLIFIER □	135	−20.0	—	—	6.0	4175	1125	4.7	11000	0.17	49
							CLASS B AMPLIFIER◆	180	0	—	—	4.0♠	—	—	—	12000	3.5†	
50	POWER AMPLIFIER TRIODE	F1	4D	F	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
53	TWIN TRIODE AMPLIFIER	D12	7B	H	2.5	2.0	AMPLIFIER	For other characteristics, refer to Type 6N7.										53
55	DUPLEX-DIODE TRIODE	D9	6G	H	2.5	1.0	TRIODE UNIT AS AMPLIFIER	For other characteristics, refer to Type 85.										55
56	SUPER-TRIODE AMPLIFIER DETECTOR★	D5	5A	H	2.5	1.0	AMPLIFIER DETECTOR	For other characteristics, refer to Type 76.										56
57	TRIPLE-GRID DETECTOR AMPLIFIER	D13	6F	H	2.5	1.0	AMPLIFIER DETECTOR	For other characteristics, refer to Type 6J7.										57
58	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	D13	6F	H	2.5	1.0	AMPLIFIER MIXER	For other characteristics, refer to Type 6U7-G.										58
59	TRIPLE-GRID POWER AMPLIFIER	E3	7A	H	2.5	2.0	TRIODE¶ CLASS A AMPLIFIER	250	−28.0	—	—	26.0	2300	2600	6.0	5000	1.25	59
							PENTODE** CLASS A AMPLIFIER	250	−18.0	250	9.0	35.0	40000	2500	100	6000	3.0	
							TRIODE● CLASS B AMPLIFIER	300 400	0 0	—	—	20.0♠ 26.0♠	—	—	—	4600 6000	15.0† 20.0†	
71-A	POWER AMPLIFIER TRIODE	D12	4D	F	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
75	DUPLEX-DIODE HIGH-MU TRIODE	D9	6G	H	6.3	0.3	AMPLIFIER	For other characteristics, refer to Type 6SQ7.										75
76	SUPER-TRIODE AMPLIFIER DETECTOR★	D5	5A	H	6.3	0.3	CLASS A AMPLIFIER	100 250	− 5.0 −13.5	—	—	2.5 5.0	12000 9500	1150 1450	13.8 13.8	—	—	76
								90♥ 300♥	Self-bias, 6500 ohms. Self-bias, 6400 ohms.	Grid Resistor, ** 0.25 megohm.						Gain per stage = 9 Gain per stage = 10		
							BIAS DETECTOR	250	−20.0 approx.	—	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
77	TRIPLE-GRID DETECTOR AMPLIFIER	D9	6F	H	6.3	0.3	CLASS A 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 Resistor, 250000 ohms. Grid Resistor,** 250000 ohms.				

TYPES 43 TO 77, INCLUSIVE

TYPES 78 TO 886, INCLUSIVE

(Applications and operation of voltage-regulator types VR-105-30, VR-150-30 are discussed in Chapter Fourteen.)

TYPE	NAME	DIMENSIONS SOCKET CONNECTIONS		CATHODE TYPE AND RATING			USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID BIAS ■ VOLTS	SCREEN SUPPLY VOLTS	SCREEN CURRENT MA.	PLATE CURRENT MA.	A-C PLATE RESISTANCE OHMS	TRANSCONDUCTANCE (GRID-PLATE) UMHOS	AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
		DIMEN.	S.C.	C.T.	VOLTS	AMP.												
78	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	D9	6F	H	6.3	0.3	AMPLIFIER MIXER	For other characteristics, refer to Type 6K7.										78
79	TWIN TRIODE AMPLIFIER	D9	6H	H	6.3	0.6	CLASS B AMPLIFIER	180 250	0 0	—	—	Power Output is for one tube at stated plate-to-plate load.				7000 14000	5.5 8.0	79
80	FULL-WAVE RECTIFIER	D12	4C	F	5.0	2.0	For other ratings, refer to Type 5Y4-G.											80
81	HALF-WAVE RECTIFIER	F1	4B	F	7.5	1.25	Maximum A-C Plate Voltage .... 700 Volts, RMS Maximum D-C Output Current .... 85 Milliamperes											81
82	FULL-WAVE ▶ RECTIFIER	D12	4C	F	2.5	3.0	Maximum A-C Voltage per Plate ...... 500 Volts, RMS Maximum D-C Output Current .... 125 Milliamperes					Maximum Peak Inverse Voltage ...... 1400 Volts Maximum Peak Plate Current .... 400 Milliamperes						82
83	FULL-WAVE ▶ RECTIFIER	E3	4C	F	5.0	3.0	Maximum A-C Voltage per Plate ...... 500 Volts, RMS Maximum D-C Output Current .... 250 Milliamperes					Maximum Peak Inverse Voltage ...... 1400 Volts Maximum Peak Plate Current .... 800 Milliamperes						83
83-v	FULL-WAVE RECTIFIER	D12	4L	H	5.0	2.0	For other ratings, refer to Type 5V4-G.											83-v
84/6Z4	FULL-WAVE RECTIFIER	D5	5D	H	6.3	0.5	Maximum A-C Voltage per Plate .... 350 Volts, RMS Maximum D-C Output Current .... 60 Milliamperes											84/6Z4
85	DUPLEX-DIODE TRIODE	D9	6G	H	6.3	0.3	TRIODE UNIT AS CLASS A AMPLIFIER	135 250	−10.5 −20.0	—	—	3.7 8.0	11000 7500	750 1100	8.3 8.3	25000 20000	0.075 0.350	85
89	TRIPLE-GRID POWER AMPLIFIER	D9	6F	H	6.3	0.4	AS TRIODE ¶ CLASS A AMPLIFIER	160 250	−20.0 −31.0	—	—	17.0 32.0	3300 2600	1425 1800	4.7 4.7	7000 5500	0.30 0.90	89
							AS PENTODE •• CLASS A AMPLIFIER	100 250	−10.0 −25.0	100 250	1.6 5.5	9.5 32.0	104000 70000	1200 1800	125 125	10700 6750	0.33 3.40	
							AS TRIODE ⊕ CLASS B AMPLIFIER	180	0	—	—	6.0♠	—	—	—	13600 9400	2.50† 3.50†	
V-99 X-99	DETECTOR ★ AMPLIFIER TRIODE	C4 D1	4E 4D	D.C. F	3.3	0.063	CLASS A AMPLIFIER	90	− 4.5	—	—	2.5	15500	425	6.6	—	—	V-99 X-99
112-A	DETECTOR ★ AMPLIFIER TRIODE	D12	4D	D.C. F	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	—	—	112-A
874	VOLTAGE REGULATOR	E4	4S	—	—	—	Minimum D-C Starting Supply Voltage ...... 125 Volts D-C Operating Voltage .... 90 Volts					D-C Operating Current .... 10-50 Ma. Maximum Current (Continuous) .... 50 Ma.						874
876	CURRENT REGULATOR	G1	—	F	—	—	Voltage Range .... 40 to 60 Volts					Operating Current .... 1.7 Amperes						876
886	CURRENT REGULATOR	G1	—	F	—	—	Voltage Range .... 40 to 60 Volts					Operating Current .... 2.05 Amperes						886

TYPE	NAME	DIMENSIONS SOCKET CONNECTIONS		CATHODE TYPE AND RATING			USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID BIAS ■ VOLTS	SCREEN SUPPLY VOLTS	SCREEN CURRENT MA.	PLATE CURRENT MA.	A-C PLATE RESISTANCE OHMS	TRANSCONDUCTANCE (GRID-PLATE) µMHOS	AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
		DIMEN.	S.C.	C.T.	VOLTS	AMP.												
1A7-GT	PENTAGRID CONVERTER□	C3	G-7Z	D.C. F	1.4	0.05	CONVERTER	For other characteristics, refer to Type 1A7-G.										1A7-GT
1D8-GT	DIODE-TRIODE-POWER AMPLIFIER PENTODE	C3	G-8AJ	D.C. F	1.4	0.1	PENTODE UNIT AS CLASS A₁ AMPLIFIER	45 90	− 4.5 − 9	45 90	0.3 1.0	1.6 5.0	300000 200000	650 925	— —	20000 12000	.035 .200	1D8-GT
							TRIODE UNIT AS CLASS A₁ AMPLIFIER	45 90	0 0	—	—	0.3 1.1	77000 43500	325 575	25 25	—	—	
1G4-G	DETECTOR AMPLIFIER TRIODE	D1	G-5S	D.C. F	1.4	0.05	CLASS A AMPLIFIER	90	− 6	—	—	2.3	10700	825	8.8	—	—	1G4-G
1H5-GT	DIODE HIGH-MU TRIODE	C3	G-5Z	D.C. F	1.4	0.05	TRIODE UNIT AS CLASS A₁ AMPLIFIER	For other characteristics, refer to Type 1H5-G.										1H5-GT
1N5-GT	R-F AMPLIFIER	C3	G-5Y	D.C. F	1.4	0.05	CLASS A₁ AMPLIFIER	90	0	90	0.3	1.2	1500000	750	—	—	—	1N5-6T
1Q5-GT	BEAM POWER AMPLIFIER	C3	G-6X	D.C. F	1.4	0.1	CLASS A POWER AMPLIFIER	90	− 4.5	90	1.6	9.5	—	2100	—	8000	0.27	1Q5-GT
1T5-GT	BEAM POWER AMPLIFIER	C3	G-6X	D.C. F	1.4	0.050	CLASS A₁ AMPLIFIER (Single tube)	90	− 6	90	1.4	6.5	—	1150	—	14000	0.17	1T5-GT
6AB7/ 1853	TELEVISION AMPLIFIER PENTODE	B3	8N	H	6.3	0.45	R-F AMPLIFIER	300	− 3 min. (See transconductance)	200	3.2	12.5	700000 (Approx.)	5000 (50, at $E_c = 22.5$)	3500 (Approx.)	—	—	6AB7/ 1853
6AC7/ 1852	TELEVISION AMPLIFIER PENTODE	B3	8N	H	6.3	0.45	R-F AMPLIFIER	300	Self bias 160 ohms min.	150	2.5	10	750000 (Approx.)	9000	6750 (Approx.)	—	—	6AC7/ 1852
6AG7	VIDEO BEAM POWER AMPLIFIER	C2	8Y	H	6.3	0.65	VIDEO VOLTAGE AMPLIFIER—CLASS A	300	−10.5	300	6.5	25	100000	7700	770	—	—	6AG7
6B5	DUAL-TRIODE DIRECT-COUPLED POWER AMPLIFIER	D12	6D	H	6.3	0.8	CLASS A AMPLIFIER	300	0	Input Triode (T_1)		9	24000	G_{T_1} to P_{T_2} 2400	58	—	—	6B5
								300	0	Output Triode (T_2)		42	24000		58	—	4	

6F5-GT	HIGH-MU TRIODE	C3	G-6M‡	H	6.3	0.3	CLASS A AMPLIFIER	For other characteristics, refer to Type 6SF5.										6F5-GT
6J5-GT	DETECTOR AMPLIFIER TRIODE	C3	G-6Q‡	H	6.3	0.3	CLASS A AMPLIFIER	For other characteristics, refer to 6J5.										6J5-GT
6J7-GT	TRIPLE-GRID DETECTOR AMPLIFIER	C3	GT-7R	H	6.3	0.3	CLASS A R-F AMPLIFIER	For other characteristics, refer to 6J7.										6J7-GT
6K6-GT	POWER AMPLIFIER PENTODE	C3	G-7S‡	H	6.3	0.4	CLASS A₁ AMPLIFIER	180 250	−13.5 −18.0	180 250	3 5.5	18.5 32	81000 68000	1850 2200	150 150	9000 7600	1.5 3.4	6K6-GT
6N6-G	DUAL-TRIODE DIRECT-COUPLED POWER AMPLIFIER	D12	G-7W	H	6.3	0.8	CLASS A AMPLIFIER	For other characteristics, refer to Type 6B5.										6N6-G
6P5-G	DETECTOR AMPLIFIER TRIODE	D3	G-6Q‡	H	6.3	0.3	CLASS A₁ AMPLIFIER	250	−13.5	—	—	5	9500	1450	13.8	—	—	6P5-G
6V6-GT	BEAM POWER AMPLIFIER	C3	G-7AC‡	H	6.3	0.45	SINGLE-TUBE CLASS A₁ AMPLIFIER	180 250	− 8.5 −12.5	180 250	3.0 4.5	29.0 45.0	— 52000	— 4100	— —	5500 5000	2.00 4.25	6V6-GT
							PUSH-PULL CLASS AB₁ AMPLIFIER	For other characteristics, refer to Type 6V6.										
12J7-GT	TRIPLE-GRID DETECTOR AMPLIFIER	C3	GT-7R	H	12.6	0.15	CLASS A AMPLIFIER	For other characteristics, refer to Type 6J7.										12J7-GT
1851	TELEVISION AMPLIFIER PENTODE	C4	7R	H	6.3	0.45	R-F AMPLIFIER	300 300	(Self-bias 160 ohms min.)	150 300	2.5 2.5	10 10	75000 75000	9000 9000	6750 6750	— —	— —	1851
1852	TELEVISION AMPLIFIER PENTODE	B3	8N	H	6.3	0.45	R-F AMPLIFIER	For other characteristics, refer to Type 6AC7.										1852
1853	TELEVISION AMPLIFIER PENTODE	B3	8N	H	6.3	0.45	R-F AMPLIFIER	For other characteristics, refer to Type 6AB7.										1853
35Z5-GT	HIGH-VACUUM HALF-WAVE RECTIFIER (With Heater Tap for Pilot Lamp)	C3	G-6AD	H	35	0.150	HALF-WAVE RECTIFIER	Maximum A-C Plate Voltage .... 125 Volts, RMS Maximum D-C Output Current— (With Type 40 Pilot Lamp and Plate-to-Heater Tap Connection) .... 50 Milliamperes Maximum D-C Output Current— (Without Type 40 Pilot Lamp, and no Plate-to-Heater Tap Connection) ....100 Milliamperes										35Z5-GT
50L6-GT	BEAM POWER AMPLIFIER	C3	G-7AC‡	H	50	0.150	SINGLE-TUBE CLASS A₁ AMPLIFIER	110	− 7.5	110	4	49	10000 (Approx.)	8200	82	1500 2000	2.1 2.2	50L6-GT

EXPLANATION OF SYMBOLS APPEARING IN PRECEDING TABLES.

★ For Grid-leak Detection—plate volts 45, grid return to + filament or to cathode.

■ Either A. C. or D. C. may be used on filament or heater, except as specifically noted. For use of D.C. on A-C filament types, decrease stated grid volts by ½ (approx.) of filament voltage.

↘ Supply voltage applied through 20000-ohm voltage-dropping resistor.

➤ Mercury-Vapor Type.

▪▪ Grid #1 is control grid. Grid #2 is screen. Grid #3 tied to cathode.

¶ Grid #1 is control grid. Grids #2 and #3 tied to plate.

● Grids #1 and #2 connected together. Grid #3 tied to plate.

⊚ Grids #3 and #5 are screen. Grid #4 is signal-input control grid.

▲ Grids #2 and #4 are screen. Grid #1 is signal-input control grid.

•• For grid of following tube.

° Both grids connected together; likewise, both plates.

† Power output is for two tubes at stated plate-to-plate load.

♠ For two tubes.

‡ This diagram is like the one having the same designation without the prefix G, except that Pin No. 1 has no connection.

♦ This diagram is like the one having the same designation without the prefix G, except that Pin No. 2 is omitted and Pin No. 1 has no connection.

♣ Obtained preferably by using 70000-ohm voltage-dropping resistor in series with a 90-volt supply.

‡‡ This diagram is like the one having the same designation without the prefix G, except that Pin No. 1 is connected to internal shield.

● Applied through plate resistor of 250000 ohms or 500-henry choke shunted by 0.25-megohm resistor.

♥ Applied through plate resistor of 100000 ohms.

✖ Applied through plate resistor of 250000 ohms.

◒ 50000 ohms.

▰ Requires different socket from small 7-pin.

□ Grid #2 tied to plate. ♦ Grids #1 and #2 tied together.

❢ Plate voltages greater than 125 volts RMS require 100-ohm (minimum) series-plate resistor.

°° Applied through plate resistor of 150000 ohms.

◖ For signal-input control-grid (#1); control-grid #3 bias, −3 volts.

■ Applied through 200000-ohm plate resistor.

Note 1: Types with octal bases have *Miniature Metal Cap;* all others have *Small Metal Cap.*

Note 2: Subscript 1 on class of amplifier service (as AB_1) indicates that grid current does not flow during any part of input cycle.

Subscript 2 on class of amplifier service (as AB_2) indicates that grid current flows during some part of the input cycle.

▲ Grids #2 and #4 are screen. Grid #3 is signal-input control grid.

*Maximum.

§ Megohms.

KEY TO TUBE DIMENSIONS

Symbol	Maximum Overall Length x Diameter	Symbol	Maximum Overall Length x Diameter	Symbol	Maximum Overall Length x Diameter	Symbol	Maximum Overall Length x Diameter	Symbol	Maximum Overall Length x Diameter
A1	1 3/4" x 1 3/16"	C3	3 5/16" x 1 3/16"	D5	4 3/16" x 1 9/16"	D11	4 11/16" x 1 7/16"	E4	5 5/8" x 2 3/16"
B1	2 5/8" x 1 1/16"	C4	3 1/2" x 1 1/16"	D6	4 5/16" x 1 3/16"	D12	4 11/16" x 1 13/16"	F1	6 1/4" x 2 7/16"
B2	2 5/16" x 1 3/16"	D1	4" x 1 3/16"	D7	4 5/16" x 1 5/8"	D13	4 15/16" x 1 9/16"	G1	8" x 2 1/16"
B3	2 5/8" x 1 3/16"	D2	4 1/8" x 1 3/16"	D8	4 15/32" x 1 9/16"	E1	5 1/32" x 1 13/16"		
C1	3 1/2" x 1 5/16"	D3	4 1/8" x 1 9/16"	D9	4 17/32" x 1 9/16"	E2	5 5/16" x 2 1/16"		
C2	3 1/4" x 1 5/16"	D4	4 3/16" x 1 3/16"	D10	4 5/8" x 1 13/16"	E3	5 3/8" x 2 1/16"		

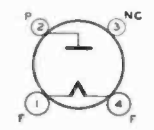
SOCKET CONNECTIONS

Bottom Views

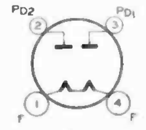
KEY TO TERMINAL DESIGNATIONS OF SOCKETS

Alphabetical subscripts D, P, T, and HX indicate, respectively, diode unit, pentode unit, triode unit, and hexode unit in multi-unit types.

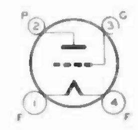
BP = Bayonet Pin
F = Filament
G = Grid
RC = Ray-Control Electrode
H = Heater
K = Cathode
NC = No Connection
P = Plate (Anode)
P_1 = Starter-Anode
P_{BF} = Beam-Forming Plates
S = Shell
TA = Target
● = Gas-Type Tube
U = Unit



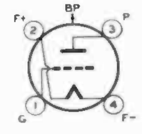
4B



4C



4D



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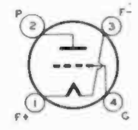
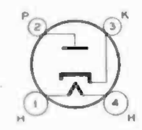
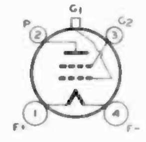


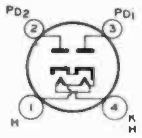
4F



4G



4K



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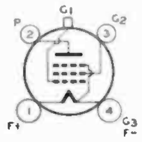

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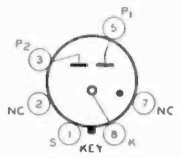

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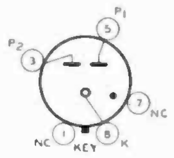

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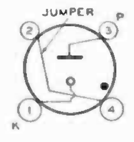

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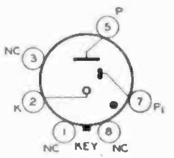

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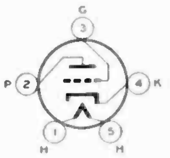

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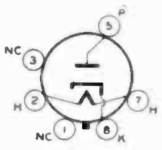

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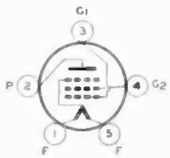

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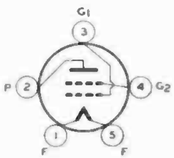

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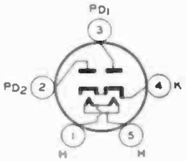

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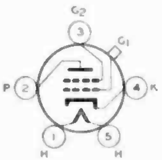

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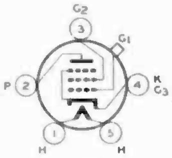

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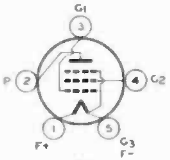

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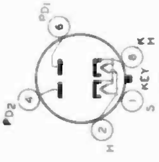

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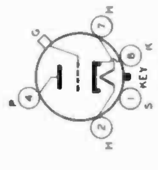

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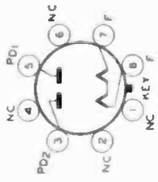

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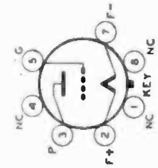

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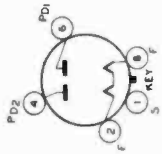

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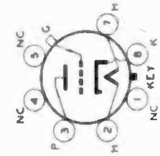

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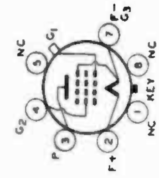

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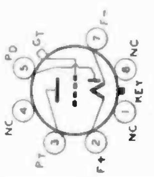

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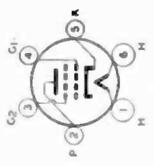

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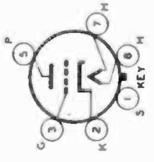

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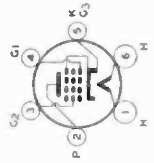

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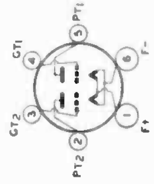

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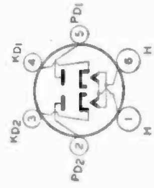

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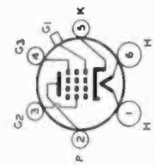

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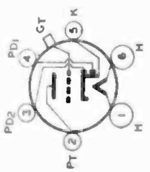

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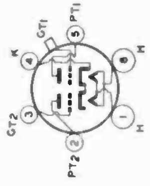

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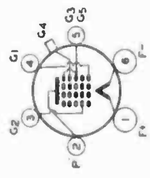

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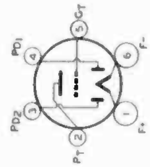

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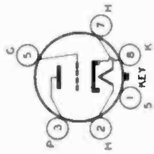

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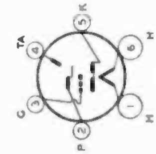

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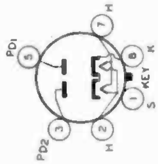

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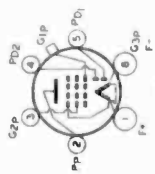

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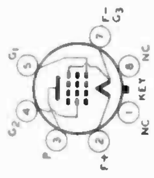

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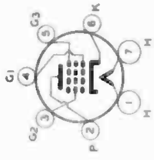

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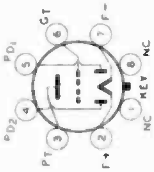

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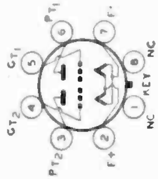

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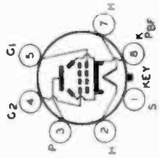

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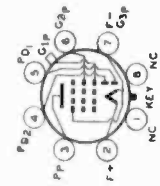

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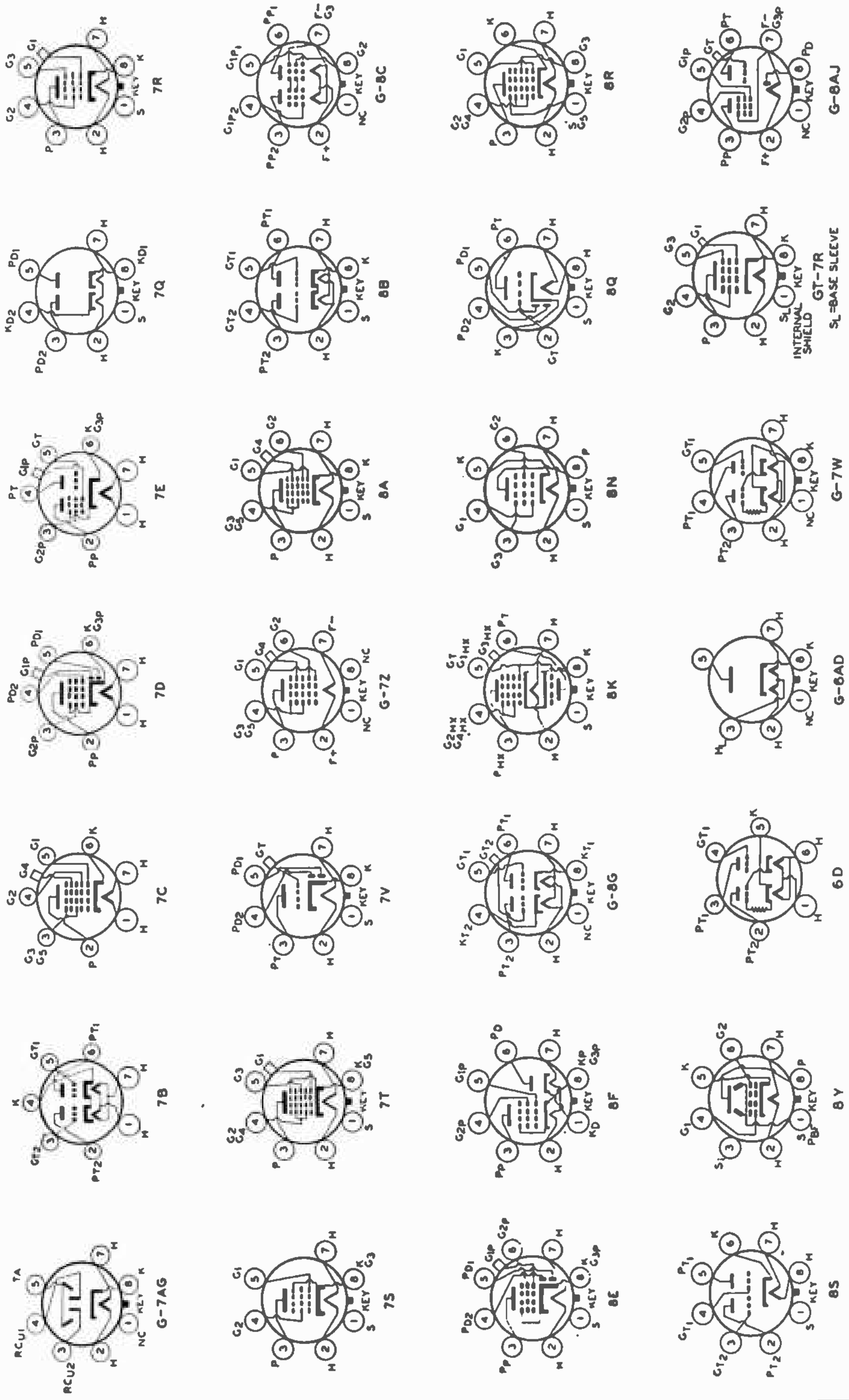


SOCKET CONNECTIONS FOR RECENTLY-RELEASED TYPES

SIX

Radio Receiver Construction

THE receivers described in this chapter can, for the most part, be constructed with a few inexpensive hand tools. Whether one saves anything over purchasing a factory built receiver depends upon several factors (see *chapter 19*). In any event, there is the satisfaction of constructing one's own equipment, and the practical experience that can be gained only by actually building apparatus.

After finishing the wiring job it is suggested that one go over the wiring very carefully to check for errors before applying plate voltage to the receiver. If possible, have someone else check the wiring after you have gone over it yourself. Some tubes can be damaged permanently by having screen voltage applied when there is no voltage on the plate. Electrolytic condensers can be damaged permanently by hooking them up backwards (wrong polarity). Transformer, choke, and coil windings can be burned out by incorrect wiring of the high voltage leads. Most any tube can be damaged by hooking up the elements incorrectly; no tube can last long with plate voltage applied to the control grid.

Before starting construction it is suggested that one read the chapter on *Workshop Practice.*

SIMPLE TWO-TUBE AUTODYNE

A simple yet versatile receiver of modest cost is illustrated in figures 1, 2, and 4. The receiver uses an autodyne detector and one stage of impedance coupled a.f. to give good earphone volume on all signals. The circuit is quite simple, as inspection of figure 3 will disclose.

The receiver uses 6.3-volt tubes, which may be supplied heater power from either a small 6.3 volt filament transformer or a regular 6-volt auto battery. For regular home use a transformer is recommended, but the provision for use with a battery permits semi-portable operation. This makes the receiver a good one for a beginner, as it can be used as a portable or emergency receiver later on should one decide to build or buy a more elaborate receiver.

Plate voltage is supplied from a standard, medium-duty 45-volt B battery. Such a battery, costing only a little over a dollar, will last over a year with normal

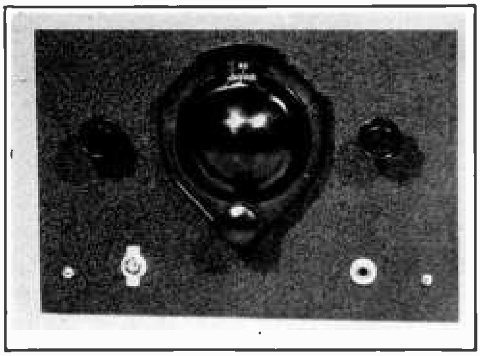


Figure 1.

SIMPLE TWO-TUBE AUTODYNE RECEIVER.

This receiver is inexpensive to build, and has excellent weak-signal response. While not as selective as more elaborate receivers, it makes a good set for the newcomer's first receiver.

Figure 2.

BACK VIEW OF THE TWO-TUBE AUTODYNE.

The chassis is made of wood and Masonite wall board. The "shield hat" for the grid leak and condenser hide most of the main tuning condenser.

use, as the B current drain of the receiver is only a few milliamperes. This voltage is sufficient for good performance of the receiver, because the full plate voltage is supplied to the detector as a result of the use of a choke (CH_1) instead of the usual plate resistor in the plate circuit of the detector. Also, the *amplification* of the 6C5 is practically as great at 45 volts as at the full maximum rated voltage of 250 volts. The maximum undistorted power output of the a.f. stage is considerably less at 45 volts, but as it is more than sufficient to drive a pair of phones, there is no point in using higher plate voltage. For these reasons a single B battery was decided upon in preference to an a.c. power pack, because the battery is not only much less expensive but permits portable operation.

When wired as shown in the diagram, the receiver should not be used with higher plate voltage, because the screen potentiometer is across the full plate voltage, and also because the 1¼-volt bias on the 6C5 is not sufficient for higher plate voltage.

The receiver can be built for about $12, including B battery and midget filament transformer, provided inexpensive components are chosen.

While the receiver will operate on 10 meters and a 10 meter coil is included in the coil table, the receiver is designed primarily for 20-, 40-, and 80-meter operation. No matter how well constructed, an autodyne receiver is not particularly effective on 10 meters, especially on phone. No provision was made for 160-meter operation, as the receiver does not have sufficient selectivity to distinguish between several very loud phone signals in the same part of the band.

For 20-, 40-, and 80-meter operation

COIL TABLE

For Two-Tube Autodyne

All coils wound with no. 22. d.c.c. on standard 1½-inch forms

80 M.	29 turns close wound; cathode tap 1½ turns from ground
40 M.	16 turns spaced 1¾ inches; cathode tap 1½ turns from ground
20 M.	7 turns spaced 1¼ inches; cathode tap 1½ turns from ground
10 M.	4 turns spaced 1¼ inches; cathode tap 1 turn from ground

C_1 — 15-$\mu\mu$fd. midget variable
C_2 — 100-$\mu\mu$fd. midget variable
C_3—100-$\mu\mu$fd. smallest size mica condenser
C_4 — 0.25-μfd. tubular, 400 v.
C_5 — .0005-μfd. midget mica
C_6 — .01-μfd. tubular, 400 v.
R_1—3 meg., ½ watt
R_2—50,000 ohm pot.
R_3—0.25 meg., ½ watt
R_4—0.5 meg., ½ watt
BC—1¼-volt bias cell
CH_1—300 or more hy., 5 ma.
L_1—See coil table

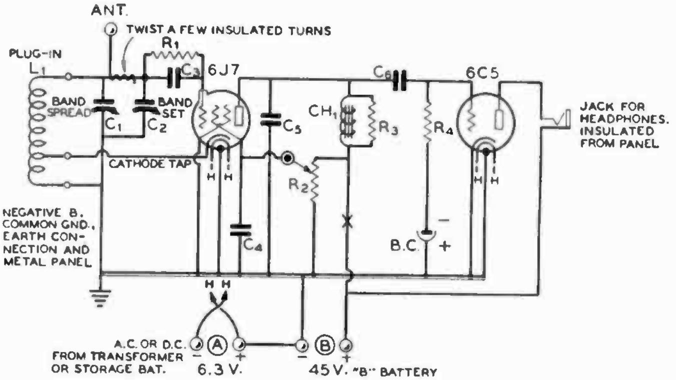


Figure 3.

WIRING DIAGRAM OF TWO-TUBE AUTODYNE.

the receiver compares favorably with the most expensive when it comes to picking up weak, distant stations, especially on c.w. However, loud local signals have a tendency to block it, and therefore more trouble will be experienced with QRM than with a superheterodyne.

The chassis consists of a 6 x 9 inch Masonite "presdwood" top and 1¾-inch back of the same material. These are fastened to two pieces of wood which form the sides of the chassis. The wooden sides are 1¾ inch high, ¾ inch thick, and are 6 inches long, *including* the Masonite back. The whole thing is held together with wood screws as may be seen in figures 2 and 4, and a 7-inch by 11-inch metal front panel is attached to the chassis by means of wood screws sunk in the wooden end pieces of the chassis.

Inexpensive wafer sockets are used. Because the thickness of the chassis would make it necessary to drill holes large enough to take the whole tube base if the sockets were mounted below the chassis as is customary with metal chassis, the sockets are mounted on *top* of the chassis. This is clearly illustrated in the photographs.

Correct connection of the socket terminals can be assured by referring to the socket connections for the 6J7 and 6C5

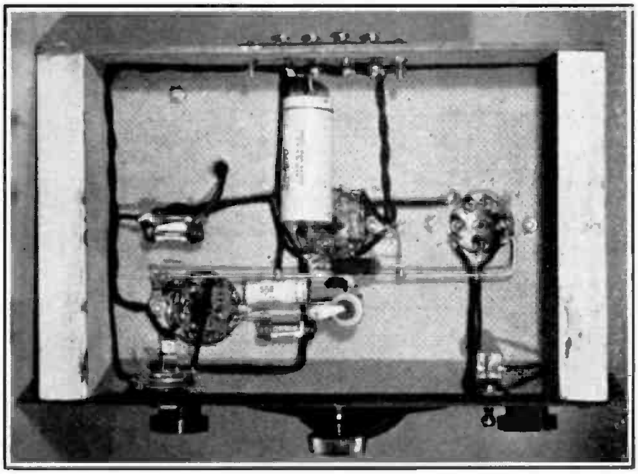


Figure 4.

UNDER-CHASSIS VIEW OF TWO-TUBE AUTODYNE.

The construction of the chassis and placement of components is clearly illustrated. If desired the phone jack may be mounted on the back of the chassis.

in *chapter 5*. Bear in mind that these are bottom views of the sockets, with the socket facing you the same as when soldering to the terminals from the underside of the chassis.

Connections for filament and plate power are made by means of a terminal strip which is mounted over a hole cut in the back of the chassis. If you do not have the proper tools for cutting out a long, rectangular hole, four separate holes about ⅜ inch in diameter will take the terminal screws and lugs. If desired, the terminal strip can be replaced by four Fahnestock clips screwed directly to the back of the chassis.

The phone jack is shown mounted on the front panel, along with a toggle switch in the B plus lead. If mounted on the metal front panel, the phone jack must be insulated from the panel by means of fiber washers to prevent shorting the plate voltage. The jack could just as well be mounted on the back of the chassis, in which case it would not require insulating washers.

The screen potentiometer is across the B battery and draws a small amount of current even with the filaments turned off; hence it is necessary either to unhook the B battery when the set is not in use or else incorporate a switch to accomplish the same thing. If desired a potentiometer with an "off switch" can be used, in which case the B battery is disconnected simply by turning the potentiometer knob all the way to the left. The heaters are turned off by turning off the 110-volt supply to the filament transformer.

As is true with any grid leak type detector, the grid lead (including the grid leak and condenser) must be shielded thoroughly in order to avoid bad hum pickup, commonly known as "grid hum." This is accomplished effectively by soldering the grid leak and grid condenser (both of the smallest physical size procurable) directly to the grid clip and shielding the whole business by means of a "hat" consisting of a regular metal tube grid shield cap to which is soldered a rectangular piece of tin or galvanized iron as shown in the illustration. The latter measures about 1½ by 3 inches and is bent in the form of a "U," then soldered to the grid clip shield. Care must be taken that the shield does not short out against any of the connecting leads.

The antenna may consist of a 50 to 100 foot length of wire as high and in clear as possible. It is capacity coupled to the receiver by means of a few turns of insulated wire around the grid lead. A small 3-30 $\mu\mu$fd. compression type mica trimmer may be substituted as a variable coupling condenser if desired.

After the correct position of the bandset condenser (C_2) is determined for a given band, a scratch or mark is made on the back rotor plate to enable one to adjust the bandset condenser for any band simply by observing the marks on the bandset condenser.

Because of the low plate voltage and loose antenna coupling this receiver does not radiate to an objectionable degree when in an oscillating condition.

SIMPLE THREE-TUBE SUPERHETERODYNE

The small superheterodyne shown in the accompanying illustrations has practically all of the advantages of sets having many more tubes. It has excellent image rejection, selectivity and sensitivity,

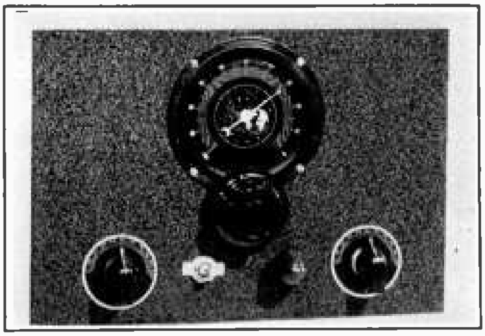


Figure 5.

SIMPLE THREE-TUBE SUPERHETERODYNE.

The bandset condenser is to the left, the detector "resonating" condenser to the right. The latter makes an effective volume control. The small knob operates the regeneration potentiometer.

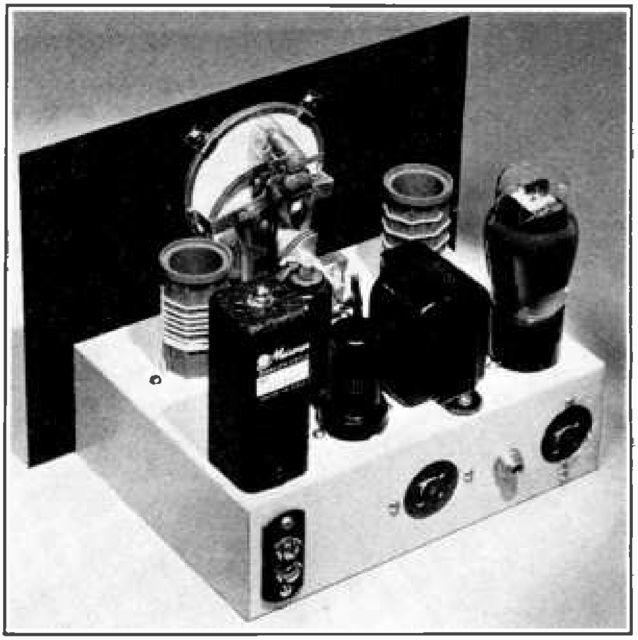


Figure 6.

REAR VIEW OF THE SIMPLE SUPER.

The detector coil is to the left, directly above the detector tuning condenser, and the oscillator coil is to the right. Antenna terminals, power socket, speaker plug socket, and earphone jack may be seen on the back drop of the chassis.

and drives either phones or a dynamic loudspeaker to good volume.

A 6K8 converter directly feeds a regenerative second detector operating just above 1500 kc. The latter is impedance coupled to a beam tetrode audio tube. The plate current and audio power output are too great for a pair of phones; so the phones are connected in the screen circuit.

Excellent selectivity and sensitivity are obtained on phone by running up the regeneration on the second detector right to the edge of oscillation. By advancing the regeneration control still farther the second detector will oscillate, thus providing autodyne reception of code signals. The regeneration also acts as a sensitivity control to prevent blocking by very loud local signals. To keep loud phone signals from blocking, the regeneration is decreased way below the edge of oscillation. To keep loud c.w. signals from blocking, the regeneration control is advanced full on.

The 6K8 converter is conventional and no special precautions need be taken with this stage except to keep the first detector leads as short as possible in order to obtain maximum performance on 10 meters. A minimum number of coils is required for all-band operation (10 to 160 meters) because the oscillator coil for each band serves as the detector coil for the next higher frequency band, the tickler serving as the antenna winding. Thus all coils except the 160-meter detector and 10-meter oscillator coils do double duty.

The set is built on a metal chassis measuring 2½ inches by 6 inches by 8 inches. This supports a 7-inch by 10-inch front panel. The correct placement of components may be determined by referring to the illustrations.

To obtain regeneration in the grid leak type second detector, a tickler coil is added to the i.f. transformer. Inspection of figure 7 will show that the second detector then resembles the common "autodyne" grid leak detector with regeneration control.

For maximum performance, the detector should go into oscillation when the screen voltage is about 35 volts. This is accomplished by using as a tickler 3 turns of no. 22 d.c.c. wound around the dowel of the i.f. transformer, right against the grid winding. Few tickler

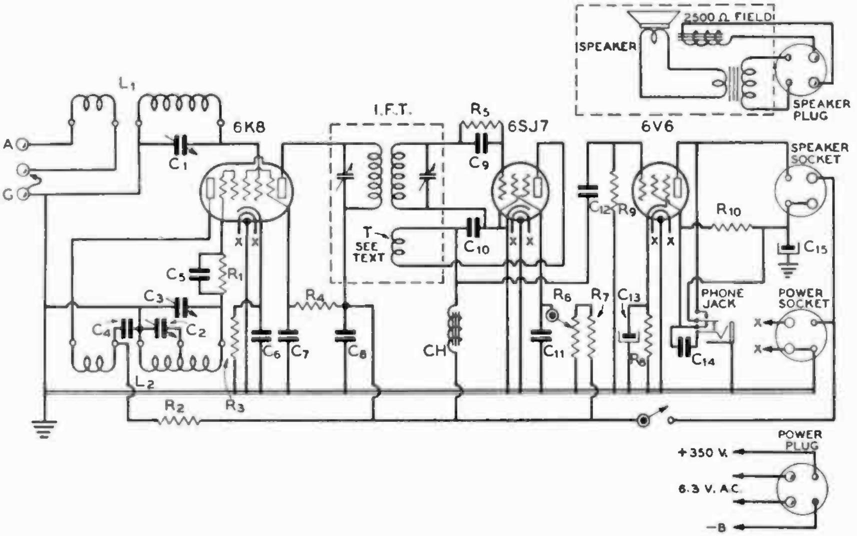


Figure 7.

WIRING DIAGRAM OF THE SIMPLE SUPER.

C_1, C_2—50-μμfd. midget variable
C_3 — 140-μμfd. midget variable
C_4, C_8, C_{11}, C_{14}—0.1-μfd. tubular, 400 v.
C_5, C_9—.0001-μfd. tubular, 600 v.
C_6, C_7, C_{12}—.01-μfd. tubular, 600 v.
C_{10} — .001-μfd. tubular, 600 v.
C_{13}—25-μfd. 25 v. electrolytic
C_{14}—4-μfd. 450 v. midget tubular electrolytic
R_1, R_2—50,000 ohms, 1½ watts
R_3—300 ohms, 1 watt
R_4—40,000 ohms, 1½ watt
R_5—5 meg. insulated ½ watt resistor
R_6—100,000 ohm potentiometer
R_7—100,000 ohms, 1½ watt
R_8—400 ohms, 10 watts
R_9—300 ohms, 1½ watt
R_{10} — 10,000 ohms, 10 watts
IFT—1500 kc. replacement type i.f. trans. (see text for tickler data)
CH — High impedance audio choke, 500 or more hy.
Phone Jack—Two circuit "filament lighting" type

turns are required, as there is no antenna to load the detector, and therefore it goes into oscillation with but little feedback.

To wind the tickler, simply remove the shield from the i.f. transformer and using a foot length of the same d.c.c. used to wind the plug in coils, wrap three turns around the dowel as closely as possible to the grid winding. Then twist the two leads together to keep the turns in place and replace the shield. The polarity of the tickler must be correct for regeneration; if oscillation is not obtained, reverse the two tickler leads.

Care must be taken with the grid leak, grid condenser, and grid lead of the 6SJ7; otherwise there will be "grid hum." The outside foil of the tubular grid condenser should go to the i.f. grid coil and *not* to the grid of the tube. Connection to the grid pin of the 6SJ7 socket should be kept as short as possible—not over a half inch, and both grid leak and grid condenser should be kept at least a half inch from other wiring. In some cases it may be necessary to shield the grid leak and condenser with a small piece of grounded tin in order to eliminate grid hum completely.

The phone jack is a special type, commonly called a two-circuit "filament lighting" jack. It is connected so that when the phones are inserted they not only are connected in the screen circuit in such a way that no d.c. flows through the phones, but the speaker transformer is shorted out in order to silence the speaker. Switching the plate of the 6V6 directly to B plus also improves the quality in the phones slightly.

Any well-filtered power supply delivering between 300 and 375 volts at 50 ma. can be used to supply the receiver.

Either a two-wire feeder or single-wire antenna worked against ground can be used. For doublet input, connect to the two antenna coil terminals. For Marconi input, ground one terminal and connect the antenna to the other.

Adjusting the mica trimmer on the grid coil of the i.f.t. changes the i.f. frequency. The trimmer on the plate coil should always be resonated for maximum signal strength. It need not be touched after the initial adjustment unless the grid trimmer is changed. The i.f. frequency should be adjusted to about 1550 kc. and then a check made to make sure it is not right on some nearby police or high fidelity broadcast station.

The only band on which images might be bothersome is the 10-meter band. In most cases objectionable images can be eliminated without serious loss in signal strength by shifting the h.f. oscillator to the other side by means of the band set condenser. The receiver will work with the oscillator either *higher or lower* by the i.f. frequency than the received signal. On the higher frequency bands the bandset condenser tunes over a wide enough band of frequencies that it hits both sides.

On certain bands the gain and sensitivity are better with the h.f. oscillator on one side of the detector than on the other.

COIL TABLE

For Simple Super

160-M. Det.

58 turns no. 24 enam. close wound on 1½ in. form, padded with 50 μμfd. midget mica fixed condenser placed inside form. Ant. coil 14 turns close wound at ground end spaced ¼ in. from grid winding.

160-M. Osc.—80-M. Det.

42 turns no. 22 d.c.c. close wound on 1½ in. form. Bandspread tap 20 turns from ground end. Tickler 9 turns close wound, spaced 1/16 in. from main winding.

80-M. Osc.—40-M. Det.

20 turns no. 22 d.c.c. spaced to 1½ in. on 1½ in. form. Bandspread tap 12 turns from ground end. Tickler 8 turns close wound, spaced ⅛ in. from main winding.

40-M. Osc.—20-M. Det.

11 turns no. 22 d.c.c. spaced to 1¼ in. on 1½ in. form. Bandspread tap 5 turns from ground end. Tickler 6 turns close wound, spaced ⅛ in. from main winding.

20-M. Osc.—10-M. Det.

5½ turns no. 22 d.c.c. spaced to 1 in. on 1¼ in. form. Bandspread tap 3 turns from ground end. Tickler 4 turns close wound, spaced 1/16 in. from main winding.

10-M. Osc.

3 turns no. 22 d.c.c. spaced to 1 in. on 1¼ in. form. Bandspread tap 1½ turns from ground end. Tickler 2 turns close wound, spaced 1/16 in. from main winding.

Tickler is always at ground end of main coil. Note that two highest frequency coils are on 1¼ in. forms, rest 1½ in. Tickler polarity must be correct or mixer will not oscillate.

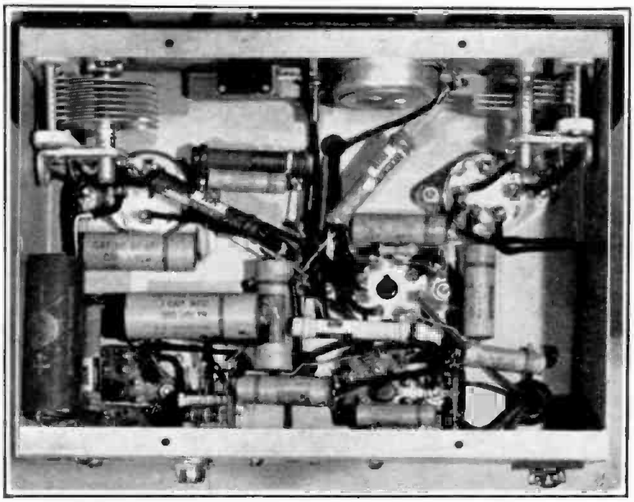


Figure 8.

UNDER-CHASSIS VIEW OF SIMPLE SUPER.

Not much room to spare, but all components fit without crowding. The phone jack is mounted directly on the rear drop of the metal chassis; because of the method of connection, no insulating washers are required.

Some experimenting with the bandset condenser should be made on those bands where it is possible to hit both the high and low side with the bandset condenser.

"SUPER GAINER" SUPERHETERODYNE

Illustrated in figures 9, 10, and 11 is the latest version of the famous Super Gainer first brought out by Jones several years ago and since improved from time to time.

This receiver is of the same general type as the simple superheterodyne just described, except that the first detector is made regenerative and the a.f. system is designed specifically for earphone output. While having only two tubes (a 6A6 dual triode is used as both second detector and a.f. stage), the receiver is a little more difficult to get going because of the regenerative first detector and ganged tuning, the latter requiring more accurate coil alignment. However, when constructed and adjusted properly, the receiver has somewhat greater sensitivity and image rejection than the Simple Super of figure 7.

The second detector is used in an oscillating condition for reception of c.w. signals and just below the point of oscillation for phone signals. The first detector is always worked just below the point of oscillation for both phone and c.w. signals.

What with use of a regenerative first detector and a relatively high intermediate frequency, image interference is not troublesome even on the highest frequency bands.

For maximum stability and gain, the h.f. oscillator tank is made considerably higher C than the detector coil. By proportioning of the two sections of the gang condenser and use of a .005-μfd. mica padder, it is possible to get each set of coils to track over an amateur band by correct setting of the trimmer and bandset condensers on the front panel.

The trimmer on the first detector also allows one to compensate for detuning effects of the antenna, thus enabling one to get the circuits to track exactly. The latter is necessary if full use is to be made of the regenerative gain.

Grid leak detection allows smooth control of regeneration at the intermediate frequency. The second detector is resistance-coupled to the other section of the 6A6 and has an RC filter in its plate lead to cut down on the filtering requirements of the power supply. Any moderately well-filtered supply delivering from 180 to 250 volts and capable of handling 15 ma. will be satisfactory.

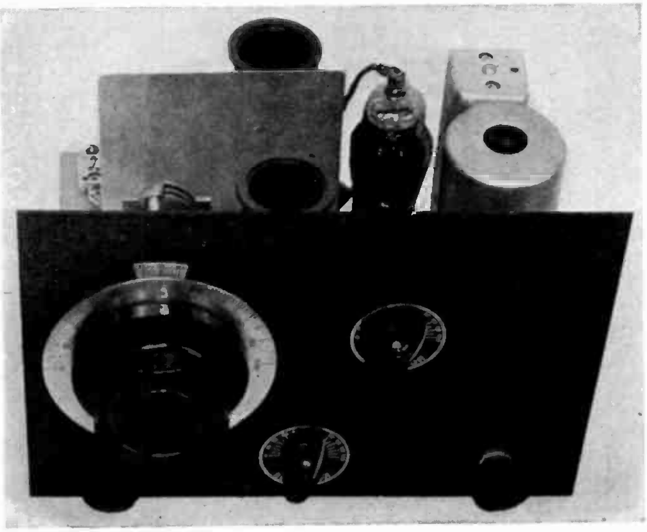


Figure 9.

FRONT PANEL VIEW OF THE POPULAR "SUPER-GAINER" TWO - TUBE SUPERHETERODYNE.

While looking like an ordinary dial, the main tuning dial has a vernier action of the planetary type, permitting fine tuning.

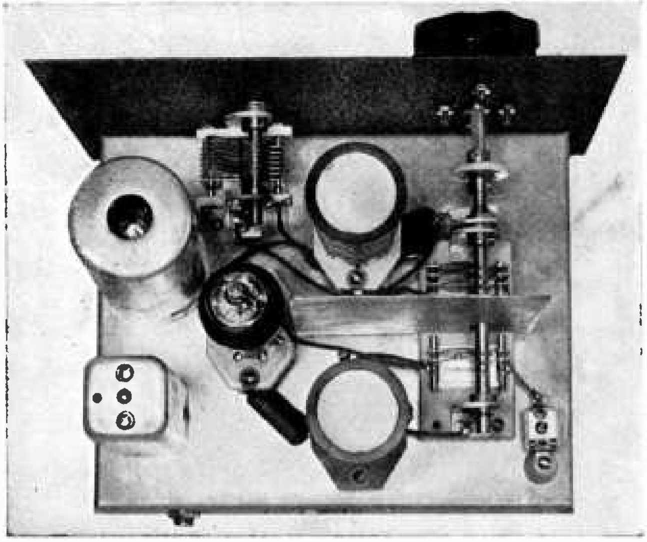


Figure 10.

LOOKING DOWN ON THE "SUPER-GAINER."
The oscillator section is toward the front panel, the detector to the rear; a shielding partition separates the two.

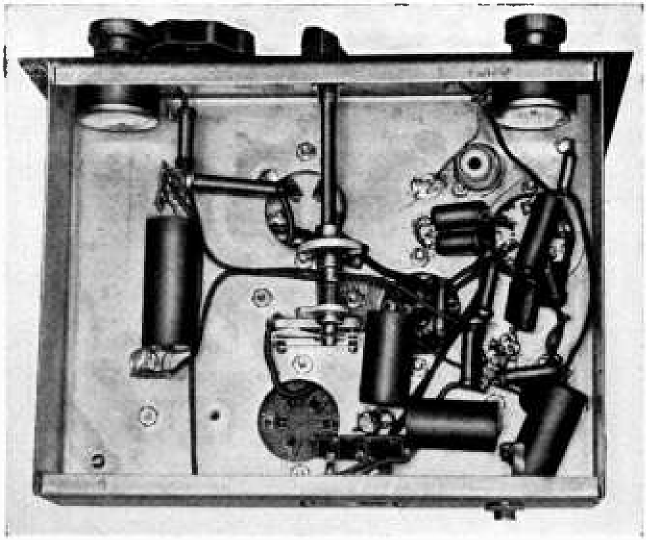


Figure 11.

UNDER THE SUPER-GAINER.
Regeneration controls, 6A6 cathode coil, first detector trimmer and various by-pass condensers are found under the "Super-Gainer" chassis. Note how the detector trimmer is tuned by means of an extension shaft. It is set back from the panel to permit shorter leads.

Resembling an ordinary type dial, the main tuning dial is a vernier dial of the planetary drive type. Because the two-gang main tuning condenser is set back from the front panel in the interest of short leads, a coupling and short piece of shaft are necessary. Though the insulation is not necessary, an insulated coupling of the flexible type is advisable because it is then not necessary to get the dial and condenser mounted in perfect alignment.

The tuning condenser is a 30-$\mu\mu$fd.-per-section two-gang double-spaced midget. Be sure to get a *tapered plate* type and not the straight line capacity (semicircular) plate type. Plates are removed until the maximum capacity of the detector section is approximately half the maximum capacity of the oscillator section. This can be done by removing plates from the detector section until the rotor-to-stator dielectric spaces are half those in the oscillator section. The condenser

SUPER-GAINER COIL TABLE

BAND	OSCILLATOR 1½" Diam. Forms		DETECTOR 1½" Diam. Forms	
	Plate	Grid	Grid	Cathode
160	26 turns #22 d.c.c. closewound	15 turns #26 d.c.c. closewound	85 turns #26 enam. closewound	9 turns #26 enam. closewound
80	17 turns #20 d.c.c. 1" long	9 turns #26 d.c.c. closewound	40 turns #24 d.c.c. 1¼" long	7 turns #26 d.c.c. closewound
40	10½ turns #20 d.c.c. 1" long	6 turns #26 d.c.c. closewound	21 turns #22 d.c.c. 1¼" long	5 turns #26 d.c.c. closewound
20	5 turns #20 d.c.c. 1" long	4½ turns #26 d.c.c. closewound	10 turns #20 d.c.c. 1¼" long	3½ turns #26 d.c.c. closewound
10	2 turns #18 enam. ½" long	2¾ turns #26 d.c.c. closewound	4-1/3 turns #18 enam. ¾" long	2 turns #26 d.c.c. closewound

shown in the illustration originally had three stator and four rotor plates in each section (six spaces). Plates were removed from the back section until two rotor and two stator plates remained (three spaces).

The .005-μfd. series padder in the oscillator tank circuit should be of the mica type and be of good quality in order to avoid frequency drift.

Referring to the front panel (figure 9), the top pointer-type knob is the oscillator bandset condenser. The lower pointer is the first detector trimmer. The plain knob at the lower left is the first detector regeneration control, while the knob of the same type at the lower right is the second detector regeneration control.

The layout of the various components can best be done by following the arrangement of figure 10. The shield enclosing the 6A6 is a necessary feature.

Construction

The receiver is constructed on a standard zinc-plated steel chassis, 7"x9"x2". The front panel is crackle finished steel, 10"x8". A partition of 14 gauge aluminum, 4½" square, is placed between the oscillator and detector sections as illustrated in figure 10. The partition is slotted to fit down over the condenser shaft. The first detector trimmer condenser is mounted below the chassis as shown in figure 11 and tuned by an extension shaft.

Separate ground leads run from each end of the gang condenser to the respective coil sockets and trimmer condenser rotors. The chassis is used as a ground return for all other circuits; by-pass condensers, etc., are soldered directly to the chassis where a ground connection is indicated in the diagram.

The Coils

The fixed cathode coil in the second detector circuit consists of 35 turns of no. 26 d.c.c. wire jumble-wound on a ½" diameter porcelain insulator as a form. The coil is not inductively coupled to the i.f. transformer, but is mounted below the chassis near the 6A6 socket as illustrated in figure 11.

Data on the plug-in high-frequency coils are given in the coil table. The two sections of the detector coil are wound in *opposite* directions, with no spacing between sections. The two sections of the oscillator coil are wound in the *same* direction with no spacing between sections. Correct polarity, number of turns, direction of turns and connections can be assured by following figure 12 and the coil table.

The antenna coupling condenser should be screwed nearly all the way out unless a very short antenna is used. A 75- to

C_1—3-30-μμfd. mica trimmer
C_2—15-μμfd. midget variable
C_3—20-μμfd. midget mica
C_4—.01-μfd. midget mica
C_5, C_6—0.1-μfd. 400-volt tubular
C_7—.00005-μfd. midget mica
C_8—0.5-μfd. 400-volt tubular
C_9—.002-μfd. mica
C_{10}—.01-μfd. 400-volt tubular
C_{11}—.04-μfd. 400-volt tubular
C_{12}—0.1-μfd. 400 volt tubular
C_{13}—30-μμfd. midget variable
C_{14}—100-μμfd. midget variable
C_{15}—.0001-μfd. midget mica
C_{16}—.005-μfd. mica
R_1—50,000 ohms, ½ watt
R_2—300 ohms, ½ watt
R_3—50,000-ohm potentiometer
R_4—25,000 ohms, 1 watt
R_5—1000-ohm potentiometer
R_6—10 megohms, ½ watt
R_7—50,000 ohms, ½ watt
R_8—25,000 ohms, ½ watt
R_9—250,000 ohms, ½ watt
R_{10}—50,000 ohms, ½ watt
IFT—1600-kc. i.f. trans.
Coils—See coil table

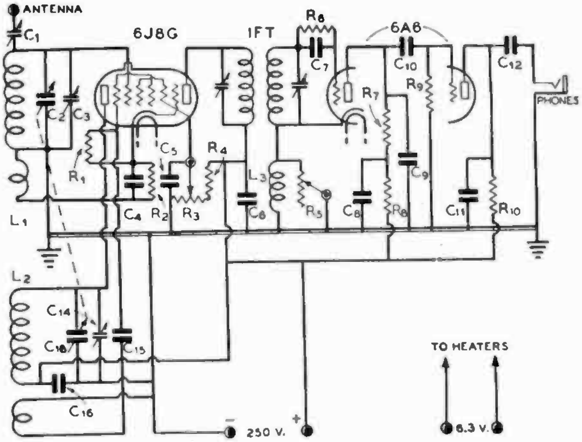


Figure 12.

SCHEMATIC WIRING DIAGRAM OF THE "SUPER GAINER."

NOTE: A 6K8 may be substituted for the 6J8G with no changes in the circuit or socket connections. The shell should preferably be grounded.

100-foot antenna is preferable to a small indoor antenna; very loose coupling can be used with such an antenna.

6-TUBE SUPERHETERODYNE OF MODEST COST

Illustrated in figures 13 to 16 is a straightforward superheterodyne having no "frills" or expensive refinements, but capable of excellent all-around performance.

A 6K8 is used as a combined oscillator and mixer, with a small amount of external capacity (about 3 μμfd.) between control grids of the oscillator and mixer sections in order to improve the performance. The external coupling is provided by twisting a short piece of insulated wire around the mixer grid lead as indicated in the diagram.

This feeds a single 1600-kc. i.f. stage which has manual gain control (sensitivity control) and no a.v.c. The latter is not practical because a power type detector is used instead of a diode in the interests of increased gain. A 6SC7 dual triode serves as combined power detector and resistance coupled a.f. amplifier. A novel bias arrangement provides fixed bias on both detector and a.f. amplifier.

The beat oscillator is conventional.

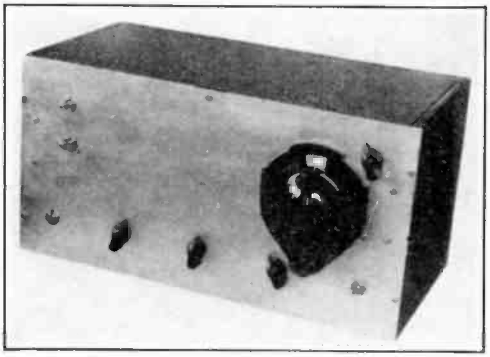


Figure 13.

FRONT PANEL VIEW OF THE "SUPER-SIX", A SIX-TUBE SUPERHETERODYNE OF MODERATE COST AND EXCELLENT PERFORMANCE.

The design is conventional and straightforward, and the constructor will experience little difficulty in getting this receiver to "perk" with gratifying results.

Figure 14.

TOP VIEW OF THE "SUPER-SIX" WITH CABINET REMOVED.
The oscillator section of the converter is toward the front panel, the mixer to the rear of the shield baffle. Half the plates of the rear section of the two gang condenser are removed to make the two circuits track.

using a 6C5, and depends upon stray coupling to provide the beat frequency. The strength of the beat can be altered if necessary by changing the size of resistor R_9, thus raising or lowering the voltage on the beat oscillator. If the chassis layout illustrated is not followed exactly, the stray coupling may be different, thus requiring adjustment of the beat oscillator voltage for optimum strength of the beat note. Too loud a beat will mask weak signals, while too weak a beat will be unsatisfactory on strong signals.

The output of the a.f. section of the 6SC7 is sufficient to drive a pair of phones to good volume, and a phone jack is provided in the plate circuit. Inserting the phone plug automatically disconnects the power output stage, silencing the speaker. The 6F6 power output stage is conventional except that it incorporates an adjustable tone control, a useful adjunct when fighting QRM or bad QRN.

As there are no trick circuits or critical adjustments to be made, even the beginner should experience little difficulty in getting this receiver to work properly.

The chassis measures 7"x13"x2" deep, and the front panel 8"x16". The oscillator section is to the rear of the shield baffle and the mixer section to the front. The baffle divides the two sections of the two-gang tuning condenser as illustrated in figure 14, and the mixer (first detector) trimmer condenser is mounted on the baffle and tuned from the front panel by means of an extension shaft. The main two-gang tuning condenser is driven by an inexpensive vernier dial of the front-of-panel type.

The power supply is mounted as far as possible from the h.f. oscillator in order to minimize heating and vibration.

COIL DATA FOR 6-TUBE SUPERHET
All Coils 1½" diameter.

BAND	DETECTOR	OSCILLATOR	
		Plate	Grid
160	85 turns no. 26 enam. closewound. Ant. coil—7 turns.	26 turns no. 22 d.c.c. closewound.	15 turns no. 26 d.c.c. closewound.
80	40 turns no. 24 d.c.c. 1¼" long. Ant. coil—5 turns.	17 turns no. 20 d.c.c 1" long.	9 turns no. 26 d.c.c. closewound.
40	21 turns no. 22 d.c.c. 1¼" long. Ant. coil—3 turns.	10½ turns no. 20 d.c.c. 1" long.	6 turns no. 26 d.c.c. closewound.
20	10 turns no. 20 d.c.c. 1¼" long. Ant. coil—2½ turns.	5 turns no. 20 d.c.c. 1" long.	4½ turns no. 26 d.c.c. closewound.
10	4 1/3 turns no. 20 d.c.c. ¾" long. Ant. coil—1½ turns.	1½ turns no. 20 d.c.c. ½" long.	2¾ turns no. 26 d.c.c. ¼" long.

Oscillator grid and plate coil windings in same direction with plate and grid leads from far ends of windings. Grid winding starts close to tuned winding on form.

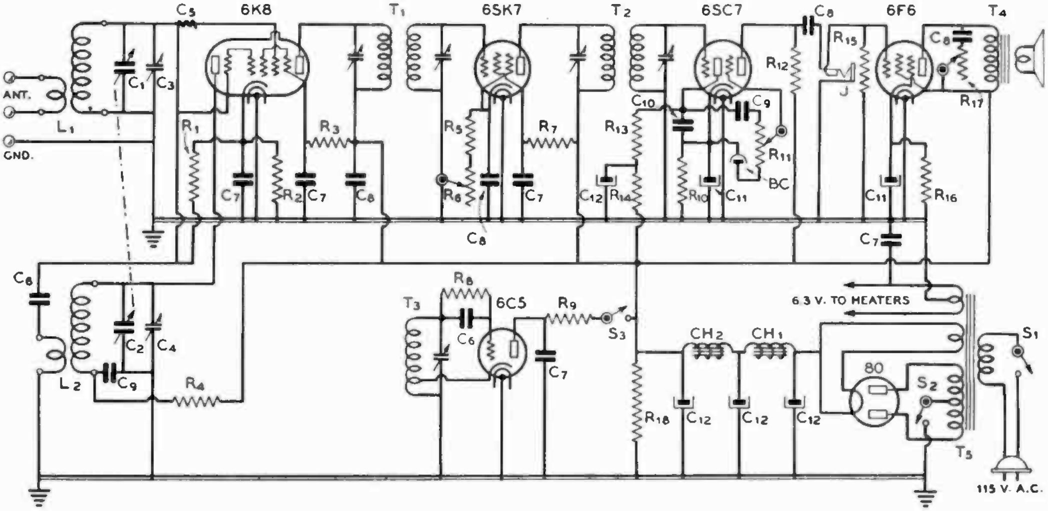


Figure 15.

GENERAL WIRING DIAGRAM OF THE "SUPER-SIX."

C_1, C_2 — Two-gang 30-μμfd. per section midget with half plates removed so that C_1 is approx. 15 μμfd.

C_3 — 20-μμfd. midget (used as trimmer)

C_4 — 100-μμfd. midget (bandset condenser)

C_5—2 turns insulated hookup wire around grid lead

C_6—.0001-μfd. midget mica

C_7—.01-μfd. tubular, 400 v.

C_8—0.1-μfd. tubular, 400 v.

C_9—.005-μfd. mica

C_{10}—.001-μfd. midget mica

C_{11}—10-μfd. 25 v. electrolytic

C_{12}—8-μfd. 450 v. electrolytic

T_1, T_2—1600-kc. i.f. trans., inexpensive type with air core and mica trimmers

T_3—1600-kc. b.f.o. trans.

T_4—Output trans., pentode to voice coil (on speaker)

T_5—325 v. each side c.t., 50 ma., and 6.3 v. and 5 v. fil. windings

CH_1—30 hy, 50 ma.

CH_2—2500 ohm, speaker field

J—Earphone jack

L_1, L_2—See coil table

R_1—50000 ohms, ½ watt

R_2—500 ohms, ½ watt

R_3—25,000 ohms, 1 watt

R_4—50,000 ohms, 1 watt

R_5—300 ohms, ½ watt

R_6—50,000 ohm pot.

R_7—100,000 ohms, ½ watt

R_8—50,000 ohms ½ watt

R_9—100,000 ohms ½ watt

R_{10}—2000 ohms, ½ watt

R_{11}—1 meg. pot.

R_{12}, R_{13}—100,000 ohms, ½ watt

R_{14}—25,000 ohms, ½ watt

R_{15}—250,000 ohms, ½ watt

R_{16}—400 ohms, 3 watts

R_{17}—15,000 ohm pot.

R_{18}—25,000 ohms, 10 watts

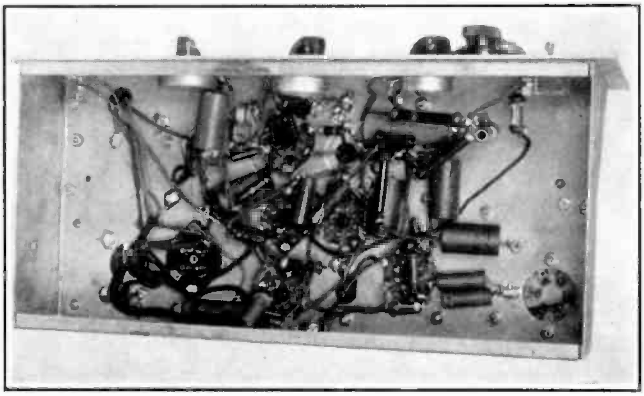


Figure 16.

UNDER - CHASSIS VIEW OF THE "SUPER - SIX" SUPERHETERODYNE.

Resistors and bypass condensers are mounted by their leads to the various components without the use of mounting strips. This does not make for neat appearance, but results in short leads and good performance.

Figure 17.

FRONT-PANEL VIEW OF THE ADVANCED SUPER-HETERODYNE.

Maximum operating flexibility is provided by having all controls on the panel. In the top row the controls are, from left to right: regeneration, noise limiter, a.f. gain, b.f.o. pitch, and bandswitch; bottom row: r.f. gain, i.f. gain, phones-speaker switch, b.f.o. injection, and standby switch.

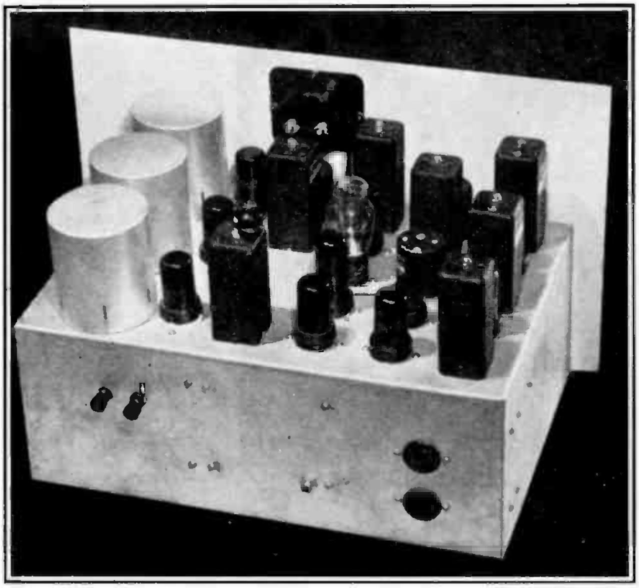


Figure 18.

SHOWING THE CHASSIS LAYOUT OF THE ADVANCED SUPER.

From the rear, the location of the various components above the chassis is clearly visible. The three large shield cans at the left edge of the chassis cover the plug-in coils which are used for the 40- and 80-meter bands.

ADVANCED BANDSWITCHING PHONE AND C. W. RECEIVER

Quite often receivers are designated as either "phone" or "c.w." sets. This is a desirable designation because the receivers in question have been designed for peak performance in one type of operation and the other use becomes of secondary importance in their circuit arrangement. However, it is quite possible to design a receiver for peak performance for both phone and c.w. Such a receiver is pictured in figures 17, 18 and 19, and diagrammed in figure 20. This receiver should appeal to the advanced constructor who has had previous experience in receiver construction.

After adequate sensitivity has been provided by a well-designed "front end," two widely differing characteristics in i.f. selectivity must be included to give a universal phone-c.w. receiver. These are: (1) a square-topped selectivity with narrow "skirts" for phone reception and (2) sharply peaked selectivity for single-signal c.w. reception. These two characteristics are provided in this receiver along

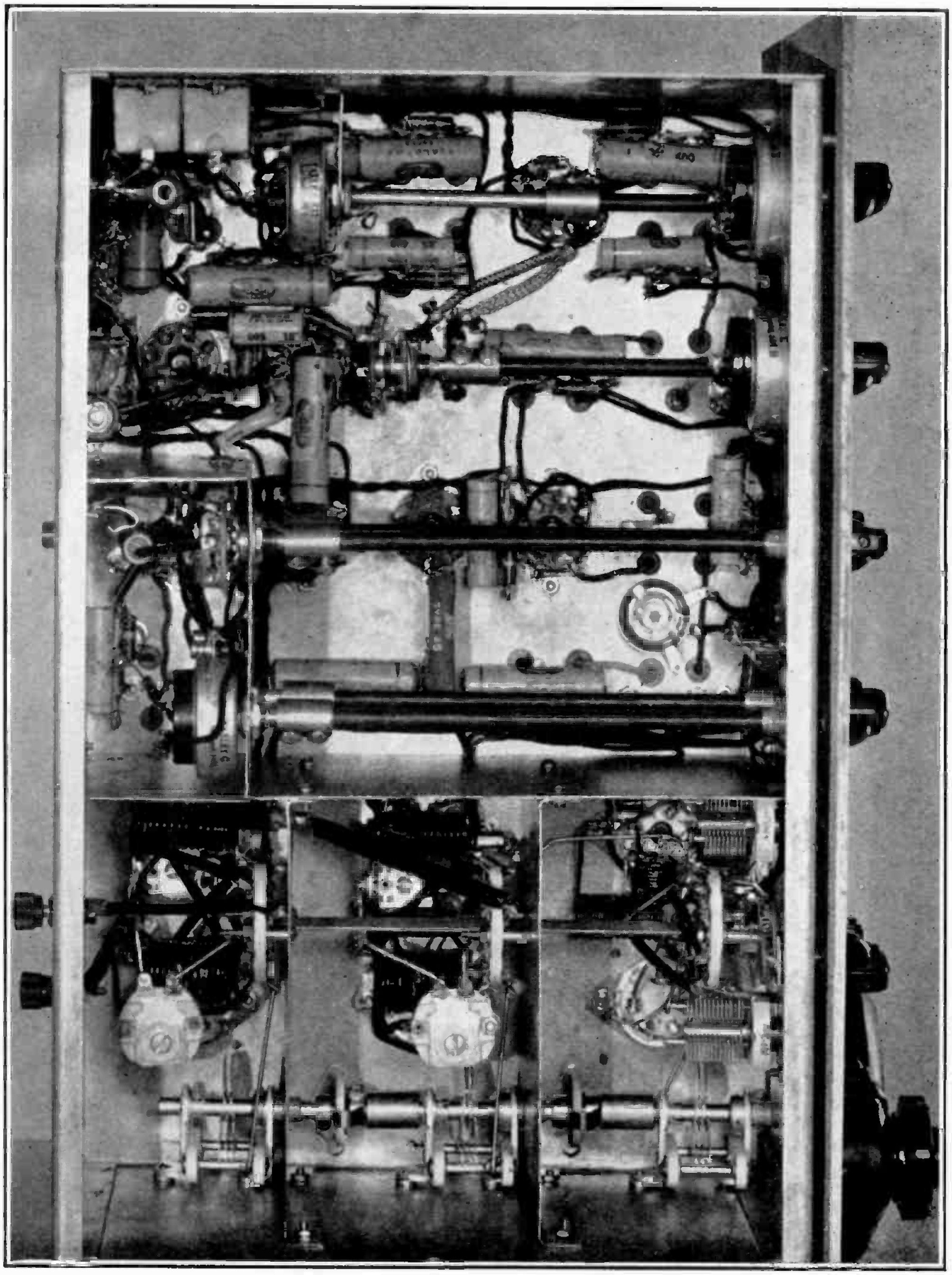


Figure 19.

UNDERNEATH THE CHASSIS OF THE ADVANCED SUPERHETERODYNE.

Note the "air-wound" 10- and 20-meter coils in the r.f., mixer and oscillator stages. The shield partition at the rear-center of the chassis mounts the b.f.o. and audio controls.

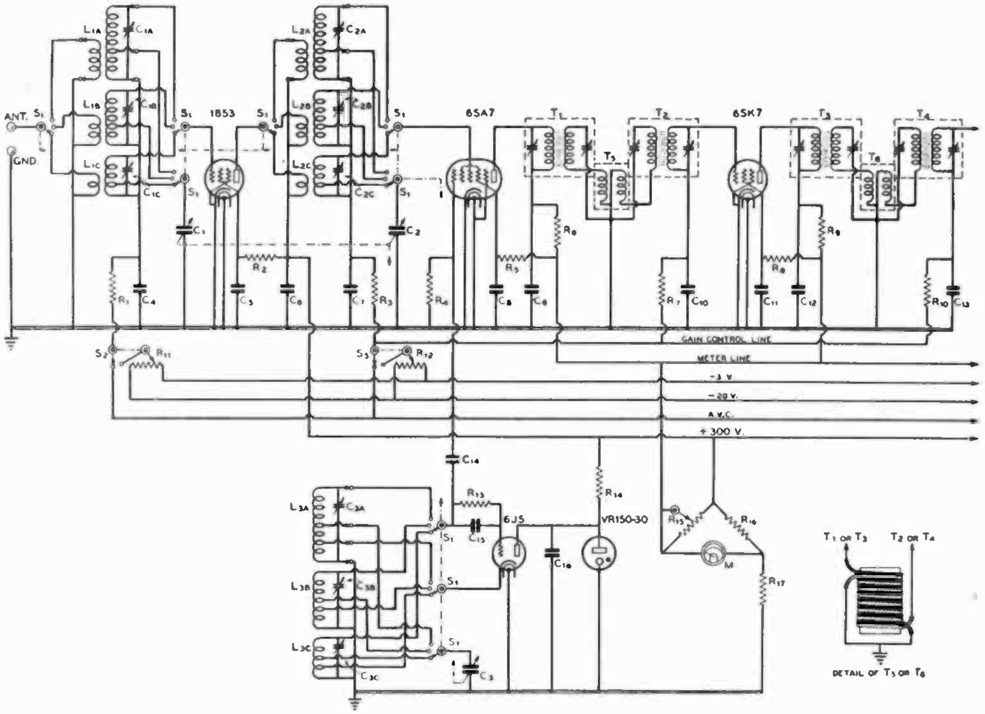


Figure 20.

SCHEMATIC DIAGRAM OF THE ADVANCED SUPERHETERODYNE.

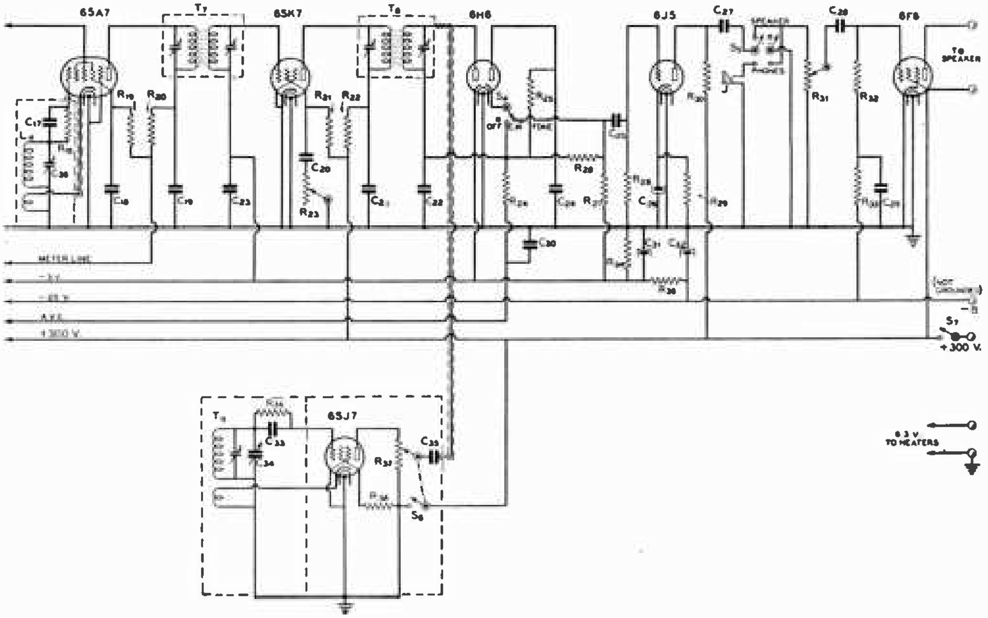
C_1, C_2, C_3 — 35-μμfd. midget variable
C_4, C_5, C_6, C_7—0.01-μfd. midget mica
C_8, C_9 — 0.1-μμfd. 400-volt tubular
C_{10} — .05-μfd. 400-volt tubular
C_{11}, C_{12}—0.1-μfd. 400-volt tubular
C_{13} — .05-μfd. 400-volt tubular
C_{14}—.00005-μfd. mica
C_{15}—.0001-μfd. mica
C_{16} — 0.1-μfd. 400-volt tubular
C_{17}—.0001-μfd. mica
C_{18}, C_{19}, C_{20}, C_{21}—0.1-μfd. 400-volt tubular
C_{22}—.0001-μfd. mica
C_{23}, C_{24}—0.1-μfd. 400-volt tubular
C_{25} — .01-μfd. 400-volt tubular
C_{26} — 10-μfd. 25-volt electrolytic
C_{27}, C_{28}—.01-μfd. 400-volt tubular
C_{29}, C_{30}—0.1-μfd. 400-volt tubular
C_{31}, C_{32}—25-μfd. 25-volt electrolytic
C_{33}—.0005-μfd. mica
C_{34} — 15-μμfd. midget variable
C_{35} — 0.1-μfd. 400-volt tubular
C_{36}—80-225-μμfd. mica trimmer
R_1—100,000 ohms, ½ watt
R_2—40,000 ohms, ½ watt
R_3—100,000 ohms, ½ watt
R_4—100,000 ohms ½ watt
R_5 — 50,000 ohms, ½ watt
R_6—2000 ohms, ½ watt
R_7, R_8—100,000 ohms, ½ watt
R_9—2000 ohms, ½ watt
R_{10}—100,000 ohms, ½ watt
R_{11}, R_{12} — 5000-ohm wire-wound potentiometer

---

with such other features as bandswitching, noise limiter, optional a.v.c. or manual gain control on either the i.f. or r.f. stages, b.f.o. injection control, and double conversion for the elimination of images.

Bandswitching

Bandswitching is seldom employed in home-constructed receivers because well-designed coil and switch assemblies are rather costly. By limiting the switching to three bands, however, the cost of the coil and switch assembly may be made little more than that of a set of plug-in coils. Three 3-pole, 3-position isolantite selector switches are used. As may be seen from the circuit diagram, each of these switches performs three switching



R_{12}—100,000 ohms, ½ watt
R_{14} — 2000 ohms, 10 watts
R_{15} — 1000-ohm wire-wound potentiometer
R_{16}—2000 ohms, ½ watt
R_{17} — 40,000 ohms, 2 watts
R_{18}, R_{19}—50,000 ohms, ½ watt
R_{20} — 2000 ohms, ½ watt
R_{21}—100,000 ohms, ½ watt
R_{22}—2000 ohms, ½ watt
R_{23} — 5000-ohm carbon potentiometer
R_{24}—250,000 ohms, ½ watt
R_{25}—1 megohm, ½ watt
R_{26}—250,000 ohms, ½ watt
R_{27}, R_{28}—1 megohm, ½ watt
R_{29}—2500 ohms, ½ watt
R_{30}—100,000 ohms, ½ watt
R_{31} — 500,000-ohm potentiometer
R_{32}—250,000 ohms, ½ watt
R_{33}—50,000 ohms, ½ watt
R_{34}—15 ohms, 10 watts
R_{35}—150 ohms, 10 watts
R_{36}—100,000 ohms, ½ watt
R_{37}—10,000-ohm potentiometer
R_{38}—250,000 ohms, ½ watt
T_1—1500-kc. input i.f. transformer
T_2, T_3, T_4—1500-kc. interstage i.f. transformer
T_5, T_6—Negative-mutual coupling coils (See text)
T_7—175-kc. input i.f. transformer
T_8—175-kc. diode output i.f. transformer
T_9 — 175-k.c. b.f.o. transformer
L_1, L_2, etc. — See coil table
L_4—B.c. band 465-kc. oscillator coil (see text)
S_1—Three section 3-pole, 3-position isolantite selector switch
S_2, S_3—Single-pole double-throw switch (on gain control)
S_4 — Single-pole three-position noise limiter switch
S_5—D.p.d.t. switch
S_6 — S.p.s.t. switch (on injection control, R_{37})
S_7—S.p.s.t. switch
L_{1A}, C_{1A}, L_{2A}, C_{2A}, etc.—See coil table

operations for each band for each stage in the "front end." The 10- and 20-meter band coils are air-supported and mounted under the 6-inch-deep chassis close to their respective switch sections. For the third band, which may be either 40 or 80 meters, a set of 5-prong sockets under the shield cans at the right edge of the chassis is switched into the circuit. Thus three bands are made available at the flip of a switch and a fourth band can be had through the use of plug-in coils.

Circuit Arrangement

To eliminate images on the higher-frequency bands and at the same time allow a high degree of selectivity, the i.f. channel employs double conversion. That is, signals are first converted to a relatively high frequency (1500 kc.) and amplified and then again converted, this time to a relatively low frequency (175 kc.) and further amplified. High selectivity is made available, when desired, through the use of optional regeneration in the 175-kc. stage. The square-topped, bandpass characteristic so necessary for phone reception is effected by negative-mutual coupling coils in the 1500-kc. i.f. amplifier.

Tube Lineup

An 1853 tube is used in the r.f. amplifier stage. This stage, as well as all the others in the receiver except the 6J5 first audio stage, receives fixed bias from the bias network, R_{34}, R_{35}. The r.f. gain potentiometer, R_{11}, varies the amount of this fixed bias from 3 to 20 volts. When the r.f. gain control is turned completely "off", the switch S_2 is operated and the 1853 grid return is connected to the a.v.c. line. The cathode of detector-a.v.c. diode is returned to the —3 volt line so that the bias on either the manual or the a.v.c. positions never falls below 3 volts. The gain control circuit on the i.f. stages is a copy of that on the r.f. stage, with either a.v.c. or manual gain being applied to the grid returns of the first mixer, 1500-kc. i.f. amplifier and second mixer. The 175-kc. i.f. amplifier stage receives fixed bias directly from the —3 volt line, as either manual or automatic adjustment of gain in this stage would result in difficulty in attempting to set the regeneration control.

The 6SA7 first mixer stage is entirely conventional, with injection from the grid side of the oscillator tank circuit through a 50-$\mu\mu$fd. condenser, C_{14}. A 6J5 is used in the oscillator in a grounded-plate Hartley circuit. 150 volts of regulated voltage is applied to this stage from the VR-150-30 regulator tube.

	R.F.			DET.			OSC.			
	ANTENNA	GRID	B. S. TAP	PLATE	GRID	B. S. TAP	GRID	B. S. TAP	CATHODE TAP	
80	5 t. close wound	29½ t. spaced to 1⅝". Padder 25-100 mica	to grid end	10 t. close wound	29½ t. spaced to 1⅝". Padder 25-100 mica	to grid end	20½ t. spaced to 1½". Padder 100 air	16 t.	3 t.	all no. 22 d.c.c. all wound on 1½" forms
40	5 t. no. 22 d.c.c. close wound	17½ t. no. 18 enam. spaced to 1½". Padder 25-100 mica	8 t.	10 t. no. 22 d.c.c. close wound	17½ t. no. 18 enam. spaced to 1½". Padder 25-100 mica	8 t.	13½ t. no. 18 enam. spaced to 1½". Padder 100 air	7 t.	2 t.	all no. 22 d.c.c. all wound on 1½" forms
20	6 t. no. 20 hookup wire inside grid coil at ground end	13 t. no. 16 enam. ¾" dia. spaced to 1¼". Padder 25-100 mica	5½ t.	6 t. no. 20 hookup wire inside grid coil at ground end	13 t. no. 16 enam. ¾" dia. spaced to 1¼". Padder 25-100 mica	5½ t.	13½ t. no. 16 enam. ½" dia. spaced to 1¼". Padder 100 air	6 t.	2½ t.	
10	5 t. no. 20 hookup wire inside grid coil at ground end	13 t. no. 16 enam. ½" dia. spaced to 1¼". Padder 3-30 mica	5 t.	5 t. no. 20 hookup wire inside grid coil at ground end	13 t. no. 16 enam. ½" dia. spaced to 1¼". Padder 3-30 mica	5 t.	6 t. no. 16 enam. ½" dia. spaced to ⅝". Padder 75 air	4 t.	1½ t.	

All taps refer to number of turns up from ground end of coil. Note that grid coil is same for both r. f. and detector on all bands. 80 and 40 m. coils are plug in.

COIL TABLE FOR DELUXE RECEIVER

Negative-Mutual Coils

The negative-mutual coupling coils in the 1500-kc. i.f. stage must be connected as shown in the diagram. These units have six turns on each winding, the coils being interwound on a ½-inch form. No. 22 d.c.c. wire is used. Following the 6SK7 1500-k.c. stage is the 6SA7 second mixer. Some changes are necessary in the oscillator coil specified in the parts list and Buyer's Guide to make it suitable for use with the 6SA7. The coil must be removed from the shield can and the leads from the original tickler winding disconnected from the terminals on the mounting strip. Next 20 turns of small silk or cotton-covered wire should be wound around the dowel coil mount as close to the bottom of the original winding as possible. If this coil is wound in the same direction as the grid winding the proper method of connection will be as indicated on the diagram. The direction of the grid winding may be observed by noting the direction in which the grid lead enters the insulating compound.

After these changes have been made the trimmer condenser C_{36} should be mounted inside the shield can with its adjusting screw protruding through a hole in the top, and the grid leak and condenser assembly, R_{18}, C_{17}, mounted within the shield. It is a rather tight squeeze to get all of these components within the shield but it is quite necessary that they be placed there as any harmonics from this oscillator section reaching the r.f. section of the receiver might cause unwanted "phantom" carriers to appear. With the parts located as described, however, there is no trouble of this type. Shielded grid and cathode leads must be run from the coil terminals to the 6SA7 socket.

175-Kc. Channel

The 175-k.c. i.f. channel is conventional except for the method of obtaining regeneration for single-signal reception of c.w. signals. The regeneration control, R_{23}, is placed between the ground side of the 6SK7 screen by-pass and ground. In some cases it may be necessary to place an additional capacity between the grid and plate of this stage to permit full regeneration to be obtained. The additional capacity can well consist of a short length of push-back wire connected to the grid terminal on the socket and run over near the plate terminal.

A 6H6 is used as the detector-noise limiter. One of the diodes serves as a diode detector and a.v.c. rectifier, while the other diode performs the function of noise limiting. A three-position switch in the noise diode cathode allows either off, phone, or c.w. settings. Returning the cathode of the detector-a.v.c. diode to the —3 volt line insures a minimum 3-volt bias at all times on the stages operating from the a.v.c. line. The audio system following the detector is entirely conventional and needs no detailed comment.

MECHANICAL LAYOUT

Looking at the receiver from the front, the components above the chassis are as follows: Along the right edge, from front to back, are the r.f., mixer, and oscillator stages. The 1500-k.c. i.f. channel progresses along the front of the chassis toward the left edge, where the 1500-k.c. to 175-k.c. mixer stage is located, with the 175-k.c. stage directly behind it along the left edge of the chassis. The audio section and the beat oscillator and voltage regulator are located in the rear-center portion of the chassis. The actual arrangement of the audio section is of little importance as long as the various controls associated with these circuits are reasonably close to the tubes with which they operate.

Underneath the chassis every effort should be made to keep all the grid and plate leads as short and direct as possible. This is particularly important in a receiver such as this, where single-ended tubes are used throughout. Large holes should not be cut under the i.f. transformers; small holes just large enough to allow the passage of the leads should be used.

The Bandswitch

The bandswitch is made up from parts supplied by the manufacturer in kit form.

The first switch section, which includes the index assembly, is mounted directly on the front drop of the chassis. The two rear sections are supported from the two interstage shield partitions. In assembling the front end, the oscillator should be wired and tested first, and then the oscillator-mixer partition added. Next, the mixer should be wired and tested and the remaining shield partition installed, the assembly progressing from front to rear until this whole section of the receiver is completed. It is necessary to drill a hole in the rear drop of the chassis to allow the flat shaft for revolving the switch sections to be installed. This hole can well be used to mount the antenna binding post.

The chassis measures 6 x 10 x 15 inches, and the panel 11 x 18 inches.

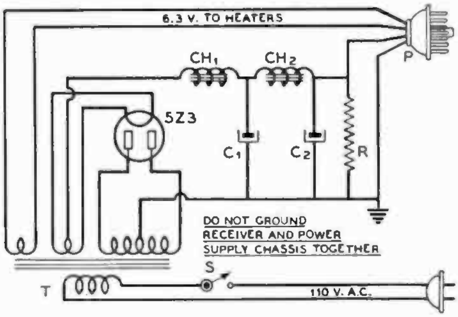


Figure 21.

POWER SUPPLY FOR RECEIVER OF FIGURE 20.

T—750 v., c.t., 150 ma; 5 v., 3 a.; 6.3 v., 5. a.
CH$_1$, CH$_2$—30 hy., 110 ma.
C$_1$, C$_2$ — 16-μfd., 450-volt electrolytic
R—50,000 ohms, 20 watts
S$_1$—S.p.s.t. switch

Alignment

After all wiring has been completed and checked, the i.f. channels should be aligned. A calibrated signal generator is almost a necessity during the alignment process. First the 175-kc. channel should be aligned. If the receiver has been wired correctly this should be quite easy, remembering that the regeneration control should be turned completely "off," that is, with the resistance all out of the circuit. When the 175-kc. stage has been aligned properly, the signal generator should be set at 1500 kc. and shifted to the grid of the second mixer. With the signal generator output connected into this circuit, adjust the 6SA7 oscillator-section trimmer (C$_{36}$) until the signal from the generator is heard at the output of the receiver. The second mixer is now converting from 1500 to 175 kc. and the 1500-k.c. channel may be aligned in the usual manner.

Power Supply

Two octal sockets are provided at the rear of the chassis for speaker and power supply connections. The additional contacts on these sockets may be used to bring leads for transmitter remote control and other remote switching circuits into the receiver. The power supply is strictly conventional; a diagram is shown in figure 21.

SPECIAL PURPOSE RECEIVERS

SUPERSELECTIVE PHONE RECEIVER

This receiver was designed for the amateur who is interested primarily in QRM-free phone reception on the crowded 20- and 75-meter phone bands. While the receiver will not separate two stations so close that they are practically on the same channel, the 12 tuned circuits in the 456-kc. i.f. amplifier provide as high a degree of selectivity as can be used for voice reception. The selectivity curve is more square topped than that of a series crystal filter, and though the "skirts" of the curve are not so wide, there is less attenuation of voice frequency side bands.

The i.f. transformers are of the air tuned iron core type, and have a high Q. Twelve high-Q circuits can be made to provide a very narrow, flat topped pass band at 456 kc.

Though six i.f. transformers are used, it will be noted that the receiver actually has only two i.f. stages. The two 6K7's provide all the gain that is needed; the extra transformers are incorporated in the interests of selectivity. The first stage runs at high gain in order to provide a satisfactory swing on the R meter. The second stage has less gain due to high cathode bias, provided to avoid any tendency toward oscillation. Two stages of iron core i.f. running wide open have so much gain that special precautions are necessary if oscillation is to be avoided; for that reason, the second i.f. stage in this receiver is run at slightly reduced gain.

The front end of the receiver starts in with a regenerative r.f. stage. A 6J7 sharp cutoff tube provides the best signal-to-noise ratio and the most gain, but trouble may be experienced due to cross-talk if any powerful amateur phones or broadcast stations are close by. In the latter event, a 6K7 can be substituted with a slight loss in gain and signal-to-noise ratio.

A 6J8-G mixer is driven by a 6F6 high-frequency oscillator. The combination provides high conversion gain with a low hiss level on all the amateur bands.

A 6H6 acts as combined noise suppressor, second detector and a.v.c. tube. The noise silencing action is very effective in reducing automobile ignition noise and similar types of interference.

A beat-frequency oscillator utilizing a 6C5 permits reception of c.w. signals, and the performance of the receiver on c.w. is highly gratifying. However, it performs no better on c.w. than some of the receivers previously described in this chapter; the ability of the receiver to dig readable phone signals out of the QRM is the receiver's chief, but very worthwhile, claim to distinction.

The audio output of the receiver is sufficient to drive a loud-speaker to good room volume. However, the phone man with "tin ears" may find a little more audio gain desirable. This can be provided simply by adding a 3-1 audio transformer for coupling between the 6C5 and 6F6 audio stages. If transformer coupling is used, an RC decoupling filter consisting of a 50,000-ohm resistor and 0.5-μfd. condenser will be necessary in

COIL DATA FOR SIX I.F.T. PHONE RECEIVER

BAND	R. F.	DETECTOR	OSCILLATOR
10	4 turns, #20 d.c.c., ¾" long tapped at ½ turn Ant. Coil—2 turns, #24	4 turns, #20 d.c.c., ¾" long	4 turns, # 20 d.c.c., ¾" long tapped at 1½ turns
20	6 turns, 20 d.c.c., 1" long tapped at ¾ turn shunt sec. with 50-μμfd. mica Ant. Coil—3 turns, #24	6 turns, #20 d.c.c., 1" long shunt sec. with 50μμfd. mica	6 turns, #20 d.c.c., 1" long tapped at 2½ turns shunt sec. with 50-μμfd. mica
40	21 turns, #20 d.c.c., 1" long tapped at ½ turn Ant. Coil—3 turns, #24	21 turns #20 d.c.c., 1" long	19 turns, #20 d.c.c., 1" long tapped at 4 turns
75	41 turns, #24 d.c.c., 1¼" long tapped at 1 turn Ant. Coil—4 turns, #24	41 turns, #24 d.c.c., 1¼" long	32 turns, #24 d.c.c., 1" long tapped at 6 turns
160	85 turns #28 enam., 1¼" long tapped at 2 turns Ant. Coil—8 turns, #32 d.s.c.	85 turns, #28 enam., 1¼" long	60 turns, #28 enam., 0.9" long tapped at 8 turns

All coils 1½" in diameter. H.F. coils on ceramic forms.

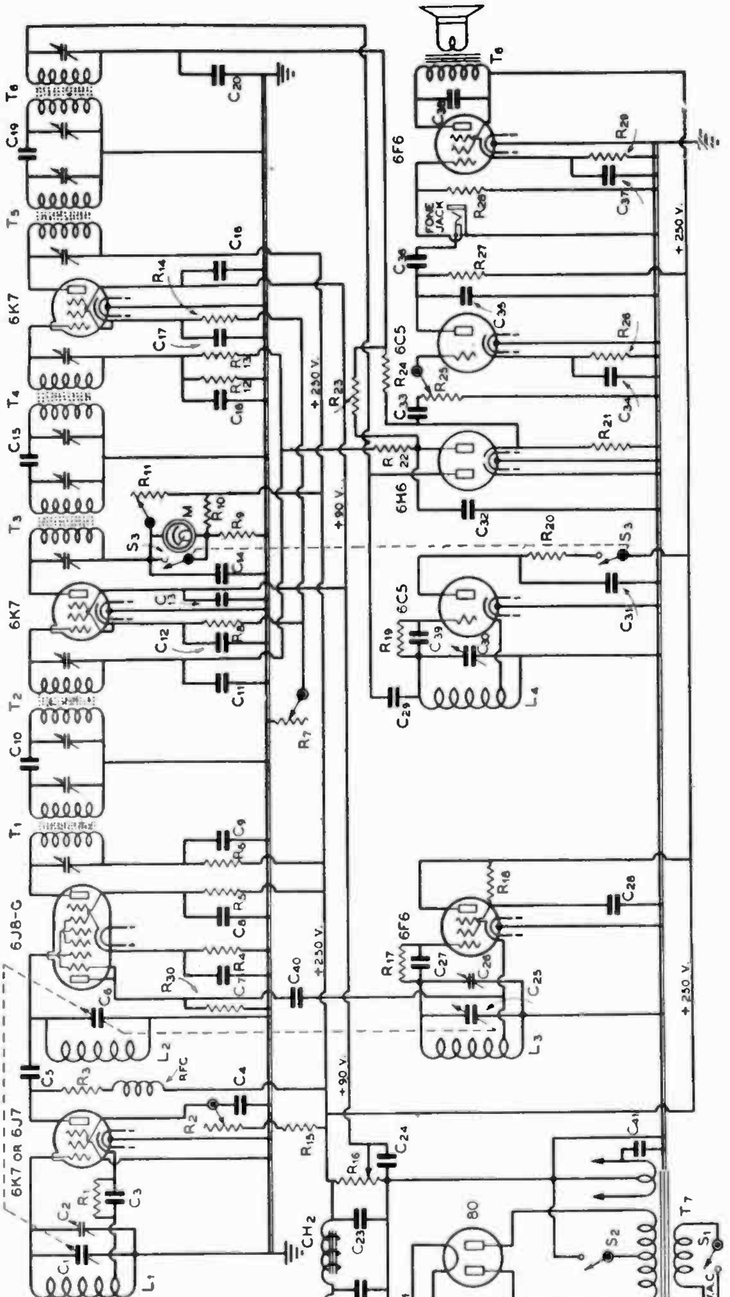


Figure 22.

SCHEMATIC WIRING DIAGRAM OF THE SUPERSELECTIVE PHONE RECEIVER. SEE OPPOSITE PAGE FOR CONSTANTS.

Figure 23.

CONSTANTS FOR THE SCHEMATIC WIRING DIAGRAM OF THE SUPER-SELECTIVE PHONE RECEIVER OF FIGURE 22.

C_1 — 15-μμfd. midget variable
C_2 — 25-μμfd. midget variable
C_3—.005-μfd. mica
C_4 — .02-μfd. 400-volt tubular
C_5 — 3-30-μμfd. mica trimmer
C_6 — 15-μμfd. midget variable
C_7 — .05-μfd. 200-volt tubular
C_8 — .01-μfd. 400-volt tubular
C_9 — .01-μfd. 400-volt tubular
C_{10} — 3-μμfd. coupling capacity
C_{11} — .02-μfd. 400-volt tubular
C_{12} — 0.1-μfd. 400-volt tubular
C_{13} — .01-μfd. 400-volt tubular
C_{14} — .02-μfd. 400-volt tubular
C_{15} — 3-μμfd. coupling capacity
C_{16} — .02-μfd. 400-volt tubular
C_{17} — 0.1-μfd. 400-volt tubular
C_{18} — .01-μfd. 400-volt tubular
C_{19} — 3-μμfd. coupling capacity
C_{20}—.0001-μfd. mica
C_{21} — 4-μfd. 450-volt electrolytic
C_{22}, C_{23}, C_{24}—8-μfd. 450-volt electrolytics
C_{25} — 15-μμfd. midget variable
C_{26} — 25-μμfd. midget variable
C_{27}—.0001-μfd. mica
C_{28}—.005-μfd. mica
C_{29}—2-μμfd. b.f.o. coupling condenser
C_{30} — B.f.o. frequency trimmer
C_{31} — .01-μfd. 400-volt tubular
C_{32} — 1.0-μfd. 400-volt tubular
C_{33} — .02-μfd. 400-volt tubular
C_{34} — 1.0-μfd. 400-volt tubular
C_{35} — .001-μfd. 400-volt tubular
C_{36} — 0.1-μfd. 400-volt tubular
C_{37}—10-μfd. 25-volt by-pass
C_{38} — .02-μfd. 400-volt tubular
C_{39}—.0001-μfd. mica
C_{40}—.0001-μfd. mica
C_{41} — .01-μfd. 400-volt tubular
R_1—500 ohms, ½ watt
R_2—50,000-ohm pot.
R_3—10,000 ohms, ½ watt
R_4—500 ohms, ½ watt
R_5—20,000 ohms, ½ watt
R_6—2000 ohms, ½ watt
R_7—25,000-ohm pot.
R_8—300 ohms, ½ watt
R_9—100,000 ohms, 2 watts
R_{10}—1000 ohms, 1 watt
R_{11}—2000-ohm rheostat
R_{12}—1 megohm, ½ watt
R_{13}—1 megohm, ½ watt
R_{14}—5000 ohms, ½ watt
R_{15} — 25,000 ohms, 1 watt
R_{16} — 20,000-ohm 50-watt voltage divider
R_{17} — 25,000 ohms, ½ watt
R_{18} — 50,000 ohms, ½ watt
R_{19} — 50,000 ohms, ½ watt
R_{20}—100,000 ohms, ½ watt
R_{21}—500,000 ohms, ½ watt
R_{22}, R_{23}—1 megohm, ½ watt
R_{24} — 50,000 ohms, ½ watt
R_{25}—500,000-ohm pot.
R_{26}—2000 ohms, 1 watt
R_{27} — 100,000 ohms, 1 watt
R_{28}—250,000 ohms, ½ watt
R_{29}—400 ohms, 10 watts
Coils—See text
RFC—2½-mh., 125-ma. choke
I.F. transformers — See text
M — 0-1 d.c. milliammeter
S_1—A.c. line switch
S_2—Communications switch
S_3 — D.p.s.t. b.f.o. and "R" meter switch
T_7—700 v. c.t., 85 ma.; 6.3 v., 3.3 a.; 5 v., 2 a.
T_8 — Pentode-to-voice coil output transformer
CH_1 — 12-hy., 85-ma. choke
CH_2 — 1500-ohm spkr. field

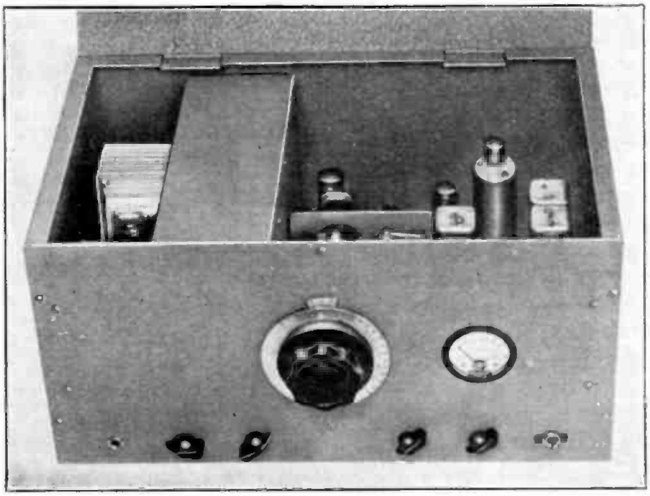


Figure 24.

SUPERSELECTIVE PHONE SUPERHETERODYNE.

Designed primarily for highly selective reception of phone signals, this receiver also works fine on c.w. Twelve tuned circuits in the i.f. amplifier give a very narrow, flat-topped response curve without the wide "skirts" common to crystal filter receivers having the conventional number of tuned i.f. circuits.

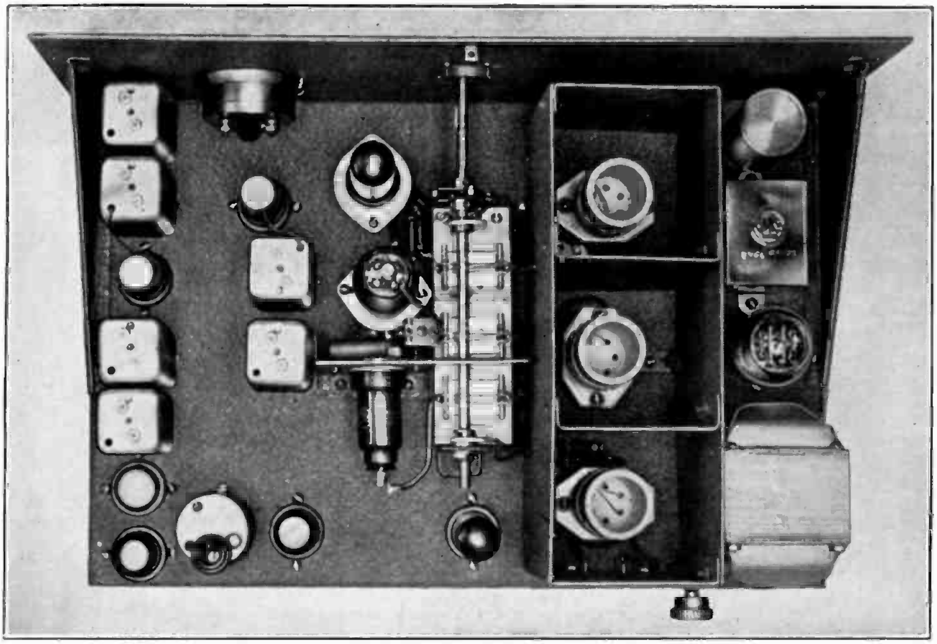


Figure 25.

ARRANGEMENT OF COMPONENTS IN THE SUPERSELECTIVE PHONE RECEIVER.
The h.f. oscillator compartment is the one farthest from the power transformer; this is necessary to minimize "warm up" drift.

the B-plus lead to the 6C5 in order to prevent motorboating.

The gang tuning condenser permits single dial tuning. For optimum adjustment of regeneration in the r.f. stage, a trimmer is provided across the r.f. coil. The gang condenser was originally 20 μμfd. per section, double spaced. One rotor and one stator plate were removed from each section, leaving a maximum capacity of a little less than 15 μμfd. per section. This is just sufficient to cover the 160-meter phone band, but not quite sufficient to cover the extreme low-frequency portion of the 80-meter c.w. band. All other bands are covered completely. The two speed vernier dial tends to spread out the tuning even on the crowded 20-meter phone band.

Referring to figure 24, the front panel controls are left to right: r.f. regeneration, r.f. trimmer, a.f. volume and a.c. on-off switch, i.f. sensitivity with a.v.c. on-off switch, and b.f.o. on-off switch.

Construction

The receiver is constructed on a steel chassis 11"x17"x2½". The front panel measures 9"x18", and is of ⅛-in. steel. The can used for a coil shield measures 10"x6"x3½". Two partitions are made from 14-gauge aluminum and placed as illustrated in figure 25. The compartment nearest the front panel houses the h.f. oscillator, the center compartment the detector and the back compartment the regenerative r.f. stage. The correct layout of the various components is illustrated in the photographs.

Alignment

The performance of this receiver depends so much upon correct alignment of the i.f. transformers that, if possible, the initial adjustment should be done with the assistance of an oscilloscope. However, the job can be done simply by means of an alignment oscillator and out-

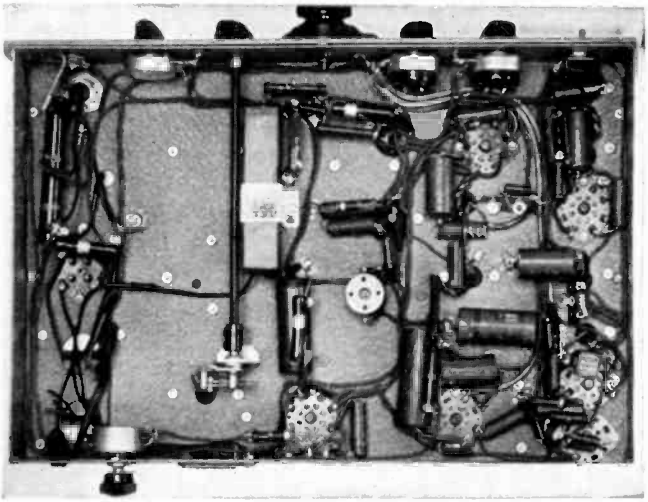


Figure 26.

UNDER CHASSIS VIEW OF THE SUPERSELECTIVE PHONE RECEIVER.

Note how the r.f. trimmer condenser is driven by means of an extension shaft. The lone potentiometer appearing on the back of the chassis should be ignored; it was not used in the final version of the receiver.

put meter if one has the patience. The transformers must first be individually coupled to the oscillator to get them in rough alignment, and then, with the line-up oscillator connected to the front end of the amplifier, touched up one at a time, again and again to get all six of them "on the nose." The R meter may be used as an alignment meter for the whole receiver, if desired, when signal frequency r.f. is applied to the antenna terminals. Incidentally, the R meter reads in a *forward* direction when wired as shown and, therefore, need not be mounted upside down.

Coil data on coils for all bands from 10 to 160 meters appear in the coil table. The specifications should be followed very carefully if the coils are to track properly.

COMPACT LONG-WAVE RECEIVER

There is much going on below 550 kc., and s.w.l.'s and amateurs who have never listened on the "other side" of the broadcast band have an interesting experience in store for them. The receiver illustrated in figures 27, 28 and 29 covers the range of from 130 to 405 kc., and is light and compact. When used with the vibrator type power supply shown it makes an excellent long-wave receiver for small boats and private airplane pilots interested in receiving weather reports and other services to be found on these frequencies. Its small size and light weight make it ideal for aircraft use. For home use the receiver need not be made so compact and attention need not be paid to weight. Also, a power pack for 110-volt a.c. operation would be substituted for the vibrator power supply.

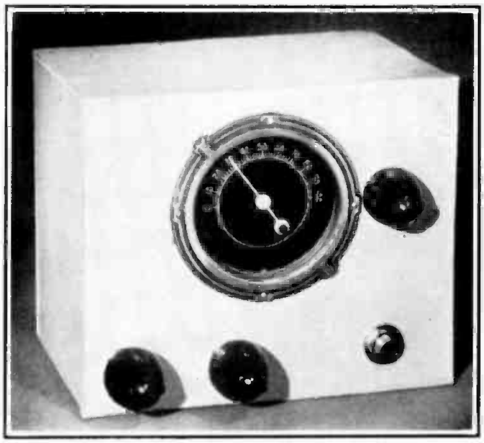


Figure 27.

COMPACT, LIGHTWEIGHT LONG-WAVE RECEIVER.

A tuned r.f. stage feeds a regenerative detector. A single 6C5 audio stage has sufficient gain to drive a pair of phones to good volume.

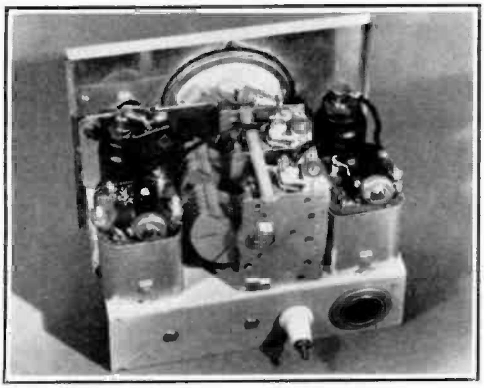


Figure 28.

SHOWING ARRANGEMENT OF COMPONENTS ABOVE CHASSIS.

The two-gang variable condenser is of the ultra-compact type. Both chassis and cabinet (including front panel) are made of thin gauge galvanized iron. If the receiver is not to be used in a plane, heavier construction is advised.

A 6K7 r.f. stage is followed by a 6J7 regenerative grid-leak type detector. A single stage of a.f. amplification is sufficient to drive a pair of phones to good volume even on a short antenna. For best results on *any* long-wave receiver, however, a fairly long antenna should be used.

The two-gang tuning condenser is of the compact type, permitting both r.f. tubes and coils to be mounted above chassis.

For reception of phone or i.c.w. signals the detector is run just below the point of oscillation. Sensitivity and selectivity to modulated signals are greatest at this point, and R_4 should be adjusted for this condition and volume controlled by potentiometer R_1. For reception of c.w. signals the control R_4 is advanced until the detector oscillates, permitting autodyne reception.

The detector coil L_2 is a standard interstage r.f. coil and has no tickler as purchased. A tickler (cathode coil) is wound of no. 22 d.c.c. right next to the grid winding. To do this, the shield can is removed and 12 turns are wound around the coil dowel as close as possible to the grid winding. The shield is then replaced. Correct polarity must be observed or oscillation will not be obtained. The simplest thing to do is to hook up the tickler without heed to polarity and if the receiver does not oscillate, simply reverse the two leads.

If an a.c. power supply is used, or if the receiver is not housed in a metal cabinet, it may be necessary to shield the detector grid lead and possibly the grid leak and condenser in order to prevent "grid hum."

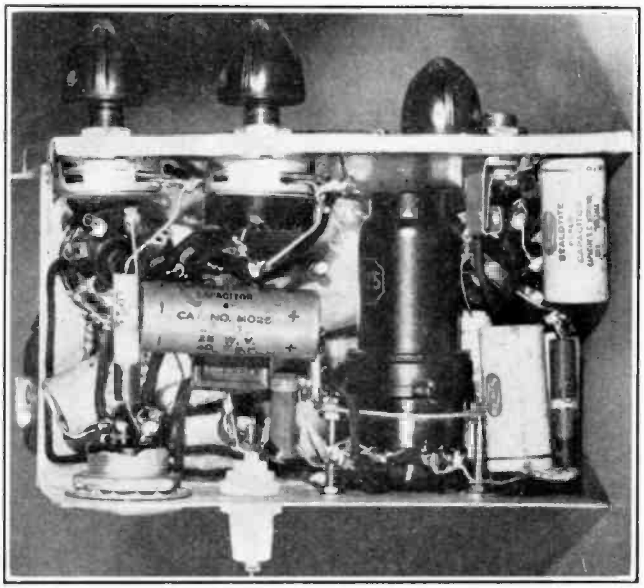


Figure 29.

BOTTOM VIEW OF COMPACT LONG-WAVE RECEIVER.

An idea of the small size of the receiver may be had by comparing it to the 6C5 a.f. amplifier tube seen under the chassis.

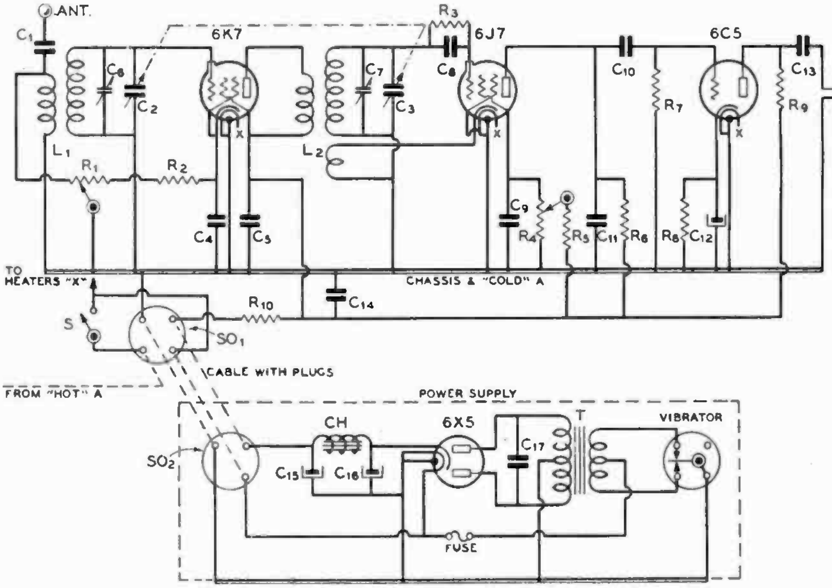


Figure 30.

WIRING DIAGRAM OF COMPACT LONG-WAVE RECEIVER.

C_1 — .001-μfd. tubular, 400 v.

C_2, C_3 — Compact type two-gang condenser, 410 μμfd. per section

C_4 — 0.1-μfd. tubular, 200 v.

C_5 — 0.1-μfd. tubular, 400 v.

C_6, C_7—Trimmers on C_1, C_2

C_8—.00025-μfd. midget mica

C_9 — 0.1-μfd. tubular, 400 v.

C_{10} — .05-μfd. tubular, 400 v.

C_{11}—.0005-μfd. tubular 400 v.

C_{12}—10-μfd. 25 v. electrolytic

C_{13} — 0.1-μfd. tubular, 400 v.

C_{14} — 4-μfd. midget electrolytic, 450 v.

C_{15} — 8-μfd. midget electrolytic, 450 v.

C_{16} — 4-μfd. midget electrolytic, 450 v.

C_{17}—.005-μfd. 1600 v. vibrator condenser

R_1—25,000-ohm midget pot. with switch

R_2—300 ohms, ½ watt

R_3—3 meg., ½ watt

R_4—100,000 ohm midget pot.

R_5—75,000 ohms, 1 watt

R_6—250,000 ohms, ½ watt

R_7—500,000 ohms, ½ watt

R_8—2000 ohms, ½ watt

R_9—50,000 ohms, 1 watt

R_{10} — 10,000 ohms, 5 watts

L_1 — Standard 130-405 kc. antenna coil

L_2—130-405 kc. r.f. coil with cathode coil added (see text)

T — 250 v. vibrator trans., 6 volt pri.

CH — 10-hy. 40-ma. choke.

Just slipping a shielding "hat" on the detector tube in order to shield the grid cap will eliminate the hum in most cases.

U.H.F. SUPERHET WITH R/C COUPLED I.F.

A simple 2½- and 5-meter resistance-coupled superheterodyne is shown in figures 31, 32 and 33. The receiver utilizes 5 metal tubes: An 1853 autodyne converter (oscillator and mixer), two 6SK7 resistance coupled i.f. stages, a 6C5 second detector, and a 6H6 noise limiter to minimize auto ignition interference.

The values of resistors and condensers in the i.f. amplifier are such that only intermediate frequencies are passed; the coupling condensers are too small to pass audio frequencies. The i.f. amplifier has a broad peak around 50,000 cycles, the selectivity being increased slightly by the resonant coil L_2, which is simply an 85-mh. radio-frequency choke. The resonant circuit formed by C_5 and L_2 would result in an order of selectivity too great to receive the less stable of the modulated oscillators heard on 2½ meters; hence the selectivity is broadened by the insertion of R_4. The selectivity can be altered by

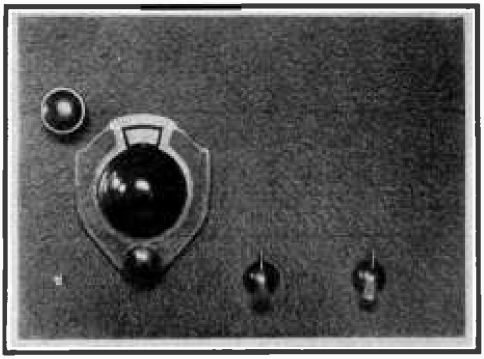


Figure 31.

SIMPLEST INEXPENSIVE 2½- and 5-METER SUPERHET.

This receiver uses an autodyne converter and resistance coupled i.f. amplifier. It is more selective than a superregenerative receiver and does not have the background hiss common to superregenerative receivers.

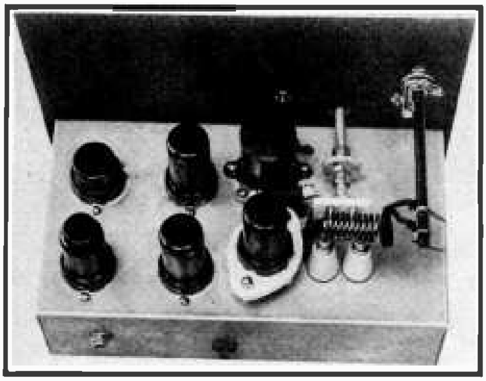


Figure 32.

BACK VIEW OF THE R/C COUPLED SUPERHET.

Five metal tubes are used. The 85-mh. radio frequency choke L_2 may be seen directly in front of the 1853. Note the method of obtaining variable antenna coupling.

changing the value of R_4; lowering the resistance will sharpen the circuit and vice versa. Selectivity will be greatest with the resistor left out of the circuit.

The 1853 oscillates weakly about 50 kc. to one side of the signal being received, thus acting both as first detector and h.f. oscillator. If there is too much regeneration or the antenna coupling is too loose, the tube will have a tendency to go into superregeneration, which prevents the rest of the receiver from functioning properly. Superregeneration is identified by a howl or loud hiss in the phones. Because the i.f. is such a low frequency and the first detector tank circuit shows no discrimination between signals only twice the i.f. (100 kc.) apart, all signals are heard at two closely spaced spots on the dial. The points are so close that signals appear to come in at one point on the dial but with a "double hump." Another way of explaining it is to say that the i.f. is so low and the first detector frequency so high that the customary superheterodyne "image" is every bit as loud as the main signal, but fortunately so close to it in frequency as to appear as part of the main signal.

In spite of the "double hump" the receiver is much more selective than a superregenerative receiver, is very sensitive (especially when used with a resonant antenna), and costs less to build than a regular superheterodyne. It is the only practical form of amateur superheterodyne for 2½-meter operation. There is only one dial to tune, and as the tuning condenser has but one section there are no circuits to align.

The 500-ohm resistor R_{17} is necessary in order to reduce the very strong regeneration resulting from the use of a cathode r.f. choke. Without this resistor the

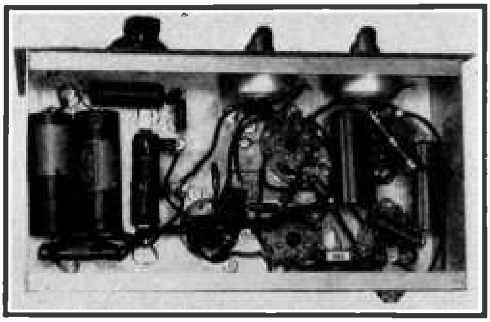


Figure 33.

UNDER-CHASSIS VIEW OF R/C SUPERHET.

Under the chassis are placed all resistors except the grid leak, and all paper by-pass condensers.

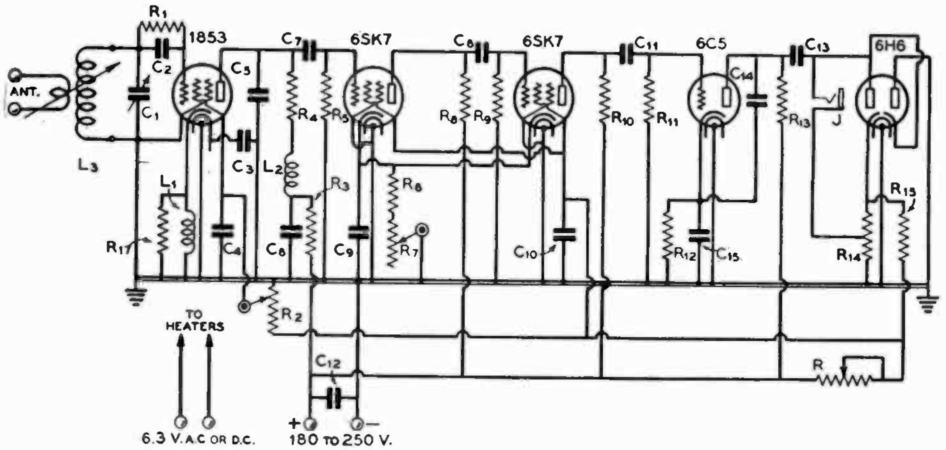


Figure 34.

WIRING DIAGRAM OF THE R/C SUPERHET.

C_1—10μμfd. 2 or 3 plate ultra midget u.h.f. condenser
C_2—50-μμfd. midget mica
C_3—.001-μfd. midget mica
C_4—.005-μfd. midget mica
C_5—.0001-μfd. midget mica
C_6—0.1-μfd. tubular, 600 v.
C_7—50-μμfd. midget mica
C_8—50-μμfd. midget mica
C_9, C_{10}—1-μfd. tubular, 200 v.
C_{11} — 50-μμfd. midget mica
C_{12} — 1-μfd. paper, 400 v.
C_{13}—0.25-μfd. tubular, 400 v.
C_{14}—.005-μfd. midget mica
C_{15} — 0.5-μfd. tubular, 200 v.
L_1 — 5 meter r.f. choke (solenoid type)
L_2 — 85-mh. r.f. choke
L_3—5-m. or 2½-m. plug-in coil. See text
R—10,000 ohms for 250 v. supply; 5000 ohms for 180 v. supply. (10 watts with slider)
R_1 — 100,000 ohms, ¼ watt
R_2—50,000 ohm pot. (det. regeneration)
R_3—10,000 ohms, ½ watt
R_4—500 ohms, ¼ watt
R_5 — 0.5 meg, ¼ watt
R_6—200 ohms, ½ watt
R_7—50,000 ohm. pot. (gain control)
R_8 — 100,000 ohms, ½ watt
R_9 — 0.5 meg., ¼ watt
R_{10} — 100,000 ohms, ½ watt
R_{11}—0.5 meg., ½ watt
R_{12} — 25,000 ohms, ½ watt
R_{13} — 50,000 ohms, ½ watt
R_{14}—100 ohms, center tapped
R_{15} — 2000 ohms, 5 watts
R_{17}—500 ohms, ¼ watt

stage has a tendency to superregenerate even when heavy antenna coupling is used.

Variable antenna coupling is necessary for maximum response to weak signals, but the coupling need seldom be touched after it is once adjusted, except when changing antennas. Regeneration in the 1853 is controlled by the resistor R_2, and the antenna coupling should be adjusted so that the 1853 goes into weak oscillation with R_2 advanced just a little more than half way. A piece of quarter-inch bakelite rod turning in a phone jack as a bearing makes the antenna coupling adjustable from the front panel, as is illustrated in figure 32.

The 1853 socket is mounted above the chassis on ¾ inch collars. The socket must be of the ceramic type, though the rest of the sockets may be of the inexpensive fiber wafer variety. All r.f. grounds in the 1853 stage are made directly from the tube prongs to a lug placed under one of the screws holding the socket. This lug (the one closest the front panel) connects with a short piece of no. 14 copper wire to the rotor of the midget tuning condenser, the latter being mounted back from the panel as illustrated in figure 32 in order to obtain the shortest possible leads. The condenser and coil jacks (jack type standoff insulators) are mounted so that the terminals on the tuning condenser can be soldered directly to the coil jacks without the need for connecting wires. All r.f. leads must be kept extremely short for good 2½-meter performance.

Both the 2½- and 5-meter coils are wound of no. 14 enamelled copper wire and are self-supporting. The ends are fastened to the small type banana plugs, which fit into the coil jacks. The 5-meter coil consists of 10 turns ½ inch in diameter and spaced to 1¼ inches. The 2½-meter coil consists of 3 turns ⅜ inch in diameter spaced to 1 inch. The antenna coil consists of about 2 turns of insulated hookup wire fastened to the bakelite shaft already mentioned, as illustrated in figure 32. For mobile work the 5-meter coil should be stiffened with polystyrene coil dope to prevent vibration of the turns.

The i.f. amplifier can be made to oscillate by advancing the gain control R_7 full on when the receiver is run at full plate voltage. If this is found objectionable the resistor R_6 should be increased to 1000 ohms. The lower value of resistor permits greater sensitivity when only a low voltage plate supply is available, as might be the case when the receiver is used with B batteries for portable work. The receiver will work quite well on about 90 volts, though operation is improved by increasing the plate voltage to 180. If the receiver refuses to oscillate satisfactorily on 2½ meters with low plate voltage, resistor R_{17} should be temporarily disconnected. Disconnecting the resistor R will reduce the battery drain considerably, but the noise silencer will no longer function. If a regular a.c. power pack is used, the receiver should be used exactly as shown in the circuit diagram.

HIGH GAIN 5-BAND PRESELECTOR

If a superheterodyne has less than two stages of preselection, its performance can be greatly improved by the addition of this high gain preselector. The improvement in image ratio and signal-to-noise ratio will be most noticeable on the higher frequency bands and will be especially noticeable if the receiver itself has no r.f. stage at all.

Figure 35.

5-BAND HIGH GAIN PRESELECTOR

This high gain preselector uses an 1851 tube, tuned output circuit and moderate regeneration. It makes a worthwhile addition to any receiver having less than two r.f. stages.

The preselector uses a type 1851 pentode. This tube has a low noise level and extremely high transconductance. In fact, it is necessary to tap the plate of the tube down from the "hot" end of the tuned plate coil in order to avoid oscillation.

The tuned plate circuit is link-coupled to the input terminals of the receiver to which the preselector is to be attached. The coupling link is of the coaxial type, made of flexible shielded conductor. The use of a tuned output circuit and an efficient coupling system makes this preselector greatly superior in performance to the simpler, more common type of one-stage preselector in which the plate of the preselector tube is capacitively coupled to the antenna post of the receiver.

The preselector is moderately regenerative; in fact, the input circuit must be

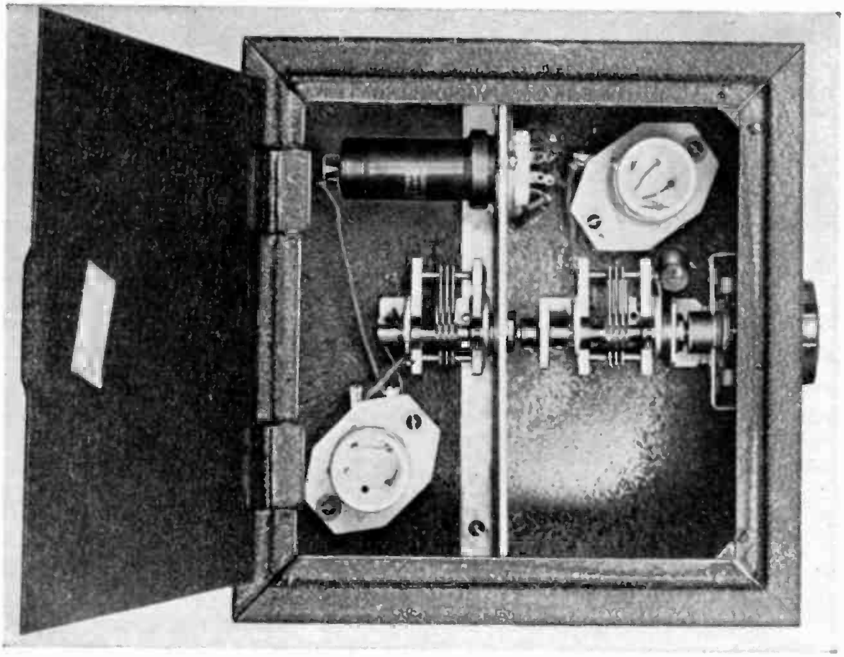


Figure 36.

LOOKING DOWN INTO THE 1851 HIGH GAIN PRESELECTOR.

An aluminum partition shields the input from the output circuit, and serves as a support for the tube and rear tuning condenser.

rather heavily coupled to an antenna or it will tend to oscillate.

The 1851 has a very low input resistance, especially on 10 meters. For this reason the grid is tapped down on the input coil, being connected approximately to the center of the coil. This reduces the grid loading to one-quarter without reducing the input voltage, due to the higher Q obtained with the tapped arrangement. Not only are selectivity and image rejection greatly improved, but tracking is greatly simplified by tapping down on the grid coil.

Tapping the grid and plate leads down on their respective coils effectively reduces the minimum shunt capacities, thus allowing a greater tuning range with a given tuning condenser. With the 50-$\mu\mu$fd. tuning condensers illustrated, approximately a 2-1 range in frequency is possible with each set of coils. This gives practically continuous coverage of the short-wave spectrum with the coils listed in the coil table. The coils cover the following ranges: 1.7 to 3.5 Mc., 3 to 6 Mc., 6.5 to 11 Mc., 10 to 19 Mc. and 18 to 33 Mc. Thus, the preselector can be used effectively with communication receivers of the continuous coverage all-wave type.

If oscillation is troublesome even when tight antenna coupling is used, the plate coil can be tapped a little farther down towards the ground (B plus) end.

If desired, a 6J7 or 6K7 can be used in place of the 1851. If one of these tubes is used, both grid and plate should be connected directly to the "hot" ends of their respective coils, instead of to the center. The gain will not be quite as high as with an 1851 and the tuning range will be reduced slightly. The latter can be offset by using 75-$\mu\mu$fd. tuning condensers instead of 50-$\mu\mu$fd. condensers.

Tracking can be checked by rotating the rear tuning condenser separately while listening to a station and watching the R meter.

Construction

The unit is built in a 7"x7"x7" cabinet and chassis. A 6¼"x5¼" aluminum partition with a ½-in. lip to permit fastening to the chassis as illustrated in figure 36 shields the input from the output circuits. The rear tuning condenser is mounted on this partition and driven from the front condenser by means of an insulated coupling. While the tube is shown mounted horizontally, it could be just as well mounted vertically; the leads would be just about as short.

For maximum gain on the higher frequency range, tuning condensers, sockets and coil forms should have ceramic insulation.

Most receivers will stand a slight additional drain on the plate and filament supplies without overheating. For this reason, the preselector voltages may be robbed from the receiver with which it is to be used. If the receiver power supply already runs quite hot, indicating that it is being overloaded, a separate power supply is advisable.

1851 PRESELECTOR COIL DATA

COIL BAND	GRID COIL	PLATE COIL
10	8 turns. #20 d.c.c. 1⅛" diam. 1" long center tapped Primary— 2 turns	Same as grid coil Secondary— 2 turns
20	15 turns #20 d.c.c. 1⅛" diam. 1" long center tapped Primary— 3 turns	Same as grid coil Secondary— 2 turns
40	24 turns #22 d.c.c. 1½" diam. 1½" long tap at 10 turns Primary— 5 turns	Same as grid coil turns tap at 12 Secondary— 3 turns
80	44 turns #24 d.c.c. 1½" diam. 1½" long tap at 15 turns Primary— 8 turns	Same as grid coil tap at 15 turns Secondary— 3 turns
160	80 turns #26 enam. 1½" diam. closewound tap at approx. 20 turns Primary— 12 turns	Same as grid coil Secondary— 3 turns

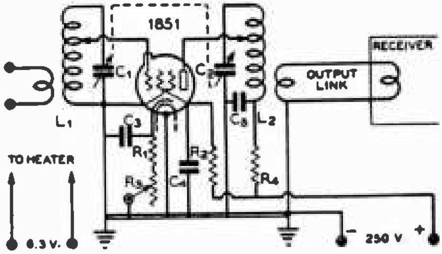


Figure 37.

SCHEMATIC CIRCUIT OF THE 1851 PRESELECTOR.

C_1, C_2—2-gang 50-$\mu\mu$fd. per section midget variable
C_3 — 0.1-μfd. 400-volt tubular
C_4, C_5—.01-μfd. 400 volt tubular
R_1 — 200 ohms, 1 watt
R_2—50,000 ohms, ½ watt
R_3—10,000-ohm potentiometer gain control
R_4—5000 ohms, 1 watt
Coils—See coil table

HIGH-FREQUENCY CONVERTERS

Few factory-built communications receivers go to five meters, and some do not include the 10-meter band. Of those that do include the 10-meter band, only a small number can be considered as being capable of really good performance. This is not a reflection on the engineers who design the receivers; it is not practicable to design for factory production at reasonable prices a receiver with a single "front end" which will include the 160-meter and possibly the broadcast band and still show peak efficiency on 10 meters, let alone 5 meters.

We are not finding fault with these receivers; the compromise between operation on both the low- and the high-frequency spectrum has been very carefully made and it is a credit to the engineers that the receivers operate as well as they do on 28 Mc. But, by designing the high-frequency end of the receiver specifically for frequencies above 28 Mc., it is not necessary that these compromises be made.

If your present receiver won't go down to 10 meters or to 5 meters, or if you are not satisfied with the performance of your receiver on 10 meters, it is suggested that you consider one of the converters shown. Any of these converters can be used on either 5 or 10 meters by using suitable coils. If your present receiver has an r.f. stage and you want improved performance on 10 meters, do not expect to get it by adding a simple one-tube converter having no r.f. stage. If you want the utmost in performance, either add the 1851 preselector just described or else construct a u.h.f. converter having an r.f. stage.

The one-tube converters using a 6J8, 6K8, or 6SA7 oscillator-mixer are especially adapted for mobile use. For peak performance either for fixed station or mobile use, however, a more elaborate converter is advisable.

Any of the converters shown may be used either for fixed station or mobile work. If the set with which the converter is used is sufficiently large, whether it be an auto set or 110 a.c. receiver, the plate voltage can probably be "robbed" from the receiver without overtaxing the power pack, and in the case of a 110-volt set the heater voltage can also be "borrowed." If the power transformer heats excessively or if the vibrator (in an auto set) "groans" when the additional load is applied, the power pack does not have sufficient capacity to handle the requirements of the converter and an auxiliary power supply will be required. An auxiliary power supply will only be needed under rare conditions, as when a three-tube converter is used with a four-tube auto set.

Simplest U.H.F. Converter

Probably the simplest yet nevertheless a highly effective 28-Mc. converter is shown in figures 38, 39 and 40. Considering the comparatively small number of parts the performance is surprising. The diagram shows heater connections for mobile use, but the converter is just as well suited for fixed station use. For mobile work there is not much point in using a more elaborate converter, as one is limited as to what one can work anyhow by the necessarily low transmitter power and lack of a highly efficient transmitting antenna. When used with a

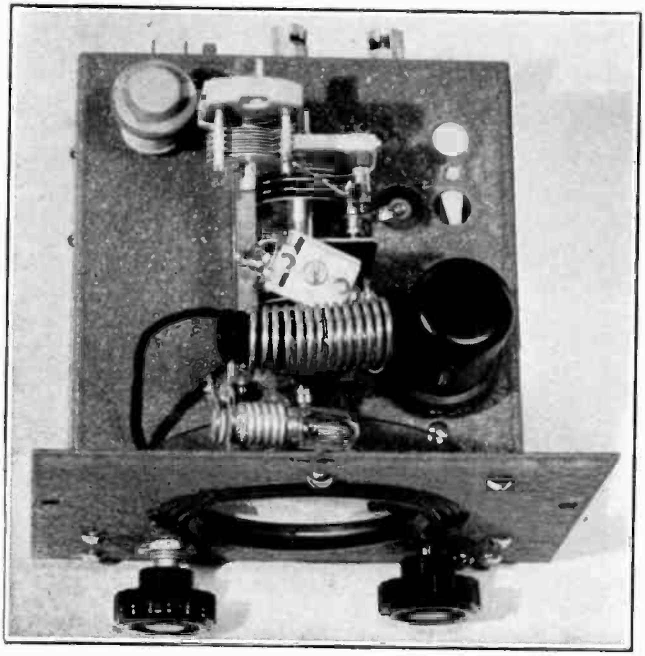


Figure 38.

SIMPLE YET HIGHLY EFFECTIVE 28-MC. CONVERTER.

This model was designed primarily for mobile work, but can be used with equally good success for fixed station use. As the plate current drain is low, the B voltage can be "robbed" from the receiver with which the converter is used.

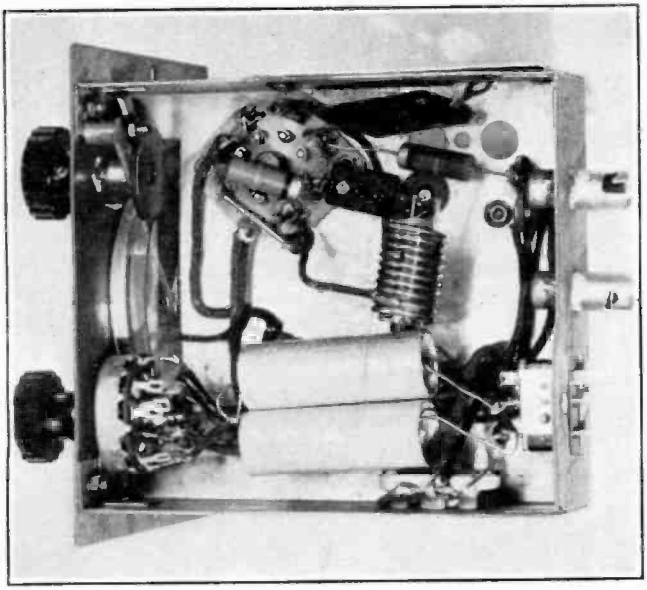


Figure 39.

UNDER-CHASSIS VIEW OF SIMPLE 28-MC. CONVERTER.

Note the small number of resistors and by-pass condensers. The oscillator coil turns must be held rigidly in place or vibration will cause frequency instability.

resonant receiving antenna the converter illustrated is almost as sensitive as the best converter one could possibly build, and for that reason is highly recommended.

The receiver with which the converter is used is tuned to slightly above 1500 kc., and serves as an i.f. amplifier. This high intermediate frequency minimizes image interference, especially when a resonant receiving antenna is used.

The voltage on grids 2 and 4 should be around 100 volts regardless of plate supply voltage; hence the contingent value of R_2 as given in the diagram. This particular mixer tube utilizes an electron coupled oscillator circuit and plate voltage changes resulting from variation in the battery load or charging rate have very little effect upon the oscillator frequency.

For maximum conversion gain the cathode tap on the oscillator coil must be adjusted for about 0.5 ma. of grid current. This will occur with the cathode tap about 1¾ turns up from the ground end of the oscillator coil. For precise adjustment, connect a 0-1.5 ma. d.c. milliammeter in series with the bottom end of R_1 and ground. Then slide the tap along the coil until exactly 0.5 ma. is indicated when the plate voltage on grids 2 and 4 is close to 100 volts as read on a high resistance voltmeter. However, the tap may be located with sufficient accuracy to give good efficiency simply by soldering it 1¾ turns up from ground.

The oscillator coil is wound of 10 turns of no. 14 wire spaced the diameter of the wire, ½ inch in diameter, tapped as noted above and stiffened by a small piece of curled up sheet celluloid, Lucite, or Plexiglas, which is held in place with duco cement. This prevents a microphonic condition and frequency instability which would otherwise occur as a result of vibration of the oscillator coil turns. The oscillator coil is mounted below the chassis as illustrated in figure 39.

The mixer coil consists of 15 turns of no. 14 wire, ½ inch in diameter, with the turns spaced the diameter of the wire. The primary or antenna coil consists of 6 turns of close wound hookup wire placed inside the ground end of the coil.

The output coil, C_3, is a small b.c.l. antenna coil which is tuned to about 1520 kc. (same frequency to which broadcast receiver is tuned) by means of a mica trimmer. The antenna winding (ordinarily the primary) is used here as a low impedance secondary.

The switch S_1 is a triple-pole double-throw affair and is used for switching on the converter. It automatically throws the quarter-wave "fishpole" antenna from

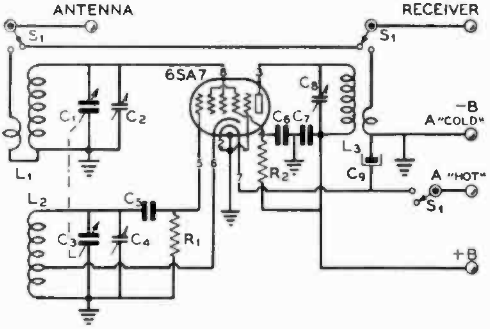


Figure 40.

GENERAL WIRING DIAGRAM OF THE SIMPLE 28-MC. MOBILE CONVERTER. FOR CHANGES IN CIRCUIT FOR A.C. OPERATION REFER TO TEXT.

C_1, C_3 — 15-μμfd. per section two-gang u.h.f. midget, altered as described in text

C_2 — 3-30-μμfd. mica trimmer, ceramic insulation

C_4 — 25-μμfd. midget air trimmer

C_5 — 40-μμfd. midget mica

C_6 — .05-μfd. tubular, 400 v.

C_7—4-μfd. 450 v. midget tubular electrolytic

C_8—25-100-μμfd. mica trimmer

C_9—10-μfd. 25 v. electrolytic

R_1—20,000 ohms, ½ watt

R_2—10,000 ohms 1 watt for 180—200 v. supply; 20,000 ohms 2 watts for 250 v. supply (B voltage on most auto sets is around 190 to 210 volts)

L_1, L_2—See text for coil data

L_3—Small b.c.l. antenna coil used "backwards"

the converter to the regular auto set when the 6SA7 heater is turned off, and vice versa.

Bandspread tuning is accomplished by removing all but one stator plate on the detector section and two on the oscillator section of the two-gang u.h.f. condenser. To align the set simply adjust the bandset condenser C_4 until the center of the 10-meter band comes at the midpoint on the dial. Then adjust the detector trimmer C_2 and output trimmer C_8 by means of a screwdriver for maximum signal strength. An adjustment of the antenna coupling by moving the primary turns in or out a bit will sometimes result in improved sensitivity.

For a.c. operation simply omit C_9 and run 6.3 v. from the heater transformer to the two heater pins, 2 and 7, and remove the ground connection from pin no. 2. If hum is present, ground this terminal through a 0.05-μfd. tubular condenser.

The converter can also be used on 56 Mc. by altering the coils. As the turns and spacing on 56 Mc. are quite critical, the exact number of turns and position for the cathode tap can best be determined by experiment. The same wire size, coil diameter, and turn spacing can be used.

TWO-TUBE 5 AND 10 METER CONVERTER

A somewhat more elaborate converter than the one just described is shown in figures 41 and 42. The use of an 1852 mixer and separate oscillator with suppressor injection to the 1852 results in high conversion efficiency, with the result that the converter is quite sensitive.

As illustrated and shown in the diagram, the converter is built primarily for

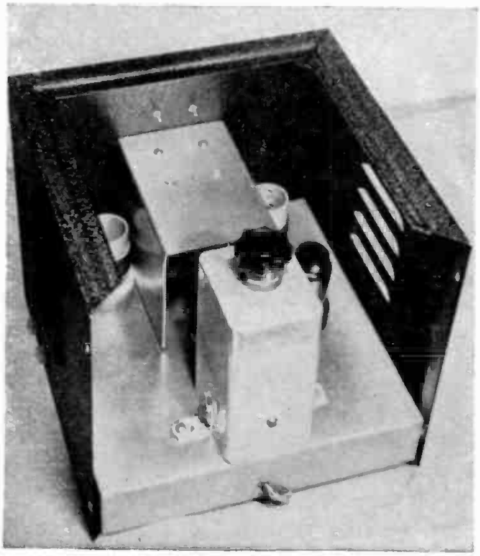


Figure 41.

INSIDE THE 1852 U.H.F. CONVERTER CABINET.

The two-gang tuning condenser is under the U-shaped shield between the two plug-in coils. The can in the foreground houses the output coil, L_4, and its trimmer, C_6. Directly behind this can and hidden from view is the 1852; the 6C5 may be seen to the right.

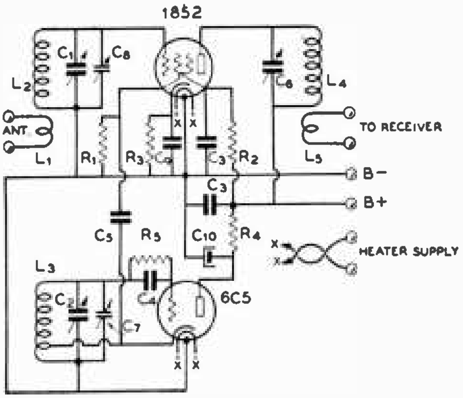


Figure 42.

GENERAL WIRING DIAGRAM OF THE 1852 CONVERTER.

C_1, C_2—Dual 25-μμfd. midget, altered as described in text.
C_3—.01 mica
C_4, C_5—.00005-μfd. mica
C_6—100-μμfd. mica trimmer
C_7—25-μμfd. air trimmer
C_8—17.5-μμfd. midget
C_9—.01-μfd. mica
C_{10}—8-μfd. 450-volt electrolytic
R_1—25,000 ohms, ½ watt
R_2—40,000 ohms, 1 watt
R_3—1500 ohms, 1 watt
R_4—5000 ohms, 1 watt
R_5—50,000 ohms, ½ watt
L_1—3 turns at cold end of L_2
L_2—5¾ turns on 1" form spaced dia. of wire for 28 Mc. 3 turns on 1" form spaced dia. of wire for 56 Mc.
L_3—4¾ turns on 1" form spaced dia. of wire for 28 Mc. 3¾ turns on 1" form spaced dia. of wire for 56 Mc. Cathode tapped ¾ turn from cold end on both bands
L_4—Solenoid type midget b.c.l. antenna coil; see text
L_5—4 turns at cold end of L_4

fixed station use. However, simply by connecting the heater leads to a 6.3 v. battery instead of 6.3 v. a.c. one can use the converter for mobile work. In the latter event it would be advisable to use a smaller cabinet and construct the unit more compactly than shown. No changes in the circuit are necessary for mobile operation. The total plate current drain is only a few ma. and B voltage may be borrowed from any auto set having 5 or more tubes. The plate voltage should be between 200 and 250 volts, preferably the latter, for good results.

Plug-in coils permit both 5- and 10-mixer coil forms (supporting L_2) should meter operation. For best results the be of a material having very low losses at ultra high frequencies.

Construction

The photographs illustrate the layout. A small stock cabinet and the chassis designed for it form the basis for the unit. Mounted in the center of the panel is a small 25 μμfd. per section dual-stator variable. The section nearer the panel, tuning the mixer input, has only one remaining stator plate; the rear portion, for the oscillator, has all but two stator plates removed. This condenser is mounted with the four tapped holes in the frame pointing upward. These holes are then used to support a shield which in addition to covering the condenser also acts as a baffle between the two coils.

Directly back of the tuning gang is the 1852 mixer; to the left is the oscillator coil, and to the right, the mixer coil. The can behind the 1852 contains a tuned output coil and link coupling to the receiver used as an i.f. channel. Below the tuning gang is a 15-μμfd. trimmer on the mixer to eliminate tracking problems on separate bands.

The Circuit

All oscillator leads should be made rigid to avoid shock detuning of the circuit. The ground leads are all brought to one point, which is even more advisable in the mixer circuit where an extra fraction of an inch in the cathode lead, common to both the grid and plate returns, is undesirable in that it affects the gain.

Suppressor injection is used through a 50-μμfd. or smaller coupling condenser. The mixer grid coils, wound on one-inch forms, have 5¾ turns on ten meters and three turns on five.

The converter is designed to work into a receiver tuned to a spot between 1500 and 1600 kc. The output coil L_4 is simply a midget b.c.l. antenna coil of the type having a low impedance primary. The coil is tuned to 1600 kc. by the mica trimmer C_6 and used backwards, the "primary" acting in this case as the secondary. A higher intermediate frequency would result in reduction of images, which might possibly be bothersome in some cases on 56 Mc. However, few auto sets are capable of tuning above 1600 kc.

If the converter is to be used only for fixed station use and one is interested in image-free 56-Mc. reception, an i.f. of around 5 to 7 Mc. can be utilized to advantage where the converter is used in conjunction with an all-wave receiver. To make the output coil L_4 hit in this range, simply remove half the turns from *both windings,* and substitute a 3-30 μμfd. mica trimmer for C_6. The turns should be removed from the outside ends of both windings so that the spacing between the windings is not disturbed.

Be sure to get a coil of the solenoid type if you are going to prune it down; otherwise it will be difficult to remove turns.

In some cases operation will be improved by connecting a .0005 μfd. midget mica condenser directly from the plate of the 6C5 to ground.

The cathode bias resistor can be anything from 1000 to 2500 ohms, somewhat larger than ordinarily recommended. This reduces the loading effect on the input circuit, the result being an improvement in both selectivity and gain.

Adjustment

The first step in lining up the converter is to adjust the output circuit to resonance with the receiver used as an i.f. amplifier. This is easily done inasmuch as the receiver noise, due both to shot effect in the mixer tube and signal or background racket at the i.f., increases when the circuit is brought in tune. The oscillator can be tuned around to locate a signal, but an easier way to set the oscillator is to listen for it in an all-wave receiver and set it at 28 Mc. plus the i.f.

When this adjustment has been made, there remains only to line up the mixer input circuit on outside noise or on a signal, using the trimmer on the panel (which also acts as a gain control). Ordinarily it will be necessary to obtain proper antenna coupling, inasmuch as high antenna pick-up and transfer to the mixer input will be important in determining weak-signal sensitivity and signal-to-noise ratio.

Voltage Regulation

If plate voltage fluctuations are sufficient to cause an objectionable shift in the oscillator frequency, as might be the case with some cars when the motor is raced or with an a.c. power pack running from a line to which several large intermittent loads are connected, the oscillator plate voltage can be stabilized simply by hooking a VR-150-30 type voltage regulator tube between the low side of R_4 and ground. The VR tube should be shunted by a .05-μfd. tubular condenser if it appears to be putting "hash" in the receiver. The plate supply should have at least 225 volts for the V.R. tube to function properly.

DE LUXE 10 METER CONVERTER

For the amateur who demands the utmost in performance and previously has had considerable construction experience, the de luxe converter of figure 43 is recommended. The newcomer should *not* tackle this converter, because unless constructed properly and aligned just right it will not work as well as the simpler converters previously described.

While the diagram shows power connections for automobile operation, the converter can be used just as well for fixed station use. In the latter case one side of the heaters would be by-passed to ground through a 0.1-μfd. tubular condenser instead of grounded directly; and S_1, C_{14}, and C_{15} could be omitted. Antenna connections for use with a concentric-line-fed Marconi antenna of the "fishpole" type are shown, but for fixed station use the converter would probably be fed from a two-wire balanced line, in which case the bottom end of the primary of L_1 would not be grounded as in the diagram.

The coil used in the tuned circuit of the oscillator is very small, wound of heavy conductor, and is made more rigid by small strips of celluloid cemented into place. The fixed padding condenser across the oscillator is a 75-μμfd. maximum capacity air padder. The normal setting for this condenser is approxi-

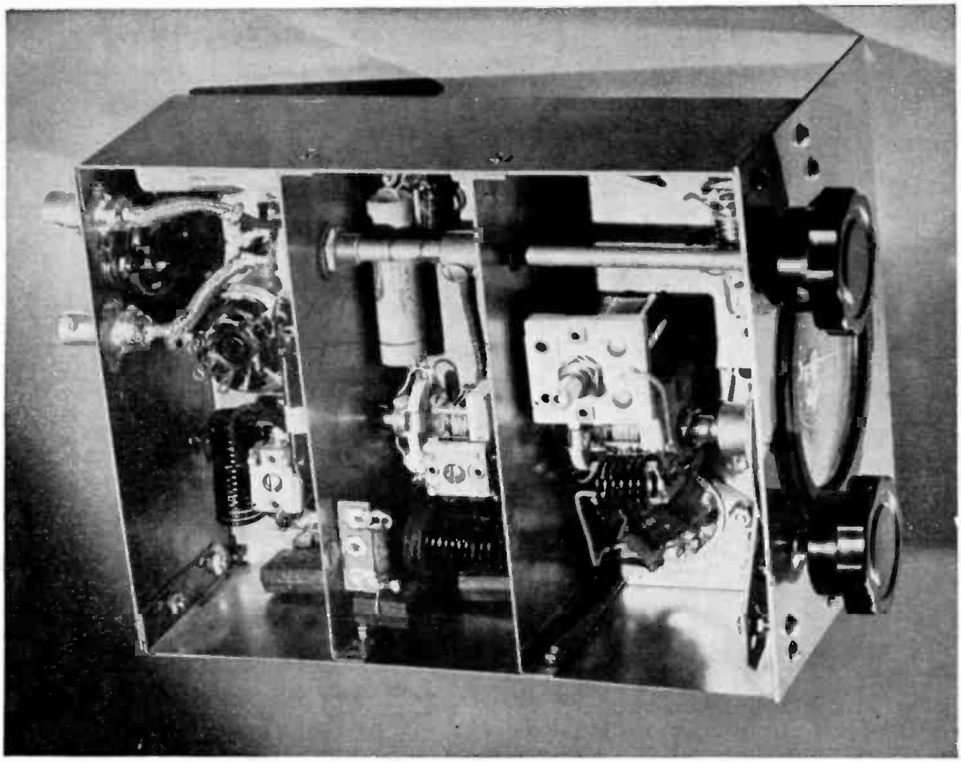


Figure 43.

UNDER-CHASSIS VIEW OF DE LUXE 10-METER CONVERTER.

The oscillator compartment is in the front, nearest the dial. The small and rigid oscillator coil can be seen mounted upon the tuning condenser and alongside the air padder condenser. The next compartment toward the rear houses the mixer stage and the rear compartment houses the r.f. stage, the sunken socket for the VR-150-30, the rotary on-off switch and the entering and leaving plugs.

mately 80 per cent meshed giving a fixed padding capacity across the entire tuned circuit of about 60 μμfd. plus tube and circuit capacities. Thus the tuned circuit itself is unusually high C, which helps considerably in reducing warm-up drift, instability with respect to changing plate voltage, and any tendency toward pulling which might be present due to coupling between the oscillator and mixer.

As a further aid to the stability of the oscillator its plate voltage is maintained as closely as possible at 150 volts through the use of a VR-150-30 regulator tube. This tube also regulates the screen voltage to the mixer stage. Either a 6C5 or a 6J5 may be used in the oscillator stage. The 6J5 was designed to be a better high-frequency oscillator in certain circuit arrangements, but in this particular arrangement with its low inherent losses and high circuit capacity both tubes operate almost exactly the same.

The r.f. stage is more or less conventional and may use either a 6SJ7 or a 6SK7 tube as the amplifier. The single-ended construction of the tube contributes greatly to the making of extremely short and direct leads from the elements to the tuned circuits. The screen voltage is taken from the 150-volt line that is regulated by the VR-150-30. Plate voltage is taken directly from the positive high-voltage line. The amplifier has a gang-

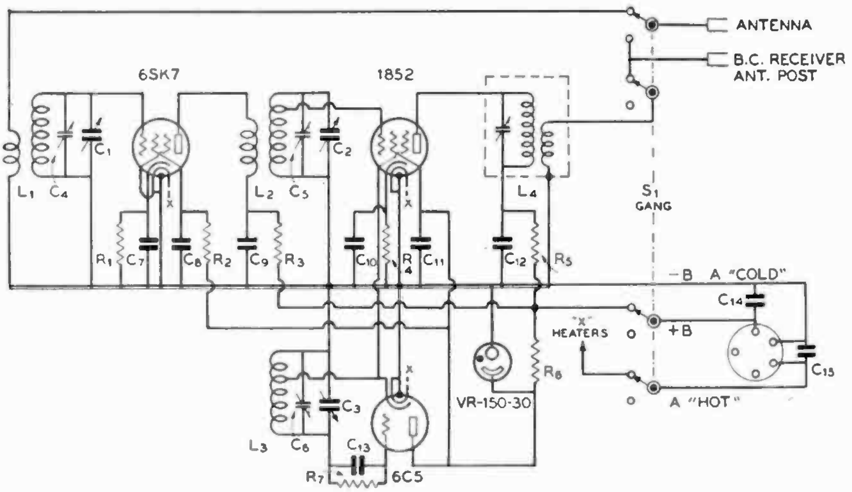


Figure 44.

WIRING DIAGRAM OF THE DE LUXE CONVERTER.

C_1, C_2 — 13-μμfd. midget
C_3—25μμfd. midget
C_4, C_5—3-30 μμfd. mica trimmer
C_6—75-μμfd. midget
C_7, C_8, C_9, C_{10}, C_{11}—.02-μfd. bakelite-cased paper
C_{12} — 0.1-μfd. 400-volt tubular
C_{13}—.0001-μfd. mica
C_{14}, C_{15} — 0.1-μfd. 400-volt tubular
R_1—300 ohms, ½ watt
R_2, R_3 — 1000 ohms, ½ watt
R_4 — 600 ohms, ½ watt
R_5—1000 ohms, ½ watt
R_6—4000 ohms, 10 watts
R_7—60,000 ohms, ½ watt
L_1 — Secondary, 15 turns no. 14 enameled ½" dia. Primary, 5 turns of hook-up wire inside secondary
L_2 — Secondary, 15 turns no. 14 enameled ½" dia., tapped at 9 turns from ground end. Primary, 5 turns of hook-up wire wound over ground end of secondary
L_3—6 turns no. 14 enameled, tapped 1 turn from ground end
L_4—Small b.c.l. band antenna coil connected "backwards", 100-μμfd. compression trimmer across grid winding (used here as plate winding)
S_1—4-pole, double-throw tap switch

tuned input circuit and its plate is inductively coupled to the grid circuit of the 1852 mixer.

The converter has a current drain of 20-25 ma. at normal auto-set voltages. Although this is a sizable drain, many auto sets will be capable of supplying the additional drain current at a sacrifice in plate voltage. The plate voltage should be at least 200 volts under load, and if the voltage falls below this when the converter is attached (or if the extra current overtaxes the vibrator or power pack), then an auxiliary power supply will be necessary. As the current drain is so low, the pack will be inexpensive. The pack should preferably have a voltage of 250 volts, with 200 as a minimum and 275 as maximum.

Tuning Up

If the unit has been wired properly, no difficulty should be encountered in getting it to operate properly with a wide variety of auto receivers. It is merely necessary to set the auto-receiver dial to some point around 1500 kc. and, after adjusting the output transformer trimmer for maximum noise or hiss, align the high-frequency stages in the converter. After the band has been located on the dial it is only necessary to align the mixer and/or r.f. trimmers for maximum signal strength and then to check the setting of the output transformer trimmer; the converter is then ready for use. It also may be of advantage to readjust the trimmers on the tuning condenser of the auto set to peak its sensitivity in the vicinity of 1500 kc. The operation of the set throughout the balance of the broadcast band will be affected but slightly.

It has been found that there will be very little difference in the sensitivity of the converter whether the oscillator is on the high or the low side. However, accurate tracking between the oscillator and the r.f. and mixer will only take place when the oscillator is on the *high-frequency* side of the mixer. This, of course, will take place when the oscillator padder condenser is at the *lower* capacity setting which gives tuning of the ten-meter band.

When the oscillator is on this side of the mixer the tracking is very close over about 90 per cent of the dial. Since the ten-meter band only covers about 75 per cent of the dial the tracking over the band is excellent.

SEVEN

Transmitter Theory

A TRANSMITTER may be defined as an electrical device whose purpose is to generate a radio-frequency signal of a desired frequency and to modulate this frequency in accordance with the intelligence to be transmitted. The r.f. energy from the transmitter is most commonly carried by a ***transmission line*** to an ***antenna*** or radiating system from whence the energy is radiated into space. The latter two subjects will be treated in the chapter devoted to *Antennas;* the theory of operation of the various divisions of the transmitter will be discussed in the following pages.

The usual transmitter will contain the following general divisions: an oscillator, either crystal or self controlled; one or more frequency multiplying stages; one or more radio-frequency amplifying stages and a system for either keying or modulating by voice the output of the final amplifier stage. However, a transmitter need not necessarily have all the stages mentioned above, and, in fact, may be merely an oscillator whose output is controlled by a telegraph key.

TYPES OF OSCILLATORS

An oscillator is essentially a vacuum-tube circuit whose function is to convert a source of direct current into radio-frequency alternating current of a pre-determined frequency. Oscillators for controlling the frequency of high-frequency radio transmitters can be divided into two classifications: self-controlled and crystal controlled.

There are a great many types of self-controlled oscillators, each one of which is best suited to a particular application. They again can be subdivided into the classifications of: negative-grid types, electron-orbit types, and negative-resistance oscillators.

Negative-Grid Oscillators

Negative-grid oscillators are essentially a vacuum-tube amplifier with a portion of the output energy coupled back into the input circuit as excitation for the grid circuit. They are called negative-grid oscillators because the grid is biased a considerable amount negative with respect to the cathode. It is this type of oscillator that finds the most common application in low- and medium-frequency transmitter control.

The various most common types of negative-grid oscillators are illustrated in figure 1. (A) is the *Hartley.* Its operation will be described as an index to the operation of all negative-grid oscillators; the only real difference between them and the Hartley is in the manner in which the energy for excitation is coupled from the plate to the grid circuit.

When the plate voltage is applied to the plus and minus terminals of the Hartley oscillator shown at (A), the sudden flow of plate current when the key is closed will cause an electromagnetic field to be set up in the vicinity of the coil. This sudden building up of the magnetic field will cause a voltage to be developed in the portion of the winding between the ca-

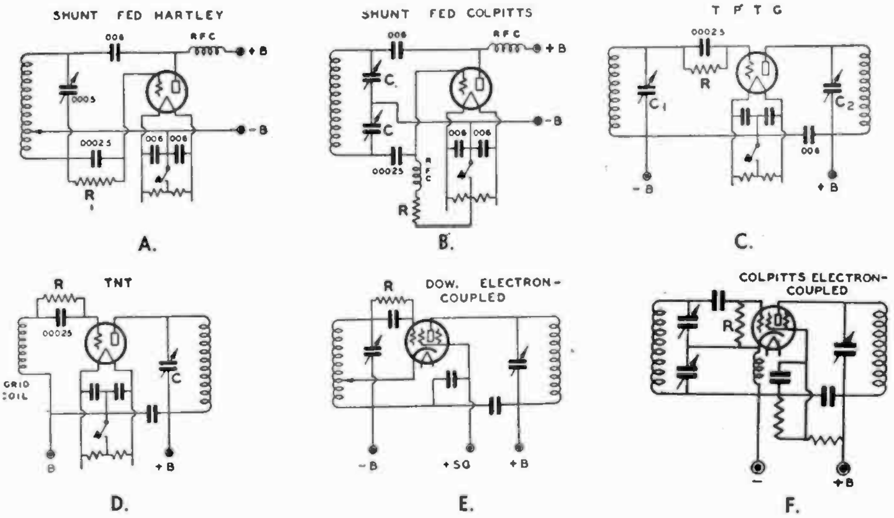


Figure 1. COMMON TYPES OF SELF-CONTROLLED OSCILLATORS.

thode tap and the grid of the tube. The instantaneous effect of the induced voltage will be to decrease the plate current of the oscillator tube. Then, as the plate current decreases, a voltage will be induced into the bottom half of the winding which will tend to increase the tube current again. This increase and decrease of the plate current of the oscillator tube will take place at a frequency determined primarily by the constants of the coil and condenser comprising the tank circuit of the oscillator. The resultant oscillations will increase in magnitude in an extremely small period of time until they are limited by the emission of the cathode of the tube, the losses of the tank circuit, or by the losses introduced by coupling a portion of the energy of the tank circuit to an external load.

The *Colpitts* oscillator is shown in (B). It can be seen that this is essentially the same circuit as the Hartley except that the tank circuit is tapped by a pair of condensers in series which comprise the tank condenser. The *tuned-plate tuned-grid* or t.p.t.g. oscillator illustrated at (C) has a tank circuit in both the plate and grid circuits and the feedback of energy from the plate to the grid circuit is accomplished by the plate-to-grid capacitance of the tube.

For best operation of the Hartley and Colpitts oscillators the voltage from grid to cathode, determined by the tap on the coil or the setting of the two condensers, should be from one-third to one-fifth that appearing between plate and cathode. In the t.p.t.g. oscillator the grid circuit should be tuned to a frequency slightly lower than that of the plate circuit for best operation. The frequency of oscillation is determined primarily by the constants of the plate circuit, and therefore a broadly resonant or aperiodic coil may be substituted for the grid tank to form the *T.N.T.* oscillator shown at (D).

Electron-Coupled Oscillators

In any of the three oscillator circuits just described it is possible to take energy from the oscillator circuit by coupling an external load to the tank circuit. Since the tank circuit determines the frequency of oscillation of the tube, any variations in the conditions of the external circuit will be coupled back into the frequency determining portion of the oscillator. These variations will result in frequency instability.

Two oscillators in which the frequency determining portion of the oscillator is coupled to the load circuit only by an electron stream are illustrated in (E) and (F) of figure 1. When it is considered that the screen of the tube acts as the plate to the oscillator circuit, the plate acting as a coupler to the load, then the similarity between the cathode-grid-screen circuit of these oscillators and the cathode-grid-plate circuits of the oscillator circuits shown above them from which they have been derived is apparent.

The advantage of the electron-coupled oscillator over conventional types is in the greater stability with respect to load and voltage variations that can be obtained. Load variations have very little effect on the frequency of operation of the e.c.o., since the only coupling between the oscillating circuit and the load is through the electron stream flowing through the other elements to the plate. The plate is electrostatically shielded from the oscillating portion by the screen, which is at ground potential with respect to r.f.

The stability of the electron-coupled type of oscillator with respect to variations in supply voltages comes from an entirely different source. It is a peculiarity of such an oscillator that the frequency will shift in one direction with an increase in screen voltage while an increase in plate voltage will cause it to shift in the other direction. By a proper proportioning of the resistors that comprise the voltage divider supplying screen voltage, it is possible to make the frequency of the oscillator substantially independent of supply voltage variations; the tendency of an increase in screen voltage to make the frequency shift in one direction is counterbalanced by the effect of the increase in plate voltage to make the frequency shift in the other direction. Electron-coupled oscillators are coming more and more into popularity as stable frequency controls for transmitters where it is desired to shift frequency throughout an amateur band. Practical application of the e.c. oscillator to transmitter control may be found in the chapter devoted to *Exciters and Low-Powered Transmitters*. Transmitter control requires that the frequency control unit be carefully constructed, both from an electrical and a mechanical standpoint.

Other Oscillator Circuits

Of the other oscillator circuits the negative-resistance and electron-orbit types are the most common of the self-excited class. Electron-orbit oscillators are used only for extremely high-frequency work (above 300 Mc.) and depend for their operation upon the fact that an electron takes a finite time to pass from one element to another inside a vacuum tube. The Gill-Morrell, Barkhausen-Kurtz, and Kozanowski oscillators are examples of this type and are described in the *Ultra-High Frequency* chapter. Another special type of u.h.f. oscillator is the *magnetron*, which is also described in the u.h.f. chapter. This type employs a filament surrounded by a split plate to which are connected rods comprising a linear tank circuit. The tube is operated in a strong magnetic field; hence the name, magnetron.

The other common type is the negative-resistance oscillator, which is used when unusually high frequency stability is desired, as in a frequency meter. The dynatron of a few years ago and the transitron of more recent fame are examples of oscillator circuits which make use of the negative resistance characteristic between different elements in a multi-grid tube. In the dynatron the negative resistance is a consequence of secondary emission of electrons from the plate of the tube. By a proper proportioning of the electrode voltages an increase of screen voltage will cause a decrease in screen current; from this comes the term, *negative resistance*. A similar effect in the transitron is produced by coupling the screen to the suppressor; the negative resistance in this case is due to interelectrode coupling rather than to secondary emission.

Another circuit which makes use of two cascaded tubes to obtain the negative-resistance effect is the Franklin oscillator illustrated in figure 2. The tubes may be either a pair of triodes, tetrodes, or pentodes, a dual triode, or a combination of a triode and a multi-grid tube. The chief advantages of this oscillator circuit are that only very loose coupling between the two tubes and the tank circuit, LC, is re-

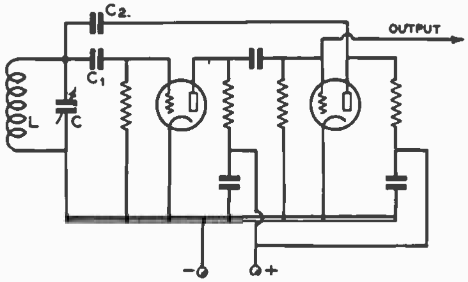


Figure 2.
THE FRANKLIN OSCILLATOR CIRCUIT.
In this oscillator circuit a separate phase-inverter tube is used to feed the output from oscillator back to the grid circuit and thus sustain oscillation.

quired, and that the frequency determining tank only has two terminals and one side of the circuit is grounded. Condensers C_1 and C_2 need be only one or two $\mu\mu$fd. for satisfactory operation of the oscillator; this means that tube capacity and input resistance variations will have only an extremely small effect on the frequency of oscillation.

CRYSTAL CONTROLLED OSCILLATORS

When it is desired to hold the frequency of a transmitter very closely to a certain definite value or to keep it within an assigned frequency tolerance, reliance is very commonly placed upon the *piezo-electric* properties of a plate cut from a natural crystal of quartz. Quartz crystals are very widely employed by amateurs and commercial services as frequency controls; hence some of the important characteristics of piezo-electric minerals will be mentioned before entering into a discussion of the oscillators that make use of these characteristics for frequency control.

Quartz Crystals

Naturally occurring quartz and tourmaline are minerals having a crystalline structure which, when cut and ground on certain crystalographic (optical) axes, possess piezo-electric properties in the influence of an electrical field. A detailed explanation of the piezo-electric effect will be found in any modern comprehensive encyclopedia.

The mechanical activity or frequency of a piezo-electric element depends upon its physical dimensions (the frequency being inversely proportional to the thickness) and upon a constant determined by the crystal cut. The stability of the oscillatory properties depends mainly upon the optical cut and the crystal-temperature coefficient.

A circuit containing a resonator (crystal) and possessing too little regeneration to oscillate itself, but which oscillates through the reaction of the crystal when the latter is vibrating near one of its normal frequencies with energy derived from the circuit, is called a *crystal controlled* or *piezo*-oscillator.

Crystal Cuts

The face of an X-cut or Y-cut crystal is made parallel to the Z axis in figure 3. Special-cut crystals, known as AT-cut, V-cut, LD2, HF2, etc., are made with the face of the crystal having an angle with respect to the Z axis, rather than being parallel to it. The purpose of these special-cut crystals is to increase their power handling ability in some cases, but especially to reduce the temperature coefficient. There is no frequency drift in crystals which have absolute zero temperature coefficient. AT, V, B5 and LD2-cut crystals have temperature coefficients approaching zero, and they should be used in radio transmitters in

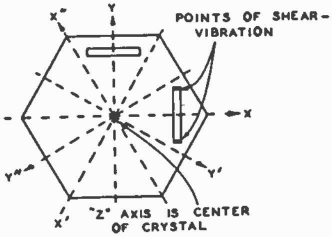


Figure 3.
SECTION THROUGH A QUARTZ CRYSTAL.
Showing the various axes of the raw quartz crystal.

which accurate frequency control is essential, such as edge-of-band operation. These crystals eliminate the need of a crystal oven for amateur work. A constant operating temperature is still required for some commercial applications, but the oven temperature need not be kept within as close limits as for an X- or Y-cut plate.

Spurious Peaks and Frequency Drift

Crystals that oscillate at more than one frequency are commonly known as crystals with twin peaks. The dual vibrational tendency is more pronounced with Y cuts, but to a certain degree is exhibited by many X cuts. The use of a well-designed, space-wound, low-C tank coil in an oscillator will tend to discourage the crystal from oscillating at two frequencies, and in addition will increase the output. Experiments have shown that the frequency stability is not improved by large tank capacities, which only tend to augment the double frequency phenomenon.

Twin frequencies appear in several ways: sometimes the crystal will have two frequencies several hundred cycles apart, and will oscillate on both frequencies at the same time to produce an acoustically audible beat note. Other crystals will suddenly jump frequency as the tank tuning condenser is varied past a certain setting. Operation with the tank condenser adjusted near the point where the frequency shifts is very unstable, the crystal sometimes going into oscillation on one frequency and sometimes on the other as the plate voltage is cut on and off. Still other crystals will jump frequency only when the temperature is varied over a certain range. And some plates will jump frequency with a change in either tank tuning or temperature, and produce an audible beat tone at the same time, showing actually two pairs of frequencies.

When operating close to the edge of one band, it is advisable to make sure that the crystal will respond to but one frequency in the holder and oscillator in which it is functioning; any crystal with two peaks can jump frequency slightly without giving any indication of the change on the meter readings of the transmitter. If the transmitter frequency is such that the operation takes place on the edge of the band at all times, under all conditions of room temperature, some form of temperature control will be required for the crystal unless it is of the zero drift type. When working close to the edges of the 14- or 28-megacycle band, it is essential that the crystal temperature be kept at a fairly constant value; the frequency shift in kilocycle per degree increases in direct proportion to the operating frequency, regardless of whether the fundamental or harmonic is used. When a crystal shifts its frequency by two kilocycles, its second harmonic has shifted 4 kilocycles. Amateurs not operating on the edge of the band generally need not concern themselves about frequency drift due to changes in room temperature.

If a pentode tube having a plate potential of approximately 300 volts is used for the crystal oscillator, the temperature of the crystal, regardless of cut, should not increase enough to cause any noticeable drift even at 14 megacycles. When a crystal oscillator is keyed on 3.5 or 1.7 megacycles, the frequency drift is not of any consequence, even with much higher values of plate input, because of the keying and of the fact that the drift is not multiplied as it would be with harmonic operation of a final amplifier.

Crystal holders have a large effect on the frequency; for example, the frequency of an 80-meter crystal can vary as much as 3 kilocycles in different holders. In fact, crystals can be purchased in variable gap holders which enable the operator to vary the frequency by varying the air gap. About 20- or 25-kc. shift can be obtained at 14 Mc. Only 40- or 80-meter AT-cut crystals are well-suited for this purpose.

High-Frequency Crystals

Forty-meter crystals can be treated much the same as 80-meter crystals, provided they are purchased in a dust-proof holder from a reliable manufacturer. However, it is a good idea with 40-meter crystals to make sure the crystal current is not excessive, as it will run higher in a given oscillator circuit than when a lower frequency crystal is used in the same circuit at the same voltage. A low loss, low-C tank circuit and a pentode or beam type oscillator tube are desirable.

Twenty- and 10-meter crystals, especially the latter, require more care in regard to circuit details, components and physical layout. Ten-meter crystals are *not* of the zero drift type, as such crystals would be too thin to be of practical use. A special thick cut operated on a harmonic is used to give the crystal sufficient mechanical ruggedness. Crystals of this cut have a drift of approximately 40-45 cycles/Mc./deg. C. This means that such crystals must be run at very low power levels not only to avoid fracture, but to prevent excessive drift. However, their use permits considerable simplification of a u.h.f. transmitter.

A type 41 tube, running at 275 volts on the plate and 100 volts on the screen, makes a good oscillator tube for a 20-meter crystal. Bias should be obtained from a 500-ohm cathode resistor rather than a grid leak. Very light loading, preferably with inductive coupling, is required. The tank coil should be low loss, preferably air-supported or wound on a ceramic form.

Medium high-μ triodes with high transconductance and low input and output capacities make excellent 10-meter crystal oscillators. The types RK34, 6J5G and 955 are the most satisfactory oscillators, the 6J5G permitting the most output besides being the least expensive.

Contrary to general practice with pentode crystal oscillators, the plate tank circuit should *not* be too low C; a moderate amount of tuning capacity should be used in a 10-meter triode crystal oscillator. The plate voltage on the oscillator tube should not be allowed to exceed 200 volts. About 2 watts output is obtainable from the 10-meter oscillator tank at this plate voltage. The tank coil can consist of 8 turns of no. 12 wire, air-wound to a ¾-inch diameter and spaced the diameter of the wire. Bias should be obtained from a 200-ohm cathode resistor (by-passed) and no grid leak. Connecting leads should be short and components small physically.

Both 10- and 20-meter crystal oscillators should be followed, where practicable, by a tube of high power gain, such as the 807. This cuts down the number of tubes required in a high-power stationary u.h.f. transmitter.

A 10-meter crystal oscillator with a 6J5G, driving a 6V6G doubler using a 150,000-ohm grid leak, makes an excellent 5-meter mobile transmitter. The latter tube can be either plate or plate-and-screen modulated. The modulation is better, especially when doubling, if both plate and screen are modulated.

Crystal Oscillators

Crystal oscillators can be divided into three classifications: (1) low-power circuits, which require several additional buffer stages to drive medium- or high-power final amplifiers; (2) high-power crystal oscillators, which minimize the number of buffer stages in a transmitter; (3) harmonic crystal oscillators, which operate on more than one harmonically-related band from one quartz crystal.

Low-power crystal oscillators are often required in transmitter design where extremely accurate frequency control is needed. The crystal oscillator tube is operated at low plate potential, such as 200 volts, with the result that oscillation is relatively weak. This means that there will be less heating effects in the quartz plate; the frequency drift, due to changes in temperature, is therefore minimized.

Mere operation of a quartz crystal oscillator tube at relatively low plate voltage does not necessarily mean a low degree of frequency drift; a type of crystal oscillator tube must be used which has high power sensitivity; high μ and low feedback (interelectrode) capacity. The amount of feedback determines the value of r.f. current flowing through the quartz plate and thus determines the amplitude of the physical vibration of the quartz plate. Any tube which requires only a very small amount of grid excitation voltage and has low grid-to-plate capacity can be used to supply relatively high-power output in a crystal oscillator without heating of the quartz plate.

High-power crystal oscillators are those which operate with as high a plate voltage as can be used with only moderate heating of the quartz crystal. Many transmitters, such as those used for amateur work, do not require as high a degree of frequency stability as do radiotelephone transmitters used for commercial services. The relatively high output from such crystal oscillators usually means the elimination of one or two buffer-amplifier stages. This simplifies the transmitter and may result in more trouble-free operation. There are a great many types of tubes suitable for high-power crystal oscillators, some of which are also used in high-stability low-power crystal oscillators by merely reducing the electrode voltages.

The crystal oscillator circuits in figures 4 and 5 are of the standard pentode-tube type. They operate on one frequency only, and the plate circuit is tuned to a frequency somewhat higher than that of the quartz crystal.

The actual power output of crystal oscillators, such as those shown in figures 4 and 5, is from one to five watts, depending upon the values of plate and screen voltage. The use of *AT-cut* or low temperature coefficient quartz plates allows higher values of output to be obtained without exceeding the safe r.f. crystal current ratings or encountering frequency drift. *X-cut* and *Y-cut* crystals, especially the latter, must be operated with comparatively low crystal current because they not only will not stand as much r.f. crystal current, but also have a higher temperature coefficient.

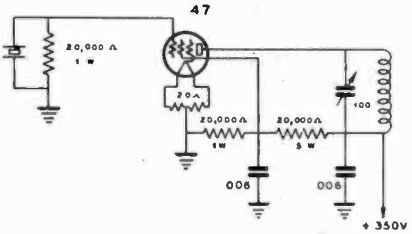


Figure 4.
TYPICAL PENTODE OSCILLATOR CIRCUIT.
This circuit is suitable for other filament-type tubes, such as the 6A4 and 33 when appropriate filament plate and filament voltages are used.

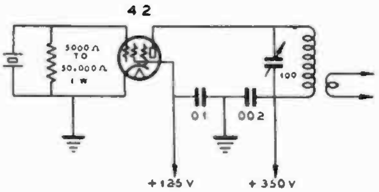


Figure 5.
CIRCUIT FOR CATHODE-TYPE PENTODE OSCILLATOR.

Pierce Crystal Oscillator

One of the earliest crystal oscillator circuits recently enjoyed a revival in popularity. This is the Pierce oscillator, in which the crystal is connected directly from plate to grid of the oscillator tube, the crystal taking the place of the tuned tank circuit in an ultra audion oscillator. Just as in the ultra audion, the amount of feedback depends upon the grid to cathode capacity. Thus, it is only necessary to connect from grid to cathode a fixed condenser permitting the proper amount of feedback for the tube and frequency band used. The capacity is not at all critical, and ordinarily it is not necessary to change the capacity even when changing hands.

The chief advantage of the oscillator is that it requires no tuned circuits. The chief disadvantage is that the maximum obtainable output is low, due to the fact that not over about 250 volts can be used safely. Also, it works well only with 160- and 80-meter crystals, though many 40-meter crystals will work satisfactorily if the constants are chosen for maximum performance on 40 meters.

The oscillator may be fed plate voltage either through an r.f. choke or a resistor of high enough resistance that it doesn't act as a low impedance path for the r.f.

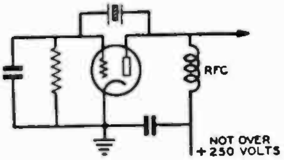


Figure 6.

GRID-PLATE PIERCE OSCILLATOR.

No tank circuit is required with this type of crystal oscillator. The crystal current is quite high for the amount of output obtained, however.

voltage. Such a resistor requires a much higher voltage plate supply for the same oscillator output than if an r.f. choke were used instead. The oscillator must of necessity be capacitively coupled to the following stage. One popular version of the Pierce circuit is shown in figure 6.

Tritet Crystal Oscillator

Any of the screen-grid tubes can be used in a tritet oscillator circuit such as the one shown in figure 7.

The tetrode of pentode plate circuit is *electron coupled* to the oscillator circuit. The plate circuit is generally tuned to the second harmonic and outputs of from 5 to 15 watts can be obtained without damage to the quartz crystal. This circuit is an improvement over the older forms of tritet in which a grid leak was used in place of the grid r.f. choke, and in which no cathode resistor and by-pass condenser were included. The improved circuit (figure 7) decreases the crystal current as much as 50 per cent, and thereby protects the crystal against fracture. The cathode circuit is high C and tuned to a frequency which is 40 per cent or 50 per cent higher than that of the crystal. If an 802 or 807 is substituted for the 6L6 tube, the plate circuit can be tuned to the fundamental frequency of the crystal without making it necessary to short-circuit the cathode tuned circuit.

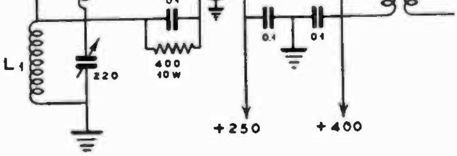


Figure 7.

TRITET CRYSTAL OSCILLATOR.

Output at the crystal harmonics may be taken from the plate circuit of this type of oscillator. Other suitable tubes are the 802, 42 and 6F6.

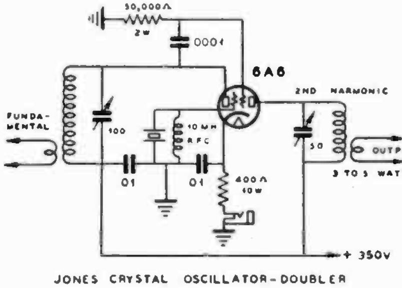


Figure 8.

DUAL-TRIODE CRYSTAL OSCILLATOR.

A dual triode such as the 53, 6A6 or 6N7 may be used to give output on either the crystal frequency or the second harmonic.

Oscillator-Doubler Circuit

The type 53 and 6A6 twin-triode tubes are popular for circuits where one triode acts as a crystal oscillator which drives the other triode as a frequency doubler; one tube, therefore, serves a dual purpose, supplying approximately 5 watts output on either the fundamental frequency or the second harmonic of the quartz crystal. Two applications of the twin-triode tube in a crystal oscillator circuit are shown in figures 8 and 9.

Figure 8 is a circuit which can be used with quartz crystals cut for 160-, 80-, 40- or 20-meter operation. The circuit shown in figure 9 can be made regenerative in the frequency-multiplier section in order to use the second triode as a tripler or quadrupler. By reducing the capacity of the feedback condenser to a low enough value, the second triode can be neutralized for use as a buffer stage. A suitable condenser for this purpose is a small mica-insulated trimmer condenser having a capacity range of from 3-to-30 $\mu\mu$fds.

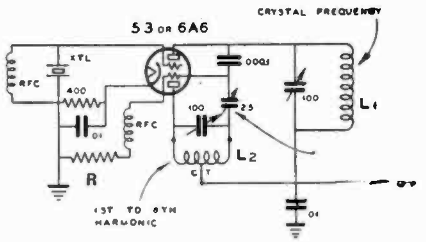


Figure 9.
TRIODE OSCILLATOR AND REGENERATIVE DOUBLER IN ONE TUBE.
By using one section of a dual triode as a crystal oscillator and the other section as a regenerative frequency multiplier, output on frequencies as high as the eighth harmonic of the crystal frequency may be obtained.

The resistor R shown in figure 9 should be from 30,000 to 50,000 ohms in value, and generally the r.f. choke shown in series with this resistor can be omitted. Coil data for any of these exciters can be obtained from those circuits (shown in the following pages) for which constructional details are given.

Regenerative Oscillators

The simple regenerative circuit of figure 10, with a triode such as a 76, will deliver as much as 2 or 3 watts with an r.f. crystal current of between 10 and 60 ma. for crystals from 160 to 10 meters. The triode circuit is excellent to drive a 6L6G buffer-doubler and the screen supply voltage for the 6L6G tube may be applied to the 76 plate circuit. This type of circuit is the only one which worked with all crystals, 10, 20, 40, 80 and 160 meters, whether they were extremely active such as a good X cut, or relatively inactive sluggish type or high-frequency crystals. The triode will furnish from 1 to 2 watts at twice crystal frequency when used with 160-, 80- or 40-meter crystals by tuning the plate circuit to the second harmonic.

In figure 10, the cathode condenser C_1 is usually left at some setting of from 40 to 50 $\mu\mu$fd. for 40-, 80- and 160-meter crystals.

A 6F6 or 42 works very well in the figure 11 circuit with a C_1 value of .0001 μfd. if heavily loaded. Eight to 12 watts output can be obtained easily from 160 to 20 meters and about 5 watts on 10 meters. A 6L6G tube requires a higher value of C_1, about .0004 μfd. unless heavily loaded.

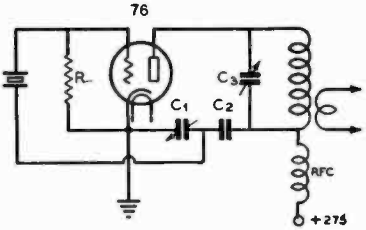


Figure 10.
REGENERATIVE TRIODE CRYSTAL OSCILLATOR.
Output on the crystal harmonics may be taken from the plate circuit of this type of oscillator.

Reinartz Crystal Oscillator

This regenerative crystal oscillator has a fixed-tune cathode circuit which is resonated to approximately *one-half* the crystal *frequency*. For example, with an 80-meter crystal the cathode circuit is tuned to 160 meters, the plate circuit to 80 meters. Either an 802 or a 6F6 tube can be used in a Reinartz crystal oscillator circuit. The output will be from 5 to 25 watts, depending upon the values of plate and screen voltages. The 6F6 is used as a high-μ triode in this same type of circuit, whereas the 802 is used as a pentode oscillator with additional con-

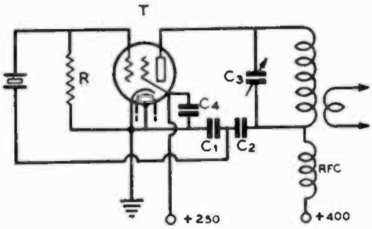


Figure 11.
REGENERATIVE TETRODE OSCILLATOR.
This type of oscillator circuit is very suitable for use with a type 6L6 tube. The amount of regeneration is controlled by the size of C_1.

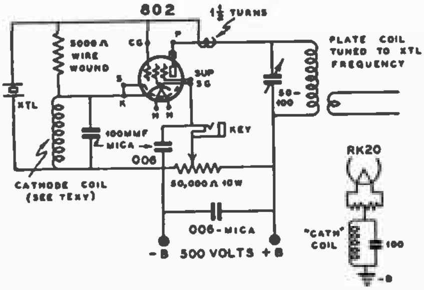


Figure 12.

REINARTZ 802 OSCILLATOR CIRCUIT.

The cathode coil in this circuit is fixed-tuned to half the crystal frequency.

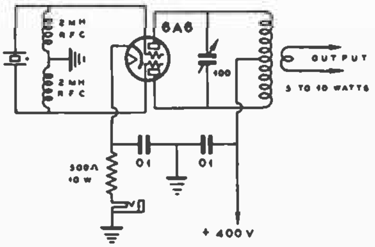


Figure 13.

PUSH-PULL CRYSTAL OSCILLATOR.

A dual triode such as the 6A6, 53 or 6N7 makes an excellent push-pull crystal oscillator.

trol grid-to-plate capacity feedback. The circuit is shown in figure 12.

The crystal r.f. current is quite low in this circuit, in comparison with the output power which can be obtained. The cathode circuit is tuned to half the frequency of the crystal, and the reactive effect produces regeneration at the harmonic frequency. This increases the operating efficiency of the tube without danger of uncontrollable oscillation at frequencies other than that of the crystal.

Push-Pull Crystal Oscillators

The type 53 twin-triode tube (2.5-volt heater) and its 6.3-volt companion tubes, 6A6 and 6N7, make good push-pull crystal oscillators. A typical twin-triode oscillator circuit is shown in figure 13.

Outputs of from 5 to 10 watts can be obtained from this circuit without exceeding the ratings of the usual X-cut crystals. The crystal current for a push-pull oscillator is but little higher than for a single triode of the same type, and twice the output can be obtained.

Some push-pull oscillators will not oscillate on 160 meters, the feedback being insufficient in the push-pull connection to sustain oscillation under load.

Crystal Oscillator Tuning Procedure

Every oscillator circuit is generally tuned for maximum output by means of an indicator of some form, such as d.c. milliammeter in the grid bias lead of the tube being driven by the oscillator. Maximum meter reading indicates maximum output from the crystal oscillator. Other indicators are: (1) A small neon bulb held near the plate end of the oscillator tuned circuit; maximum glow of the bulb indicates maximum oscillator output. (2) A flashlight bulb or a pilot light bulb, connected in series with a turn of wire fastened to a long piece of wood dowell (to protect the operator) can be coupled to the oscillator coil for indicating r.f. output. Maximum brilliancy of the lamp denotes maximum output from the oscillator.

The type 53 or 6A6 oscillator-doubler circuit is adjusted by tuning the oscillator section for maximum output, and the doubler section for greatest dip in cathode or plate current. The crystal plate section should generally be tuned until the circuit approaches the point where oscillation is about to cease; this is towards the higher-capacity setting of the oscillator plate tuning condenser and operation in this manner provides most output in proportion to r.f. crystal current and frequency drift.

Harmonic crystal oscillators are always tuned for maximum output and minimum plate, or cathode current. The regeneration or feedback condenser is adjusted or chosen to provide a good plate current dip when the plate circuit is tuned to the second harmonic of the crystal oscillator. Too much regeneration will cause the tube to oscillate for all settings of the plate tank condenser, without any sharp dip at the harmonic frequency of the crystal. Insufficient regeneration will result in low second harmonic output.

A plate potential of 400 volts is generally considered a safe upper limit for a type 6L6 oscillator tube. The screen-grid voltage affects the degree of regeneration and harmonic output; this voltage should generally range between 250 and 275 volts. The cathode current will run between 50 and 60 milliamperes for fundamental frequency operation, and 60 to 75 milliamperes for harmonic operation, at these plate and screen voltages. The crystal r.f. current normally runs between 25 and 75 milliamperes in this type of oscillator, depending on the frequency and plate voltage used.

RADIO-FREQUENCY AMPLIFIERS

Since the output of the oscillator stage in a transmitter (whether it be self-controlled or crystal controlled) must be kept down to a fairly low level to maintain stability and to maintain a factor of safety from fracture of the crystal when one is used, the low power output of the oscillator is brought up to the desired power level by means of radio-frequency amplifiers. The two classes of amplifiers that find widest application in amateur transmitters are the class B and class C types.

The Class B Amplifier

Class B amplifiers are used in a radiotelegraph transmitter when maximum power gain is desired in a particular stage. A class B amplifier operates with cutoff bias and a comparatively small amount of excitation. Power gains of 20 to 200 or so are obtainable in a well-designed class B amplifier. The plate efficiency of a class B c.w. amplifier will run around 65 per cent.

Another type of class B amplifier is the class B linear stage as employed in radiaphone work. This type of amplifier is used to increase the level of a modulated carrier wave and depends for its operation upon the linear relation between excitation power and output power. Or, to state the fact in another manner, the power output of a class B linear stage varies linearly with the square of the excitation voltage. The class B linear amplifier is operated with cutoff bias and a small value of excitation, the actual value of exciting power being such that the power output under carrier conditions is one fourth of the peak power capabilities of the stage. Class B linears are very widely employed in broadcast and commercial installations, but are comparatively uncommon in amateur application, since tubes with high plate dissipation are required for moderate output. Another reason for their unpopularity among amateurs is that the power limitation upon amateurs is placed upon power *input* to the final stage and not upon power *output*. The approximately 33 per cent efficiency of the class B linear makes the power capability of a transmitter with a linear amplifier in the final stage less than half that of a high-level modulated transmitter whose maximum efficiency may be as high as 75 or 80 per cent. This assumes, of course, that the maximum legal input of one kilowatt is being employed.

Grid Excitation

Sufficient grid excitation must be available for class B or class C service. The excitation for a plate-modulated class C stage must be sufficient to drive a normal value of d.c. grid current through the bias supply of about 2½ times cutoff. The bias voltage preferably should be obtained from a combination of grid leak and fixed C-bias supply. Cutoff bias can be calculated by dividing the amplification factor of the tube into the d.c. plate voltage. This is the value normally used for class B amplifiers (fixed bias, no grid leak). Class C amplifiers use from 1½ to 5 times this value, depending upon the available grid drive, or excitation, and the desired plate efficiency. Less grid excitation is needed for c.w. operation, and the values of fixed bias (if greater than cutoff) may be reduced, or the value of the grid leak resistor can be lowered until normal d.c. grid current flows. This value should be between 75% and 100% of the value listed under tube characteristics.

The values of grid excitation listed for each type of tube may be reduced by as much as 50% if only moderate power output and plate efficiency are desired. When consulting the tube tables, it is well to remember that the power lost in the tuned circuits must be taken into consideration when calculating the available grid drive. At very high frequencies, the r.f. circuit losses may be greater than that required for grid drive unless low loss tank circuits are used.

Readjustments in the tuning of the oscillator, buffer or doubler circuits, will result in greater grid drive to the final amplifier. The actual grid driving power is proportional to the d.c. voltage developed across the grid leak (or bias supply) multiplied by the d.c. grid current.

Link coupling between stages, particularly to the final amplifier grid circuit, normally will provide more grid drive than can be obtained from other coupling systems. The number of turns in the coupling link and the location of the turns on the coil can be varied with respect to the tuned circuits to obtain the greatest grid drive for allowable values of buffer or doubler plate current. Slight readjustments sometimes can be made after plate voltage has been applied.

Excessive grid current will damage the tubes by overheating the grid structure; beyond a certain point of grid drive no increase in power output can be obtained for a given plate voltage.

The Class C Amplifier

Class C amplifiers are very widely employed in all types of transmitters. A good power gain may be obtained (values of gain from 3 to 20 are common) and the plate circuit efficiency may be under certain conditions as high as 85 per cent. Class C amplifiers operate with considerably more than cutoff bias and ordinarily with a rather large amount of excitation as compared to a class B amplifier. The bias for a normal class C amplifier is such that plate current on the stage flows for approximately 120° of the 360° excitation cycle. Class C amplifiers are used in transmitters where a fairly large amount of excitation power is available and where good plate circuit efficiency is desired.

The characteristic of a class C amplifier which makes it linear with respect to changes in plate voltage allows such an amplifier to be plate modulated for radiotelephony. Through the use of higher bias than is required for a c.w. class C amplifier and greater excitation, the linearity of such an amplifier may be extended from zero plate voltage to twice the normal value. The output power of a class C amplifier adjusted for plate modulation varies with the square of the plate voltage. Since this is the same condition that would take place if a resistor equal to the voltage on the amplifier divided by its plate current were substituted for the amplifier, it is said the stage presents a resistive load to the modulator.

If the grid current on a class C amplifier is reduced to a low value and the plate loading is increased to the point where the plate dissipation approaches the rated value, such an amplifier may be grid modulated for radiotelephony. If the plate voltage is raised to quite a high value and the stage is adjusted carefully, efficiencies as high as 42 to 45 per cent with good modulation capability and comparatively low distortion may be obtained. This type of operation is termed class C grid modulation and is coming into increasing favor among amateur radiotelephone operators.

NEUTRALIZATION OF R.F. AMPLIFIERS

The plate-to-grid feedback capacity of triodes makes it necessary that they be neutralized for operation as r.f. amplifiers at frequencies above about 1500 kc. Those screen-grid tubes, pentodes, and beam tetrodes which have a plate-to-grid capacity of a small fraction of one micromicrofarad may ordinarily be operated as an amplifier without neutralization. A neutralizing circuit is merely an elec-

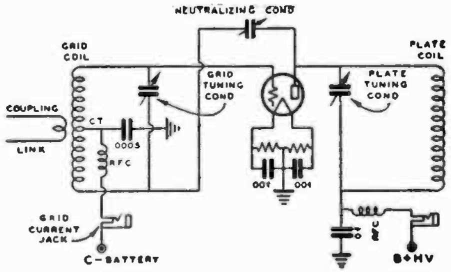


Figure 14.
ONE TYPE OF NEUTRALIZING CIRCUIT.
In this grid-neutralized amplifier out-of-phase voltage for neutralizing is obtained by using a center-tapped grid coil. A split-stator grid condenser with a grounded rotor may also be used. In the latter case the by-pass condenser from the center of the coil to ground would be eliminated.

trical arrangement for coupling back an amount of energy equal to that fed back by the plate-to-grid capacity and 180° out of phase with it.

Neutralizing Circuits

Single-tube amplifiers can be either plate or grid-neutralized. A typical *grid neutralized* circuit is shown in figure 14.

The out-of-phase neutralizing voltage can also be obtained by using a split-tank connection in the plate, rather than in the grid circuit, as shown in figure 15.

The circuit shown in figure 14 is suitable for low- or medium-C tubes, in which the grid-to-filament capacitance is less than 8 or 10 $\mu\mu$fds. Tubes with higher interelectrode capacitance cannot be satisfactorily neutralized in circuits which have a single-section tuning condenser in both plate and grid circuits. The circuit in figure 14 becomes more regenerative as the frequency increases, and cannot be used at frequencies on the order of 28 megacycles. The tuning condenser which is connected across the neutralizing circuit should be of the split-stator variety for frequencies above 7 Mc. The *electrical center* of the tuning condenser (rotor of a split-stator condenser) is connected to ground, or by-passed to ground, but the center tap of the coil is *not* by-passed to ground. This holds for either plate or grid neutralization. An r.f. choke is necessary at the center tap for external connection to the plate supply or grid-bias supply. Grid and plate neutralization are equally satisfactory below 30 Mc., and the choice between the two usually depends upon the type of equipment available when building the r.f. amplifier. This point is emphasized later in this chapter, where a number of r.f. amplifier designs are treated.

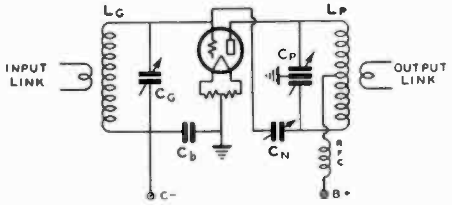


Figure 15.
PLATE NEUTRALIZATION.
As in the grid-neutralization circuit, out-of-phase voltage may be obtained either through the use of a center-tapped coil or center-tapped (split-stator) condenser.

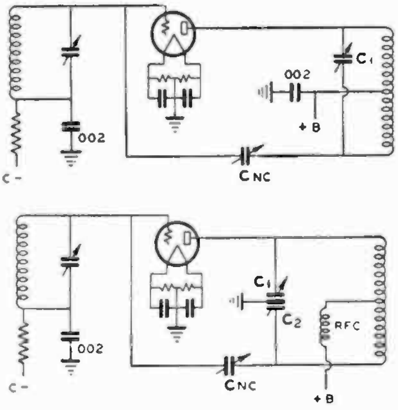


Figure 16.
TWO TYPES OF BALANCED PLATE CIRCUITS.
The upper circuit has a center-tapped plate coil by-passed to ground; the lower circuit uses a split-stator plate tuning condenser with an r.f. choke in the coil center-tap connection.

A comparison between split-stator and single-section plate neutralized circuits can be seen in figure 16.

As was previously stated, the single-section condenser tuned circuit is somewhat regenerative, and therefore is more easily driven from a low power source of grid excitation. *Some* regeneration can be tolerated in an amplifier for c.w. transmission, but not for radiophone service. The split-stator tuned circuit *always* should be used in modulated r.f. amplifiers which operate at high frequencies. The single-section condenser tuned circuit requires less grid driving power than the split-stator tuned circuit. In c.w. transmitter design, this may eliminate one buffer stage or allow higher efficiencies to be obtained from the final amplifier. The efficiency of the final amplifier is dependent to a large extent upon the amount of grid drive; if there is a deficiency in the latter, the amplifier efficiency may drop to a low value, with attendant low r.f. power output and excessive plate dissipation.

The same grid excitation requirements hold true for the two types of grid neutralized circuits as well as for the two types of plate neutralized circuits.

Push-Pull R. F. Circuits

Two tubes can be connected for *push-pull* operation so as to obtain twice as much output as that of a single tube. A push-pull amplifier, such as that shown in figure 17, also has an advantage in that the circuit can more easily be balanced than a single-tube r.f. amplifier. The various interelectrode capacities and neutralizing condensers are connected in such a manner that those on one side of the tuned circuits are exactly equal to those on the opposite side. For this reason, push-pull r.f. amplifiers can be more easily neutralized in very-high-frequency transmitters; also, they usually remain in perfect neutralization when tuning the amplifier to different bands.

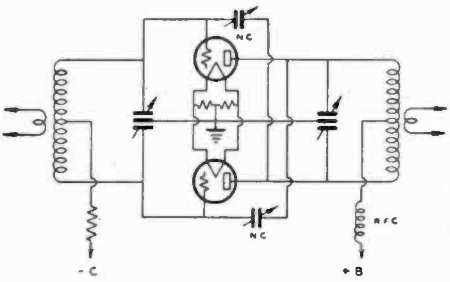


Figure 17.
PUSH-PULL R.F. AMPLIFIER STAGE.
Capacities on both sides of the circuit are balanced in this type of amplifier, making it more easily neutralized and more stable at high frequencies than single-ended arrangements.

The center tap of the grid coil is sometimes by-passed to ground; in other cases it can float. It is possible to use a single-section plate tuning condenser with twice the plate spacing between adjacent plates as that of a normal split-stator tuning condenser, providing a *split-stator grid* tuning condenser is used in the push-pull amplifier. The center-tap of the plate tuned circuit should be by-passed to ground in this case.

The plate tuning condenser preferably should be of the split-stator type, with the stator connected to ground, or by-passed to ground by means of a high-voltage .002-μfd. mica condenser in series with the rotor of the variable condenser and ground. The latter connection is particularly desirable because it prevents a d.c. arc from being formed and damaging the r.f. choke and power supply components in the event of r.f. flashover across the plates of the tuning condenser.

Neutralizing Procedure

The r.f. amplifier is neutralized to prevent self-oscillation or regeneration. A neon bulb, a flashlight lamp and a loop of wire, or an r.f. galvanometer can be used as a *null indicator* for neutralizing low-power stages. Plate voltage is disconnected from the r.f. amplifier stage while it is being neutralized. Normal grid drive then is applied to the r.f. stage, the neutralizing indicator is coupled to the plate coil and the plate tuning condenser is tuned to resonance. The neutralizing condenser (or condensers) then can be adjusted until *minimum* r.f. is indicated for resonant settings of both grid and plate tuning condensers. Both neutralizing condensers are adjusted simultaneously and to approximately the same value of capacity when a push-pull stage is being neutralized.

A final check for neutralization should be made with a d.c. milliameter connected in the grid leak or grid-bias circuit. There will be no movement of the meter reading as the plate circuit is tuned through resonance (without plate voltage being applied) when the stage is completely neutralized. The milliammeter check is more accurate than any other means for indicating complete neutralization and it also is suitable for neutralizing the stages of a high-power transmitter.

Push-pull circuits usually can be more completely neutralized than single-ended circuits when operating at very high frequencies. In the intermediate range of from 3 to 15 megacycles, single-ended circuits will give satisfactory results. Single-ended operation in the 3-to-15 megacycle range is most stable with split-stator tuning condensers; for example: a grid-neutralized circuit requires a split-stator grid tuning condenser, while a plate-neutralized circuit requires a split-stator plate tuning condenser.

Neutralizing Problems

When a stage cannot be completely neutralized, the difficulty can be traced to one or more of the following causes: (1) The filament leads may not be by-passed to the common ground bus connection of that particular stage. (2) The ground lead from the rotor connection of the split-stator tuning condenser to filament may be too long. (3) The neutralizing condensers may be in a field of excessive r.f. from one of the tuning coils. (4) Electromagnetic coupling may exist between grid and plate coils, or between plate and preceding buffer or oscillator circuits. (5) Insufficient shielding or spacing between stages, or between grid and plate circuits in compact transmitters may prevent neutralization or give false indications of neutralizing adjustments. (6) If shielding is placed too close to plate circuit coils, neutralization will not be secured because of induced currents in the shields. (7) Parasitic oscillations may take place when plate voltage is applied. The cure for the latter is to rearrange the parts, change the length of grid or plate or neutralizing leads, insert an ultra-high-frequency r.f. choke in the grid lead or leads, or eliminate the grid r.f. chokes which may be the cause of a low-frequency parasitic (in conjunction with plate r.f. chokes).

Plate Circuit Tuning

When the amplifier is completely neutralized, reduced plate voltage should be applied before any load is coupled to the amplifier. This reduction in plate voltage should be at least 50% of normal value because the plate current will rise to excessive values when the plate tuning condenser is not adjusted to the point of resonance. The latter is indicated by the greatest dip in reading of the d.c. plate current milliammeter; the r.f. voltage across the plate circuit is greatest at this point. With no load, the r.f. voltage may be several times as high as when operating under conditions of full load; this may result in condenser flashover if normal d.c. voltage is applied. The no-load plate current at resonance should dip to 10% or 20% of normal value. If the plate circuit losses are excessive, or if *parasitic oscillations* are taking place, the no-load plate current will be higher.

The load (antenna or succeeding r.f. stage) then can be coupled to the amplifier under test. The coupling can be increased until the plate current at resonance (greatest dip in plate current meter reading) approaches the normal values at which the tube is rated. The value at reduced plate voltage should be proportionately less in order to prevent excessive plate current load when normal plate voltage is applied. Full plate voltage should not be applied to an amplifier unless the r.f. load also is connected; otherwise the condensers will arc-over or flash-over, thereby causing an abnormally high tube plate current which may damage the tube. The tuned circuit impedance is lowered when the amplifier is loaded, as are the r.f. voltages across the plate condenser.

Grid Saturation

Excessive grid excitation is just as injurious to a vacuum tube as abnormal plate current or low filament operation. Too much grid driving power will overheat the grid wires in the tube, and will cause a release of gas in certain types of tubes. An excess of grid drive will not appreciably increase the power output and increases the efficiency only slightly after a certain point is reached. The grid current in the tube should not exceed the values listed in the *Tube Tables,* and care also should be exercised to have the bias voltage low enough to prevent flashover in the stem of the vacuum tube.

Grid excitation usually refers to the actual r.f. power input to the grid circuit of the vacuum tube, part of which is used to drive the tube, and part of which is lost in the C-bias supply. There is no way to avoid wasting a portion of the excitation power in the bias supply.

FREQUENCY MULTIPLIERS

Quartz crystals are not ordinarily used for direct control of the output frequency of high-frequency transmitters. *Frequency multipliers* are needed to multiply the frequency to the desired value. These multipliers operate on exact multiples of the crystal frequency; a 3.6-megacycle crystal oscillator can be made to control the output of the transmitter on 7.2 or 14.4 megacycles, or even on 28.8 megacycles, by means of one or more frequency multipliers. When used at twice frequency, as they most usually are, they are often termed *frequency doublers.* A simple doubler circuit is shown in figure 18. It consists of a vacuum tube with its plate circuit tuned to *twice* the frequency of the grid driving circuit. This doubler can be excited from a crystal oscillator, or connected to another doubler or buffer amplifier stage.

Doubling (*frequency multiplication*) is accomplished by operating the tube with extremely high grid bias in order to make the output plate circuit rich in harmonics. The grid circuit is driven approximately to normal values of d.c. grid current through the r.f. choke and grid leak resistor, shown in figure 18. The resistance value generally is from two to five times as high as that used with the tube for simple amplifying. For the same value of grid current the grid bias is several times as high.

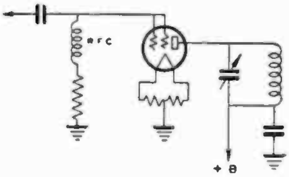


Figure 18.

CONVENTIONAL DOUBLER CIRCUIT.

A high-μ, dual-grid triode make a good doubler. The plate circuit is tuned to twice the excitation frequency.

Neutralization is seldom absolutely necessary in a doubler circuit, since the plate is tuned to twice the frequency of the grid circuit. The feedback from the doubler plate circuit to the grid circuit is at *twice* the frequency of the grid driving circuit to which the coupling condenser (figure 18) is connected. The impedance of this external tuned grid driving circuit is very low at the doubling frequency and thus there is no tendency for self-excited oscillation when ordinary triode tubes are used. At very high frequencies however, this impedance may be great enough to cause regeneration, or even oscillation, at the tuned output frequency of the doubler.

A doubler can either be neutralized or made more regenerative by adjusting C_2 in the circuit shown in figure 19.

When condenser C_2 is of the proper value to neutralize the plate-to-grid capacity of the tube, the plate circuit can be tuned to twice the frequency (or to the same frequency) as that of the source of grid drive; the tube can be operated either as a neutralized amplifier or doubler. The capacity of C_2 can be increased so that the doubler will become *regenerative,* if the r.f. impedance of the external grid driving circuit is high enough at the output frequency of the

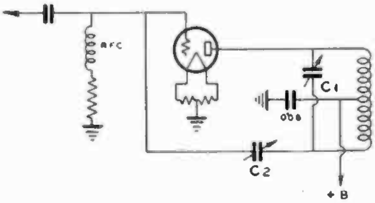


Figure 19.
REGENERATIVE DOUBLER OR NEUTRALIZED BUFFER.
This circuit may be used for a neutralized buffer or, when the capacity of C_2 is increased beyond the "neutralized" setting, as a regenerative doubler.

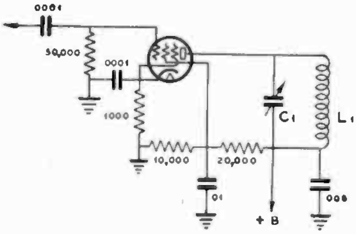


Figure 20.
REGENERATIVE HIGH-FREQUENCY DOUBLER.
This circuit tends to be regenerative at high frequencies. At low frequencies, however, it is liable to be degenerative.

doubler. This doubler is regenerative at its output frequency; regeneration will increase the efficiency when there is a lack of sufficient grid excitation. A doubler which receives sufficient grid excitation does not require regeneration to obtain efficiencies of from 50% to 60%. This efficiency refers to the ratio of r.f. power output to d.c. power input of the doubler plate circuit. The circuit in figure 19 generally is operated with the condenser C_2 adjusted for exact neutralization, so that the tube can be operated either as an amplifier or doubler for two-band operation.

Frequency doublers require *bias* of several times cutoff; high-μ tubes therefore are desirable for this type of service. Tubes which have amplification factors of from 20 to 200 are suitable for doubler circuits. Tetrodes and pentodes usually have high amplification factors. Low-μ triodes, having amplification constants of from 3 to 10, are not applicable for *doubler* service because in some cases the grid voltage must be as high as the plate voltage for efficient doubling action. The necessary d.c. grid voltage for high-μ tubes can be obtained more easily from average driver stages in conventional exciters.

Cathode Regeneration

Another form of regenerative doubler is shown in figure 20. This circuit employs a pentode tube with its cathode only partially by-passed for radio frequencies. This provides a common impedance for both plate and grid circuits and causes a regenerative effect at high frequencies, such as 14 or 28 megacycles. The circuit tends to be *degenerative,* rather than *regenerative* at the low frequencies.

Angle of Flow in Frequency Multipliers

The angle of plate current flow in a frequency multiplier is a very important factor in determining the efficiency. As the angle of flow is decreased for a given value of grid current, the efficiency increases. To reduce the angle of flow, higher grid bias is required so that the grid excitation voltage will exceed the cutoff value for a shorter portion of the exciting-voltage cycle. Frequency doublers of all types should have an angle of flow of 90 degrees or less, triplers 60 degrees or less and quadruplers 45 degrees or less.

Normally, a smaller angle of flow requires quite high bias and excitation. However, by altering the shape of the exciting voltage from its usual sine wave shape at the exciting frequency, it is possible to decrease the angle of flow and thus increase the efficiency without resorting to increases in the excitation voltage and bias.

The angle of flow may be decreased by adding some third harmonic voltage to the excitation. The result of adding the third harmonic voltage to the fundamental is shown graphically in figure 21. As shown by the dotted curve, E_g, when the fundamental and third harmonic voltages are

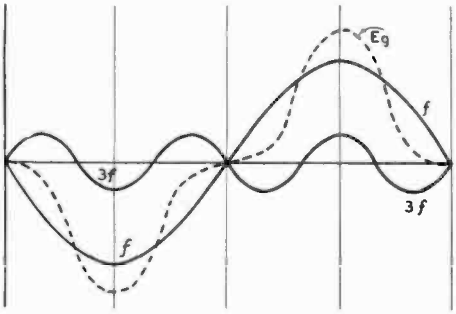


Figure 21.
SHOWING HOW A PEAKED WAVE FORM IS OBTAINED WHEN FUNDAMENTAL AND THIRD-HARMONIC ENERGY ARE ADDED.
When fundamental-frequency (f) energy and third-harmonic (3f) energy are added in the proper phase the result is a peaked wave form as shown by E_g. This peaked wave form, when used as excitation for a doubler stage, results in higher doubler efficiencies.

added in the proper phase the result is a grid excitation voltage having a peaked wave form, exactly what is required for high - efficiency frequency multiplying. The method by which the third harmonic is added is shown in figure 22. A small, center-tapped tank circuit tuned to three times the driver frequency is placed between the driver plate and the coupling condenser to the frequency-multiplier stage. The center tap of this coil is connected to the "hot" end of the driver plate tank, which remains tuned to the fundamental frequency. The third-harmonic tank circuit can be tuned accurately to frequency by coupling to it a small, low-current dial lamp in a loop of wire and tuning for maximum brilliancy. An absorption wavemeter may be coupled to the third-harmonic tank after it has been tuned to make sure that it is on the correct harmonic. The tuning of this circuit is not critical; one setting will serve to cover an amateur band.

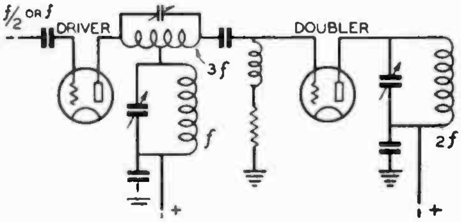


Figure 22.
CIRCUIT USED FOR COMBINING THIRD-HARMONIC AND FUNDAMENTAL FREQUENCIES.
A small third-harmonic tank circuit connected as shown adds the fundamental and the third harmonic in the proper phase.

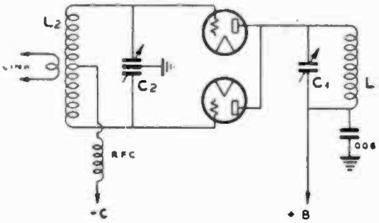


Figure 23.
PUSH-PUSH DOUBLER CIRCUIT.
In this type of doubler the grids are connected in push-pull and the plates in parallel. A small dual-triode may be used in place of the two tubes shown.

Push-Push Doublers

Two tubes can be connected with the grids in push-pull, and the plates in parallel, for operation in a so-called *push-push doubler,* as shown in figure 23.

This doubler circuit will deliver twice as much output as a single-tube circuit; it has proven popular in amateur transmitters because of its *operating ease.* In previous doubler circuits, capacitive coupling was shown. *Link coupling* to the tuned circuit in a preceding stage is shown in figure 23. This coupling arrangement simplifies the push-pull connection of the two grid circuits.

The circuit C_2-L_2 is tuned to the same frequency as that of the preceding tuned circuit, and the doubler plate circuit C_1-L_1 is tuned to *twice* the frequency. The grid circuit should be tuned by means of a split-stator condenser, connected as shown in figure 23, rather than by means of the single-section tuning condenser and bypassed center-tapped coil arrangement. The latter would provide a relatively high

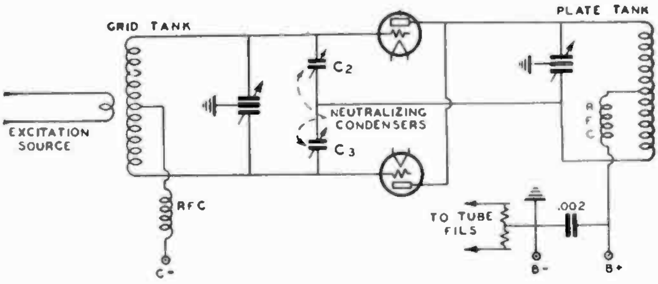


Figure 24.
NEUTRALIZED PUSH-PUSH DOUBLER.
Some high-transconductance tubes require neutralization when used as push-push doublers.

impedance at the doubling frequency. The push-push doubler then would be highly regenerative, and in most cases it would break into self-oscillation. The split-stator tuning circuit provides a *capacitive* reactance at the doubling frequency, so that there is very little regenerative action; the circuit, therefore, is quite stable if the grid tank is not made too low C.

Some multigrid crystal oscillators are designed so that frequency doubling can be accomplished directly in the oscillator tube circuit by connecting the various grids in push-pull (2 tubes) and the output plates in parallel.

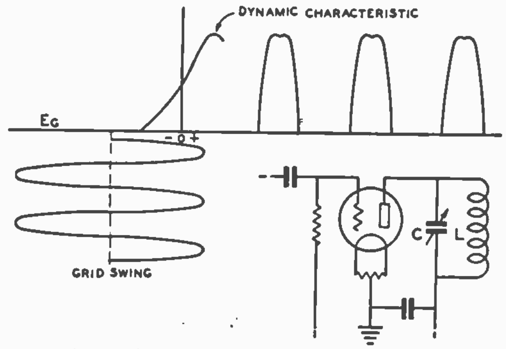
High-power push-push doubler stages for use with such tubes as the HK-354D or 250TH may become too highly regenerative at high plate voltage. They can be neutralized, as shown in the circuit in figure 24. Each tube is separately neutralized (the plate voltage having first been removed) with the plate circuit tuned to the *same frequency* as that of the grid circuit. The plate circuit then can be tuned to twice the frequency of the grid circuit (*after* the neutralizing process has been completed) without danger of self-oscillation.

The push-push circuit makes a very efficient doubling arrangement because each grid is being excited on a positive half of the exciting voltage and, since the grids are in push-pull, this means that plate current flows to one or the other of the parallel plates twice during every cycle of the exciting voltage. Thus the current pulses in the plate circuit occur at twice the exciting-voltage frequency, resulting in extremely efficient doubling action. The push-push doubler may also be used as a quadrupler by tuning the plate circuit to the fourth harmonic of the grid-excitation frequency. As with a single ended doubler, short-pulse excitation is required for good efficiency.

TANK CIRCUIT CAPACITIES

Tuning capacity values for class C amplifiers are important subjects to anyone building a radio transmitter. The best value of capacity can be determined closely by charts or formulas for any frequency of operation. The ratio of C to L, capacitance to inductance, depends upon the operating plate voltage and current, and upon the type of circuit. Proper choice of capacity-to-inductance ratio for resonance at any given frequency is important in obtaining low harmonic output and also low distortion in the case of a modulated class C amplifier.

A class C amplifier produces a very distorted plate current wave form in the form of pulses as shown in figure 25. The LC circuit is tuned to resonance and its purpose is to smooth out these pulses into a sine wave of radio-frequency output, since any wave form distortion of the carrier frequency is illegal, causing harmonic interference in higher-frequency channels. A class A radio-frequency amplifier would produce a sine wave output. However, the a.c. plate current would be flowing during the full 360° of each r.f. cycle, resulting in excessive plate loss in the tube for any reasonable value of output. The class C amplifier has a.c. plate current flowing during only a fraction of each cycle, allowing the plate to cool off during the remainder of



CLASS C AMPLIFIER PLATE CURRENT WAVEFORM

Figure 25.

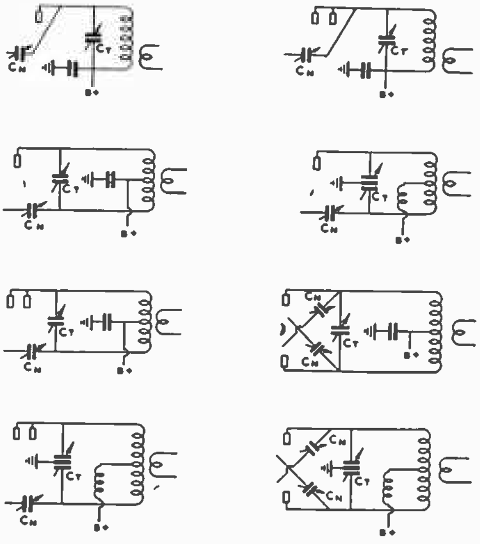


Figure 26.
TYPICAL TANK CIRCUITS.
Examples of amplifier stages employing these circuits will be found in chapter 15.

each cycle. If the plate current is zero for 2/3 of each cycle, the *angle of plate current flow* is said to be 120°, since current is flowing during ⅓ of 360°. The tube in a class C amplifier could have several times as much power input for a given plate loss as when used in a class A amplifier.

The tuned circuit must have a good flywheel effect in order to furnish a sine-wave output to the antenna when it is receiving energy in the form of very distorted pulses such as shown in figure 25. The LC circuit fills in power over the complete r.f. cycle, providing the LC ratio is correct. The flywheel effect is generally defined as the ratio of radio-frequency volt-amperes to actual power output, or VA/W. This is equivalent to Q and should not be much less than 4π, or 12.5, for a class-C amplifier. At this value of VA/W or Q, one-half of the stored energy in the LC circuit is absorbed by the antenna. If a lower value of Q is used, the storage power is insufficient to produce a sine (undistorted) wave output to the antenna and power will be wasted in radiation of harmonics.

Too high a value of VA/W or Q will result in excessive circulating r.f. current loss in the LC circuit and lowered output to the antenna. In high-fidelity radiophone transmitters, too high a Q will cause attenuation of the higher side band frequencies and consequent loss of the higher audio frequencies. A too low a Q has its disadvantages also; so most transmitters are operated with LC circuit values of between 10 and 25. A value of 20 seems to be high enough for modulated class C amplifiers; about 10 to 12 is enough for c.w. transmitters. With values of Q less than about 10, the maximum r.f. output will not occur at the point of minimum plate current in the amplifier tuning adjustment.

Opinions vary as to the correct value of Q, but a careful analysis of the whole problem seems to indicate that a value of 12 is suitable for most amateur phone or c.w. transmitters. A value of 15 to 20 will result in less harmonic radiation at the expense of a little additional heat power loss in the tank or LC circuit. The charts shown have been calculated for an operating value of Q=12.

The curves shown in figure 27 indicate the sharp increase in harmonic output into the antenna circuit for low values of Q. The curve for the second harmonic rises nearly vertically for Q values of less than 10. The third harmonic does not become seriously large for values of Q greater than 4 or 5. These curves show that push-pull amplifiers may be operated

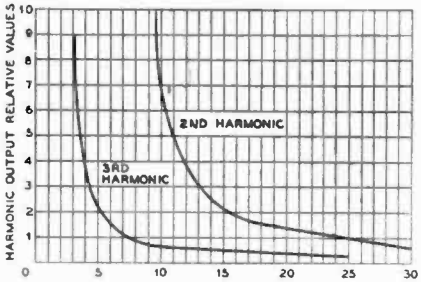
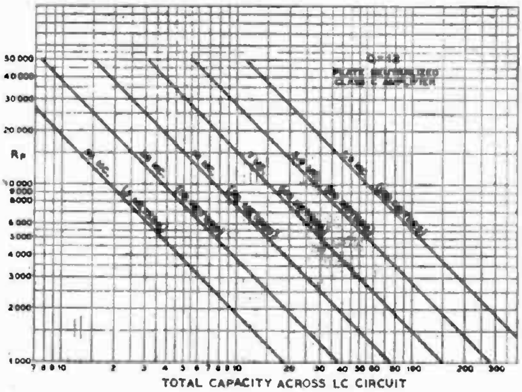


Figure 27.

Harmonic output versus tank-circuit Q for class C operation.



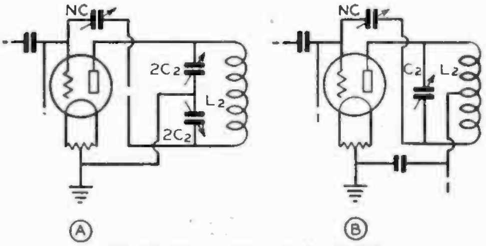


PLATE-NEUTRALIZED AMPLIFIERS

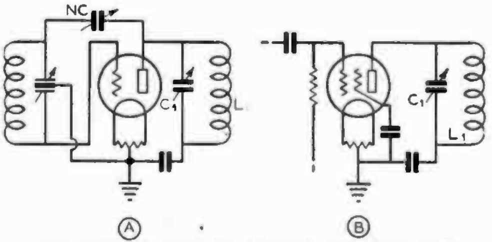
Figure 29.

at lower values of Q if necessary, since the second harmonic is cancelled to a large extent *if there is no capacitive or unbalanced coupling* between the tank circuit and the antenna feeder system.

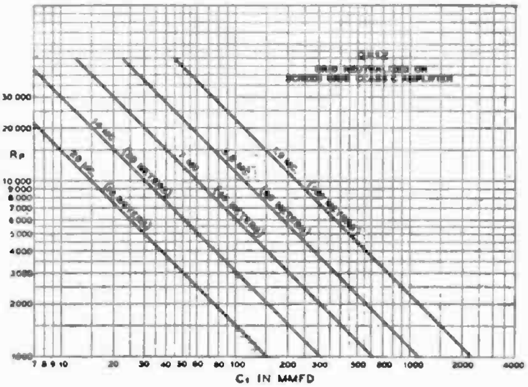
Effect of Loading on Q

The Q of a circuit depends upon the resistance in series with the capacitance and inductance. This series resistance is very low for a low-loss coil not loaded by an antenna circuit. The value of Q may be from 100 to 200 under these conditions. Coupling an antenna circuit has the effect of increasing the series resistance, though in this case the power is consumed as useful radiation by the antenna. Mathematically, the antenna increases the value of R in the expression $Q = \omega L/R$ where L is the coil inductance and ω is the term $2 \pi f$, f being in cycles per second.

Figure 28.

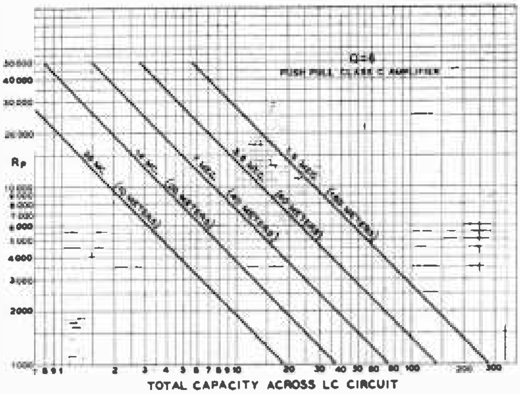


GRID-NEUTRALIZED OR SCREEN-GRID AMPLIFIER



The antenna coupling can be varied to obtain any value of Q from 3 to values as high as 100 or 200. However, the value of Q = 12 (or Q = 20 if desired) will not be obtained at normal values of d.c. plate current in the class C amplifier tube unless the C-to-L ratio in the tank circuit is correct for that frequency of operation.

The values of C_1, C_2 and C_3 shown in figures 28, 29 and 30 are for the total capacity across the inductance. This includes the tube interelectrode capacities, distributed coil capacity, wiring capacities and tuning condenser capacity. If a split-



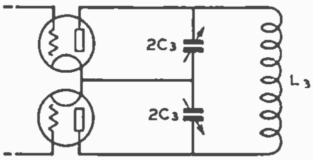


Figure 30.

PUSH-PULL AMPLIFIER.

stator condenser is used, the effective capacity is equal to half of the value of each section since the two sections are in series across the tuned circuit. The total stray capacities range from approximately 2 up to 30 $\mu\mu$fd. and largely depend upon the type of tube or tubes used in the class C amplifier.

In the push-pull circuit of figure 30, each tube works on a portion of each half cycle so less storage of flywheel effect is needed and a value of $Q = 6$ may be used instead of $Q = 12$.

The values of R_p are easily calculated by dividing the d.c. plate supply voltage by the total d.c. plate current (expressed in amperes). Correct values of total tuning capacity are shown in the charts for the different amateur bands. The shunt stray capacity can be estimated closely enough for all practical purposes. The coil inductance should then be chosen which will produce resonance at the desired frequency with the total calculated tuning capacity.

The capacities shown are the minimum recommended values and they should be increased 50% to 100% for modulated class C amplifiers where economically feasible. The values shown in the charts are sufficient for c.w. operation of class C amplifiers. It is again emphasized that these values are *total capacities* across the tank circuit, and should not be considered as the capacity *per section* for a *split-stator* condenser. If a split-stator condenser is to be used, the *per section* capacity should be *twice* that indicated by the charts.

TUNING CONDENSER AIR GAP

Plate-Spacing Requirements for Various Circuits and Plate Voltages

In determining condenser air gaps the peak r.f. voltage impressed across the condenser is the important item, since the experimental and practical curves of air gap versus peak volts as published by the Allen D. Cardwell Mfg. Corp. may be applied to any condenser with polished plates having rounded edges. Typical peak breakdown voltages for corresponding air gaps are listed in the table. These values can be used in any circuit. The problem is to find the peak r.f. voltage in each case and this can be done quite easily.

The r.f. voltage in the plate circuit of a class C amplifier tube varies from nearly zero to twice the d.c. plate voltage. If the d.c. voltage is being modulated by an audio voltage, the r. f. peaks will reach four times the d.c. voltage. These are the highest values reached in any type of loaded amplifier: a class B linear, class C grid- or plate-modulated or class C c.w. amplifier. The circuits shown in figures 32 and 34 require a tuning condenser with plate spacing which will have an r.f. peak breakdown rating at least equal to 2 times or 4 times the d.c. plate voltage for c.w. and plate-modulated amplifiers respectively.

It is possible to reduce the air gap to one-half by connecting the amplifier so

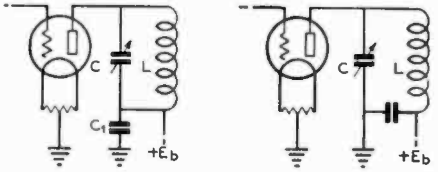


Figure 31. Figure 32.
TWO TYPES OF SINGLE-ENDED TANK CIRCUITS.

BREAKDOWN RATINGS OF COMMON PLATE SPACINGS	
AIR-GAP IN INCHES	PEAK VOLTAGE BREAKDOWN
.030	750
.050	1500
.070	3000
.078	3500
.084	3800
.100	4150
.144	5000
.175	5700
.200	6200
.250	7200
.300	8200
.350	9250
.375	10,000
.500	12,000

that the d.c. plate voltage does not appear across the tuning condenser. This is done in figures 31 and 33. These circuits should always be used in preference to those of figures 32 and 34 since the tuning condenser is only about one-fourth as large physically for the same capacity. Consequently, it is proportionately less expensive.

The peak r.f. voltage of a plate-modulated class C amplifier varies at 100% modulation from nearly zero to four times E_b, the d.c. plate voltage, but only one-half of this voltage is applied across the tuning condensers of figures 31 and 33. For a class B linear, class C grid-modulated or c.w. amplifier, the r.f. voltage across the tube varies from nearly zero up to twice E_b. The r.f. voltage is an a.c. voltage varying from zero to a positive and then to a negative maximum over each cycle. The fixed (mica) condenser C_1 in figure 31, and C_2 in figure 33 insulates the rotor from d.c. and allows us to subtract the d.c. voltage value from the tube peak r.f. voltage value in calculating the breakdown voltage to be expected.

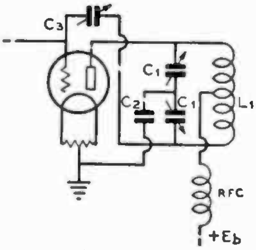


Figure 33.
SPLIT TANK CIRCUIT.
The power supply will not be shorted in case of condenser flashover if this circuit is used.

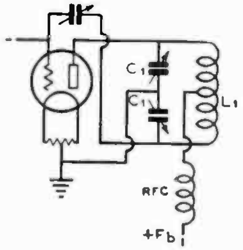


Figure 34.
SPLIT TANK CIRCUIT.
A tank condenser flashover will short the power supply when this circuit is used.

This gives us a simple rule to follow for a normally-loaded plate-modulated r.f. amplifier. The peak voltage across the tuning condenser C or C_1 of figures 31 and 33 respectively will be *twice the d.c. plate voltage.* If a single-section condenser is used in figure 33, with the bypass condenser C_2 connected to the coil center tap, the plate spacing or air gap must be twice as great as that of a split-stator condenser; so there is no appreciable saving in costs for a given capacity.

In c.w. amplifiers the air gap must be great enough to withstand a peak r.f. voltage *equal to the d.c. plate voltage,* for each section C_1 of figure 33, or, C of figure 31.

These rules apply to a loaded amplifier or buffer stage. If the latter is ever operated without an r.f. load, the peak voltages may be very much greater—by as much as two or three times in ordinary LC circuits. For this reason no amplifier should be operated without load when anywhere near normal d.c. plate voltage is applied.

A factor of safety in the air-gap rating should be applied to insure freedom from r.f. flashover. This is especially true when using the circuits of figures 32 and 34; in these circuits the plate supply is shorted

Recommended Air gap (approx. 100% factor of safety) for the circuits of figures 31 and 33. Spacings should be multiplied by 1.5 for same factor of safety with circuits of figures 32 and 34.

D.C. PLATE VOLTAGE	C. W.	PLATE MOD.
400	.030	.050
600	.050	.070
750	.050	.100
1000	.070	.084
1250	.070	.144
1500	.078	.200
2000	.100	.250
2500	.175	.375
3000	.200	.500
3500	.250	.600

when a flashover occurs. Knowing the peak r.f. voltage, an air gap should be chosen which will be about 100% greater than the breakdown rating. The air gaps listed will break down at the approximate peak voltages in the table. If the circuits are of the form shown in figures 32 and 34, the peak voltages across the condensers will be nearly twice as high and twice as large an air gap is needed. The fixed condensers, usually of the mica type, shown in figures 31 and 33, must be rated to withstand the d.c. plate voltage plus any audio voltage. This condenser should be rated at a d.c. working voltage of at least *twice the d.c. plate supply in a plate modulated amplifier* and at least *equal to the d.c. supply* in any other type of r.f. amplifier.

Push-Pull Stages

The circuits of figures 33 and 34 apply without any change in calculations to push-pull amplifiers. Only one tube is supplying power to the tuned circuit at any given instant, each one driving a part of each half cycle. The different value of Q and increased power output increase the peak voltages slightly but for all practical purposes, the same calculation rules may be employed.

These rules are based on average amateur design for any form of r.f. amplifier with a recommended factor of safety of 100% to prevent flashover in the condenser. This is sufficient for operation into normal loads at all times, providing there are no freak parasitic oscillations present. The latter sometimes cause flashover across air gaps which should ordinarily stand several times the normal peak r.f. voltages. This is especially true of low-frequency parasitics.

The actual peak voltage values of a stable, loaded r.f. amplifier are somewhat less than the calculations indicate, which gives an additional factor of safety in the design.

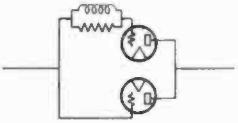
PARASITIC OSCILLATION IN R. F. AMPLIFIERS

Parasitics are undesirable oscillations either of very high or very low frequencies which occur in radio-frequency amplifiers.

They may cause additional signals (which are often rough in tone), other than normal harmonics, hash on each side of a modulated carrier, key clicks, voltage breakdown or flashover, instability or inefficiency, and shortened life or failure of the tubes. They may be damped and stop by themselves after keying or on modulation cycles, or they may be undamped and built up during ordinary unmodulated transmission, continuing if the excitation is removed. They may be at audio or radio frequency, in either type of amplifier (though only the r.f. amplifier is treated in this discussion). They may result from series or parallel resonant circuits of all types including the dynatron. Due to the neutralizing lead length or the nature of most parasitic circuits, the amplifier usually is not neutralized for the parasitic frequency.

Sometimes the fact that the plate supply is keyed obscures parasitic oscillations that might be very severe if the plate voltage were left on and only the excitation removed.

In some cases, an all-wave receiver will prove helpful in finding out if the amplifier is without spurious oscillations, but it may be necessary to check from one meter on up, to be perfectly sure. A normal harmonic is weaker than the fundamental but of good tone; a strong harmonic or a rough note at any frequency generally indicates trouble.



PARASITIC SUPPRESSOR FOR PARALLEL OR PUSH-PULL R F AMPLIFIERS

Figure 35.

One type of unwanted oscillation often occurs in shunt-fed circuits in which the grid and plate chokes resonate, coupled through the tube's interelectrode capacity. It can also happen with series feed. This oscillation is generally at a lower frequency than the desired one and causes additional carriers to appear, spaced from twenty to a few hundred kilocycles on either side of the main wave. One cure is to change the type of feed in either the grid or plate circuit or to eliminate one choke. Another is to use much less inductance in the grid choke than in the plate choke, or to replace the grid choke by a wire-wound resistor if the grid is series fed. In a class C stage with grid-leak bias, no r.f. choke is required if the bias is series fed.

This type of parasitic may take place in push-pull circuits, in which case the tubes are effectively in parallel for the parasitic and the neutralization is not effective. The grids or plates can be connected together without affecting the undesired oscillation; this is a simple test for this type of parasitic oscillation.

Paralled Tubes

A very high frequency inter-tube oscillation often occurs when tubes are operated in parallel. Noninductive damping resistors in the grid circuit, or short interconnecting grid leads together with small plate choke coils, very likely will prove helpful.

Tapped Inductances

When capacity coupling is used between stages, particularly when one of the stages is tapped down from the end of the coil, additional parasitic circuits are formed because of the multiple resonant effects of this complex circuit. Inductive or link coupling permits making adjustments without forming these undesired circuits. Likewise, a condenser tapped across only part of an inductance, for bandspread tuning or capacity loading, makes the situation more complex.

Multi-Element Tubes

Screen-grid and pentode tubes may help to eliminate parasitic circuits by using no neutralization, but their high gain occasionally makes parasitic oscillation easy, particularly when some form of input-output coupling exists. Furthermore, the by-pass circuit from the additional elements to the filament must be short and effective, particularly at the higher frequencies, to prevent undesired internal coupling. At the high frequencies, a variable screen by-pass condenser at some settings may improve the internal shielding without causing a new parasitic oscillation. A blocking (relaxation) effect may occur if the screen is fed through a series resistor. The screen circuit can, of course, act as the plate in a tuned-grid tuned-plate oscillation that can be detuned or damped at the control grid terminal.

Crystal Stages

Crystal oscillators are seldom suspected of parasitic oscillation troubles, but are often guilty. Ordinary as well as parasitic circuit coupling between the grid and plate circuits should be held to a minimum by separating or shielding the grid and plate leads, and by reducing the area of the loop from the grid through the crystal holder to the filament. Keeping the grid circuit short, even adding a small choke coil of a few turns in the plate lead next to the tube, will probably eliminate the possibility of high-voltage series-tuned parasitics.

Parasitic Suppressors

The most common type of parasitic is of the u.h.f. type, which fortunately can usually be dampened by inserting a parasitic suppressor of the type illustrated in figure 35 in the grid lead, or in *one* grid lead of either a push-pull or parallel tube amplifier.

GRID BIAS

Radio-frequency amplifiers require some form of *grid bias* for proper operation. Practically all r.f. amplifiers operate in such a manner that plate current flows in the form of short peaked impulses which have a duration of only a fraction of an r.f. cycle. The plate current is cut off during the greater part of the r.f. cycle, which makes for high efficiency and high power output from the tubes, since there is no power being dissipated by the plates during a major portion of each r.f. cycle. The grid bias must be sufficient to cut off the plate current, and in very high efficiency class C amplifiers this bias may be several times the cutoff value. Cutoff bias, it will be recalled, is that value of grid voltage which will reduce the plate current to zero, and the method for calculating it has been indicated previously. This theoretical value of cutoff will not reduce the plate current completely to zero, due to the variable-μ tendency which is characteristic of all tubes as the cutoff point is approached. This factor, however, is of no importance in practical applications.

Class C Bias

Radiophone class C amplifiers should be operated with the grid bias adjusted to values between two and three times cutoff at normal values of d.c. grid current to permit linear operation (necessary when the stage is plate-modulated). C.w. telegraph transmitters can be operated with bias as low as cutoff, if limited excitation is available and high plate efficiency is not a factor. In a c.w. transmitter, the bias supply or resistor should be adjusted to the point which will allow normal grid current to flow for the particular amount of grid driving r.f. power available. This form of adjustment will allow more output from the under-excited r.f. amplifier than when twice cutoff, or higher bias is used with low values of grid current.

Grid-Leak Bias

A resistor can be connected in the grid circuit of an r.f. amplifier to provide grid-leak bias. This resistor R_1 in figure 35 is part of the d.c. path in the grid circuit.

The r.f. excitation is applied to the grid circuit of the tube. This causes a pulsating d.c. current to flow through the bias supply lead and any current flowing through R_1 produces a voltage drop across that resistance. The grid of the tube is positive for a short duration of each r.f. cycle, and draws electrons from the filament or cathode of the tube during that time. These electrons complete the circuit through the d.c. *grid return*. The voltage drop across the resistance in the grid return provides a *negative bias* for the grid. The r.f. chokes in figures 36, 37, 38 and 39 prevent the r.f. excitation from flowing through the bias supply, or from being short-circuited to ground. The by-pass condenser across the bias source proper is for the purpose of providing a low impedance path for the small amount of stray r.f. energy which passes through the r.f. choke.

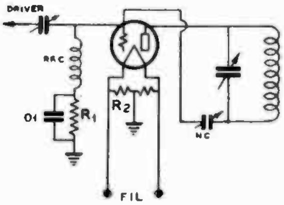


Figure 36.
GRID-LEAK BIASED STAGE.
Illustrating how a resistor may be connected in the grid-return lead to obtain bias.

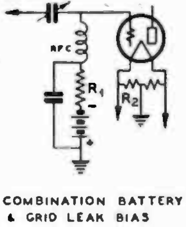


Figure 37.
A battery may be added to the grid-leak bias system to provide protection in case of excitation failure.

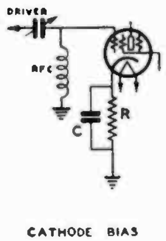


Figure 38.
A resistor in the cathode lead gives cathode, or "automatic" bias. The voltage drop across the resistor is applied to the grid in the form of negative bias.

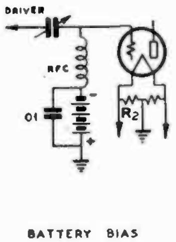


Figure 39.
Battery bias is suitable for stages which do not draw a great deal of grid current.

Grid-leak bias automatically adjusts itself even with fairly wide variations of r.f. excitation. The value of grid-leak resistance should be such that normal values of grid current will flow at the maximum available amount of r.f. excitation. Grid-leak bias cannot be used for grid-modulated or linear amplifiers in which the average d.c. grid current is constantly varying with modulation.

Grid-leak bias alone provides no protection against excessive plate current in case of failure of the crystal oscillator, or failure of any other source of r.f. grid excitation. A *C-battery* or *C-bias* supply can be connected in series with the grid leak, as shown in figure 37. This additional C-bias should at least be made equal to cutoff bias. This will protect the tube in the event of failure of grid excitation.

Cathode Bias

A resistor can be connected in series with the cathode or center-tapped filament lead of an amplifier to secure *automatic bias*. The plate current flows through this resistor, then back to the cathode or filament, and the voltage drop across the resistor can be applied to the grid circuit by connecting the grid bias lead to the grounded, or power supply end of the resistance R, as shown in figure 38.

The grounded (B-minus) end of the cathode resistor is negative relative to the filament by an amount equal to the voltage drop across the resistor. The value of resistance must be so chosen that the desired plate current flowing through the resistor will bias the tube for proper operation at that plate current.

This type of bias is used more extensively in audio-frequency than in radio-frequency amplifiers. The voltage drop across the resistor must be subtracted from the total plate supply voltage when calculating the power input to the amplifier, and this loss of plate voltage in an r.f. amplifier may be excessive. A class A audio amplifier is biased only to approximately one-half cutoff, whereas an r.f. amplifier may be biased to twice cutoff, or more, and thus the plate supply voltage loss may be a large percentage of the total available voltage when using low- or medium-μ tubes.

Separate Bias Supply

C-batteries or an external C-bias supply sometimes are used for grid bias of an amplifier, as shown in figure 39.

Battery bias gives very good voltage regulation and is satisfactory for grid-modulated or linear amplifiers, which operate nearly at zero grid current. In the case of class C amplifiers which operate with high grid current, battery bias is not very satisfactory. This d.c. current has a charging effect on the dry batteries; after a few months of service the cells will become unstable, bloated and noisy.

A separate a.c. operated power supply can be used as a substitute for dry batteries. The bleeder resistance across the output of the filter can be made sufficiently low in value that the grid current of the amplifier will not appreciably change the amount of negative grid-bias voltage. This type of bias supply is used in class B audio and class B r.f. linear amplifier service where the voltage regulation in the C-bias supply is important.

For a class C amplifier it is not so important, and an economical design of components in the power supply therefore can be utilized. However, in a class C application the bias voltage must be adjusted with normal grid current flowing as the grid current will raise the bias when it is flowing through the bias-supply bleeder resistance.

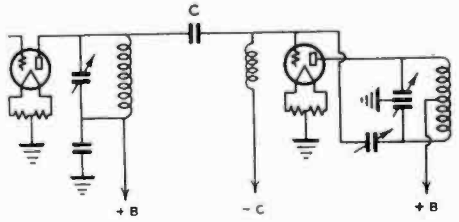
R. F. COUPLING SYSTEMS

In transmitters energy can be coupled from one circuit into another in the following ways: *capacitive coupling, inductive coupling* or *link coupling*. The latter is a special form of inductive coupling. The choice of a coupling method depends upon the purpose for which it is to be used.

Capacitive Coupling

Capacitive coupling between an amplifier or doubler circuit and a preceding driver stage is shown in figure 40.

The coupling condenser, C, isolates the d.c. plate supply from the next grid and provides a low impedance path from the r.f. energy between the tube being driven and the driver tube. This method of coupling is simple and economical for low-power amplifier or exciter stages, but has certain disadvantages. The grid leads in an amplifier should be as short as possible, but this is difficult to attain in the physical arrangement of a high-power amplifier with respect to a capacitively-coupled driver stage.



CAPACITIVE COUPLING

Figure 40.

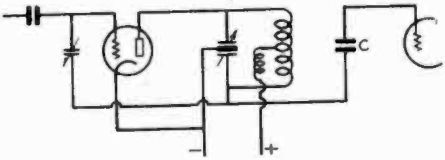


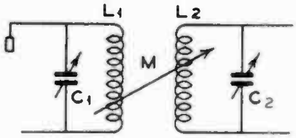
Figure 41.

This type of capacitive coupling between stages helps to equalize the capacities across the two sides of the driver plate tank.

The r.f. choke in series with the C-bias supply lead must offer an extremely high impedance to the r.f. circuit, and this is difficult to obtain when the transmitter is operated on several harmonically related bands. Another disadvantage of capacitive coupling is the difficulty of adjusting the load on the driver stage. Impedance adjustment can be accomplished by tapping the coupling lead a part of the way down on the plate coil of the tuned stage of the driver circuit. However, when this lead is tapped part way down on the coil, a *parasitic oscillation* tendency becomes very troublesome and is difficult to eliminate. If the driver stage has sufficient power output so that an impedance mismatch can be tolerated, the condenser C in figure 40 can be connected directly to the top of the coil, and made small enough in capacity for the particular frequency of operation that not more than normal plate current is drawn by the driver stage.

The impedance of the grid circuit of a class C amplifier may be as low as a few hundred ohms in the case of a high-μ tube, and may range from that value up to a few thousand ohms for low-μ tubes.

Capacitive coupling places the grid-to-filament capacity of the driven tube directly across the driver tuned circuit, which reduces the LC ratio and sometimes makes the r.f. amplifier difficult to neutralize because the additional driver stage circuit capacities are connected into the grid circuit. Difficulties from this source can be partially eliminated by using a center-tapped or split-stator tank circuit in the plate of the driver stage and capacity coupling to the opposite end from the plate. This method places the plate-to-filament capacity of the driver across one half of the tank and the grid-



INDUCTIVE COUPLING

Figure 42.

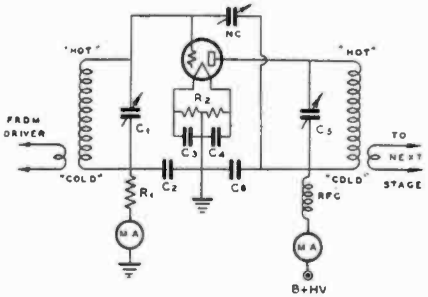


Figure 43.
LINK COUPLING CIRCUIT.
Showing the link coupling arrangement used between single-ended stages.

to-filament capacity of the following stage across the other half. This type of coupling is shown in figure 41.

Capacitive coupling can be used to advantage in reducing the total number of tuned circuits in a transmitter so as to conserve space and cost. It also can be used to advantage between stages for driving tetrode or pentode amplifier or doubler stages. These tubes require relatively small amounts of grid excitation.

Inductive Coupling

The r.f. amplifier often is coupled to the antenna circuit by means of *inductive coupling,* which consists of two coils electromagnetically coupled to each other. The antenna tuned circuit can be of the series-tuned type, such as is illustrated for *Marconi*-type 160-meter antennas in the chapter on *Antennas.* Parallel resonant circuits sometimes are used, as shown in figure 42, in which the antenna feeders are connected across the whole or part of the circuit L_2-C_2.

The degree of coupling is controlled by varying the mutual inductance of the two coils, which is accomplished by changing the spacing between the coils.

Inductive coupling also is used extensively for coupling r.f. amplifiers in radio receivers, and occasionally in transmitting r.f. amplifier circuits. The mechanical problems involved in adjusting the degree of coupling in a transmitter make this system of limited practical value.

Link Coupling

A special form of inductive coupling which is applied to radio transmitter circuits is known as *link coupling.* A low impedance r.f. transmission line, commonly known as a *link,* couples the two tuned circuits together. Each end of the line is terminated in one or more turns of wire, or *loops,* wound around the coils which are being coupled together. These loops should be coupled to each tuned circuit at the point of zero r.f. potential. This *nodal* point is the center of the tuned circuit in the case of plate-neutralized for push-pull amplifiers, and at the positive-B end of the tuned circuit in the case of screen grid and grid-neutralized amplifiers.

The nodal point in an antenna tuned circuit depends upon the type of feeders, and the node may be either at the center or at one end of the tuned circuit.

The nodal point in tuned grid circuits is at the C-bias or grounded end of plate-neutralized or screen-grid r.f. amplifiers,

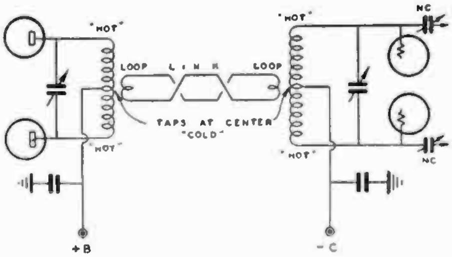


Figure 44.
LINK COUPLING BETWEEN PUSH-PULL STAGES.
When link coupling is used between push-pull stages or between "split" tank circuits, the coupling loops are placed at the center of the coils.

and at the center of the tuned grid coil in the case of push-pull or grid-neutralized amplifiers. The link coupling turns should be as close to the nodal point as possible. A ground connection to one side of the link is used in special cases where harmonic elimination is important, or where capacitive coupling between two circuits must be minimized.

Typical link coupled circuits are shown in figures 43 and 44.

Some of the advantages of link coupling are listed here:

(1) It eliminates coupling taps on tuned circuits.

(2) It permits the use of series power supply connections in both tuned grid and tuned plate circuits, and thereby eliminates the need of r.f. chokes.

(3) It allows separation between transmitter stages of distances up to several feet without appreciable r.f. losses.

(4) It reduces capacitive coupling and thereby makes neutralization more easily attainable in r.f. amplifiers.

(5) It provides semiautomatic impedance matching between plate and grid tuned circuits, with the result that greater grid swing can be obtained in comparison to capacitive coupling.

(6) It effectively reduces harmonic radiation when a final amplifier is coupled to a tuned antenna circuit, due to the additional tuned circuit and, particularly, it eliminates capacitive coupling to the antenna.

The link coupling line and loops can be made of no. 18 or 20 gauge push back wire for coupling low-power stages. High-power circuits can be link-coupled by means of no. 8 to no. 12 rubber-covered wire, twisted low-impedance antenna-feeder wire, concentric lines or open-wire lines of no. 12 or no. 14 wire spaced ¼ to ½ inch.

The impedance of a link coupling line varies from 75 to 200 ohms, depending upon the diameter of the conductors and the spacing between them.

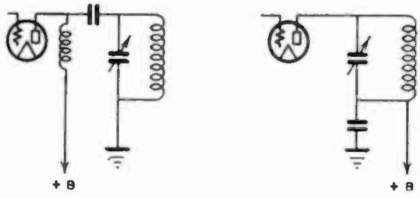
RADIO-FREQUENCY CHOKES

Radio-frequency chokes are connected in circuits for the purpose of preventing r.f. energy from being short-circuited, or escaping into power supply circuits. They consist of inductances wound with a large number of turns, either in the form of a solenoid or universal pie-winding. These inductances are designed to have as much inductance and as little distributed or shunt capacity as possible, since the capacity by-passes r.f. energy. The unavoidable small amount of distributed capacity resonates the inductance, and this frequency normally should be lower than the frequency at which the transmitter or receiver circuit is operating. R.f. chokes for operation on several harmonically related bands must be designed carefully so that the impedance of the choke will be extremely high (several hundred thousand ohms) in each of the bands.

The r.f. choke is resonant to the harmonics of its fundamental resonant frequency; however, the *even* harmonics have a very low impedance, so that an r.f. choke designed for maximum impedance in the 80-meter amateur band would not be satisfactory for operation in the 40-meter band. The harmonic resonance points of the r.f. choke usually are made to fall between frequency bands, so that a reasonably high value of impedance is obtained on all bands. The d.c. current which flows through the r.f. choke largely determines the size of wire to be used in the windings. The inductance of r.f. chokes for very short wavelengths is much less than for chokes designed for broadcast and ordinary short-wave operation, so that the impedance will be as high as possible in the desired range of operation. A very high inductance r.f. choke has more distributed capacity than a smaller one, with the result that it will actually offer *less* impedance at very high frequencies.

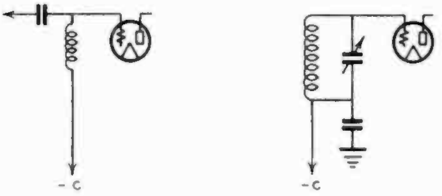
Shunt and Series Feed

Direct-current grid and plate connections are made either by *shunt* or *parallel feed* systems. Simplified forms of each



PARALLEL FEED SERIES FEED

Figure 45.



SHUNT BIAS FEED SERIES BIAS FEED

Figure 46.

are shown in figures 45 and 46.

Series feed can be defined as that in which the d.c. connection is made to the grid or plate circuit at a point of very low r.f. potential. Shunt feed always is made to a point of high r.f. voltage and always requires a high impedance r.f. choke or resistance in the connection to the high r.f. point in order to prevent loss of r.f. power.

PARALLEL AND PUSH-PULL TUBE CIRCUITS

The comparative r.f. power output from parallel or push-pull operated amplifiers is the same if proper impedance matching is accomplished and if sufficient grid excitation is available in both cases.

Operating tubes in parallel has some advantages in transmitters designed for operation on 40, 80 and 160 meters, or for broadcast band operation. Only one neutralizing condenser is required for parallel operation, as against two for push-pull. However, on wavelengths below 40 meters, parallel tube operation is not advisable because of the unbalance in capacity across the tank circuits. Low-C types of vacuum tubes can be connected in parallel with less difficulty than the high-C types, in which the combined interelectrode capacities might be quite high in the parallel connection.

The push-pull connection provides a well-balanced circuit insofar as miscellaneous capacities are concerned; in addition the circuit can be neutralized more easily, especially in high-frequency amplifiers. The LC ratio in a push-pull amplifier can be made higher than in a plate-neutralized parallel-tube operated amplifier. Push-pull amplifiers, when perfectly balanced, have less second-harmonic output than parallel or single-tube amplifiers. In actual practice, undesired capacitive coupling and circuit unbalance tend to offset the theoretical harmonic-reducing advantage of push-pull r.f. circuits.

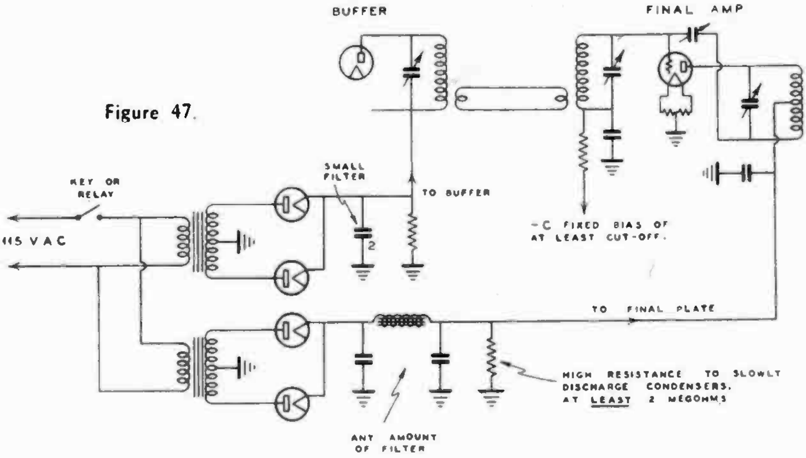
KEYING SYSTEMS

The carrier frequency signal from a c.w. transmitter must be broken into dots and dashes in the form of *keying* for the transmission of code characters. The carrier signal is of a constant amplitude while the key is closed, and is entirely removed when the key is open. If the change from the no-output condition to *full-output* occurs too rapidly, an undesired *key-click* effect takes place which causes interference in other signal channels. If the opposite condition of full output to no output condition occurs too rapidly, a similar effect takes place.

The two general methods of keying a c.w. transmitter are those which control either the excitation, or the plate voltage which is applied to the final amplifier. Plate voltage control can be obtained by connecting the key in the primary line circuit of the high voltage plate power supply. A slight modification of direct plate voltage control is the connection of the c.w. key or relay in the filament center-tap lead of the final amplifier. *Excitation keying* can be of several forms, such as crystal oscillator keying, buffer stage keying or blocked-grid keying.

Key clicks should be eliminated in all c.w. telegraph transmitters. Their elimination is accomplished by preventing a too-rapid make-and-break of power to the antenna circuit. A gradual application of

Figure 47.



PRIMARY KEYING WITHOUT CLICKS OR "TAILS"

power to the antenna, and a similarly slow cessation, will eliminate key clicks. Too much lag will prevent fast keying, but fortunately key clicks can be practically eliminated without limiting the speed of manual (hand) keying. Some circuits which eliminate key clicks introduce too much time-lag and thereby add *tails* to the dots. These tails may cause the signals to be difficult to copy at high speeds.

Eliminating key clicks by some of the key-click filter circuits illustrated in the following text is not certain with every individual transmitter. The constants in the time-lag and spark-producing circuits depend upon the individual characteristics of the transmitter, such as the type of filter, power input and various circuit impedances. All keying systems have one or more disadvantages, so that no particular method can be recommended as an ideal one. An intelligent choice can be made by the reader for his particular transmitter requirements by carefully analyzing the various keying circuits.

Primary Keying

Key clicks (except those arising from arcing at the key, which usually do not carry beyond a few hundred feet) can be eliminated entirely by means of primary keying, in which the key is placed in the a.c. line supply to the primary of the high voltage plate supply transformer. This method of keying also has the advantage that grid leak bias can be used in the keyed stages of the transmitter. As ordinarily applied, the plate voltage to the final amplifier is controlled by the action of the key. The filter in the high voltage rectifier circuit creates a time-lag in the application and removal of the d.c. power input to the r.f. amplifier. Too much filter will introduce too great a time lag, and add tails to the dots. If a high-power stage is keyed, the variation in load of the house-lighting circuits may be sufficient to cause blinking of the lights. A heavy-duty key or keying relay is necessary for moderate or high-power transmitters to break the inductive a.c. current. The exciting current or surge current may be several times as high as the average current drawn by the transformer which is being keyed. This will cause difficulty from sticking key contacts or burnt points on the keying relay. This effect can be minimized by proper design of the power transformer, which should have a high primary inductance and an iron core of generous size.

An improved primary keying circuit is shown in figure 47. This circuit makes high speed keying possible, without clicks or tails, and the plate supply to the final

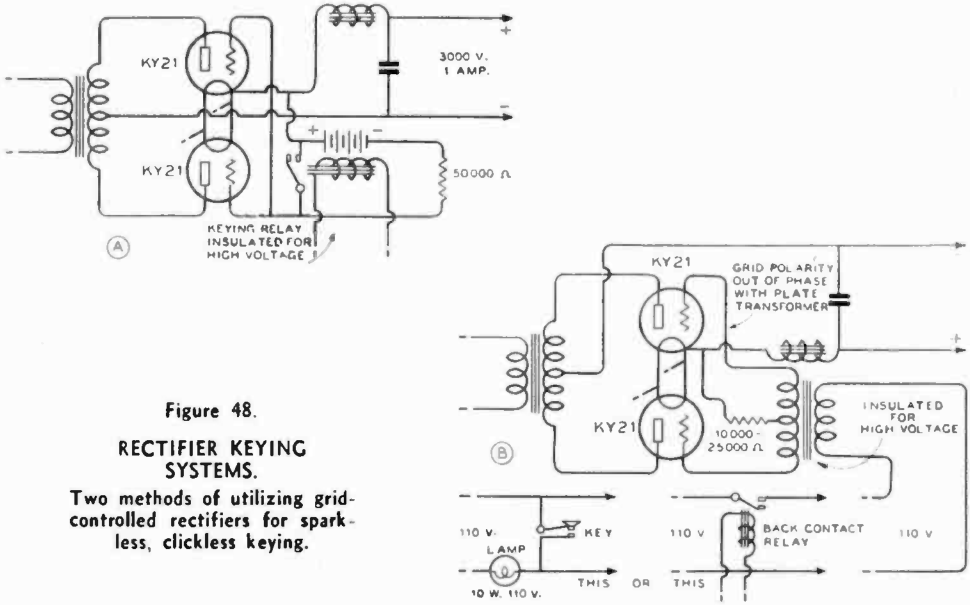


Figure 48.

RECTIFIER KEYING SYSTEMS.

Two methods of utilizing grid-controlled rectifiers for sparkless, clickless keying.

amplifier can be very well filtered without introducing tails to the dots.

The final amplifier must have a fixed bias supply equal to more than cut off value, so that when the grid excitation from the buffer stage is removed the amplifier output will drop immediately to zero, in spite of the filter condenser's being fully charged in the final amplifier circuit. The bleeder across the final plate supply filter should have a very high resistance so that the filter condenser will hold its charge between dots and dashes. This will allow a quick application of plate voltage as soon as the grid excitation, supplied by the buffer stage, is applied to the final amplifier.

The buffer plate supply is keyed; its filter circuit consists of a single 2-μfd. filter condenser, shunted by the usual heavy-duty high-current bleeder resistor. This small filter has no appreciable time-lag, and will not add tails to the dots and dashes, but it does provide sufficient time-lag for key click elimination. The small amount of filter will not introduce a.c. hum modulation into the output of the final amplifier, because the latter is operated in class C, under saturated grid conditions. A moderate a.c. ripple in the grid excitation will not introduce hum in the output circuit under this operating condition.

Grid-Controlled Rectifiers

By the incorporation of grid-controlled rectifiers in a high-voltage power supply, one can enjoy keying that has practically all the advantages of primary keying with none of the disadvantages. The only disadvantage to this type of keying as compared to primary keying is that of the small amount of additional equipment needed and the additional expense of the special rectifiers.

Inasmuch as no power is required to block the grids, there is little sparking at the relay contacts. And because the keying is ahead of the power supply filter, the wave train or keying envelope is rounded enough that clicks and keying impacts are eliminated. In fact, it is important that no more filter be used than is required to give a good T-9 note, inasmuch as excessive filter will introduce lag and put tails on the keying. The optimum ratio and amounts of inductance and capacity in the filter will be determined by

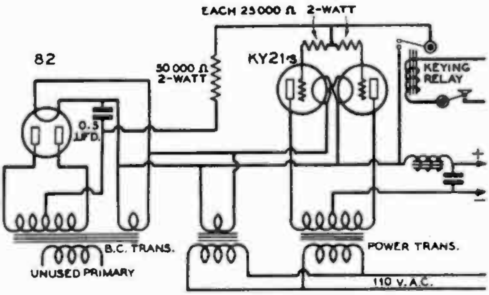


Figure 49.
An ordinary broadcast-receiver power transformer may be used with this circuit. The whole transformer must be well-insulated from grounded parts of the circuit.

the load on the filter (plate voltage divided by plate current). With high plate voltage and low plate current (high impedance load) more inductance and less capacity should be used, and vice versa.

Of the large number of possible circuit combinations, three of the most practical are illustrated. The circuit shown in figure 48 at A is perhaps the simplest and most trouble-free, but has the disadvantage of requiring bias batteries. The relay contacts handle little power, but must be insulated from ground for the high voltage.

At B is shown the simplest method not requiring batteries. If used as shown, the bias transformer must be insulated for the full plate voltage (secondary to both primary and case). Unfortunately, b.c.l. transformers were not designed to withstand 3,000 or 4,000 volts r.m.s., either between windings or to the case. The circuit shown in figure 49 allows the use of a small broadcast-receiver type transformer for bias supply to the rectifiers. In this case the whole transformer is at the power-supply voltage above ground and it must be well insulated from metal chassis and other grounded portions of the circuit.

Blocked Grid Keying

The negative grid bias in a medium- or low-power r.f. amplifier can easily be increased in magnitude sufficiently to reduce the amplifier output to zero. The circuits shown in figures 50 and 51 represent two methods of such blocked grid keying.

In figure 50, R_1 is the usual grid leak. Additional fixed bias is applied through a 100,000-ohm resistor R_2 to block the grid current and reduce the output to zero. As a general rule, a small 300- to 400-volt power supply with the positive side connected to ground can be used for the additional C-bias supply.

The circuit of figure 51 can be applied by connecting the key across a portion of the plate supply bleeder resistance. When the key is open, the high negative bias is applied to the grid of the tube, since the filament center tap is connected to a positive point on the bleeder resistor. Resistor R_2 is the normal bleeder; an additional resistor of from one-fourth to one-half the value of R_2 is connected in the circuit for R_1. A disadvantage of this circuit is that one side of the key may be placed at a positive potential of several hundred volts above ground, with the attendant danger of shock to the operator. Blocked grid keying is not particularly effective for eliminating key clicks.

Oscillator Keying

A stable and quick-acting crystal oscillator may be keyed in the plate, cathode or screen-grid circuit for the purpose of minimizing key clicks and for break-in operation. This type of keying requires either fixed or cathode bias, since the r.f. excitation is removed from all of the grid circuits. The key clicks are minimized by the presence of several tuned circuits between the antenna and crystal oscillator in a multistage transmitter. The key

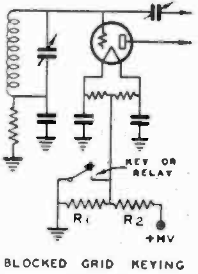


Figure 50.

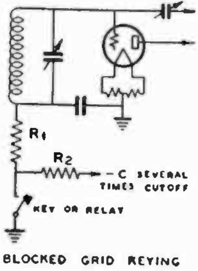
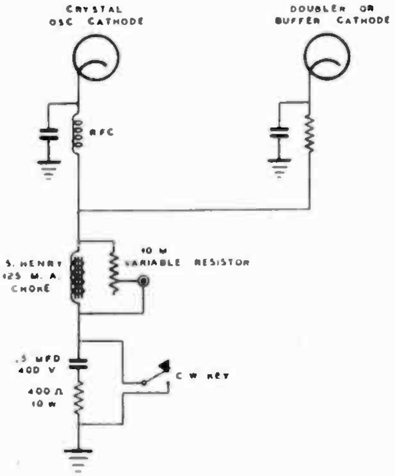


Figure 51.



BREAK-IN CLICKLESS KEYING CIRCUIT

Figure 52.

clicks act as sideband frequencies and are attenuated somewhat in a multistage transmitter by the resonant tuned circuits which are tuned to the carrier frequency.

If a key click filter is placed in the crystal oscillator circuit, the tone may become chirpy and tails may be added to the ends of the transmitted characters. A practical circuit for clickless keying is illustrated in figure 52, in which both the cathode of the crystal oscillator and the cathode of the next succeeding buffer or doubler circuit are connected through a key click filter.

Two tubes can be keyed very effectively with this type of circuit. The choke coil, shunted with a semivariable resistor, provides a series inductance for slowing down the application of cathode current to the two tubes. The inductance of the choke coil can effectively be lowered to one or two henrys by shunting it with a semivariable resistance so that the time-lag will not be excessive. The 0.5-μfd. condenser and 400-ohm resistor are connected across the key contacts, as *close to the key* as possible, and these serve to absorb the spark at the telegraph key each time the circuit is opened. This effectively prevents a click at the end of each dot and dash. This same type of key click filter can be connected in the center-tap lead of a final amplifier or buffer-amplifier stage for the elimination of clicks.

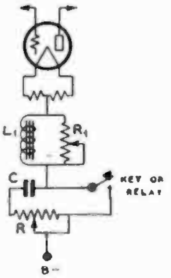


Figure 53.
CENTER - TAP KEYING SYSTEM WITH ADJUSTABLE CLICK FILTER.
Good results can be obtained with this system. The amount of inductance and capacity used in the filter depends upon the current being keyed. Ordinarily L_1 will be between 1 and 5 henrys, R_1 20,000 ohms, C between ¼ and 2 μfd, and R about 2000 ohms.

When keying in the crystal stage, or for that matter any stage ahead of the final amplifier, the stages following the keyed one must be absolutely stable so that parasitic or output-frequency oscillation will not occur when the excitation is rising on the beginning of each keying impulse. This type of oscillation give rise to extremely offensive key clicks which cannot be eliminated by any type of click filter; in fact a filter designed to slow up the rate at which signal comes to full strength may only make them worse.

Center-Tap Keying

The lead from the center-tap connection to the filament of an r.f. amplifier tube can be opened and closed for keying a circuit. This opens the B-minus cir-

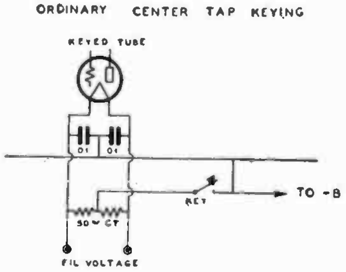


Figure 54.
ORDINARY CENTER-TAP KEYING.
The center tap of the filament transformer must not be grounded. Usually the transformer which supplies the keyed stage will not be used to supply any of the other stages.

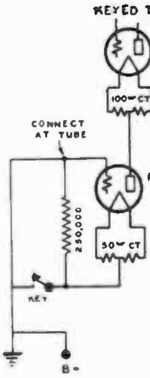


Figure 55.
VACUUM-TUBE KEYING CIRCUIT.
One of the more simple vacuum-tube keying circuits. Some current flows through the key in this circuit, and clicks are sometimes produced when the key is opened. Both filament transformers must be insulated from each other and from ground.

cuit, and at the same time opens the grid-bias return lead. For this reason the grid circuit is blocked at the same time that the plate circuit is opened, so that excessive sparking does not occur at the key contacts. Unfortunately, this method of keying applies the power too suddenly to the tube, producing a serious key click in the output circuit, which generally is coupled to the antenna. This click often can be eliminated with the key click eliminator shown in figures 52 and 53.

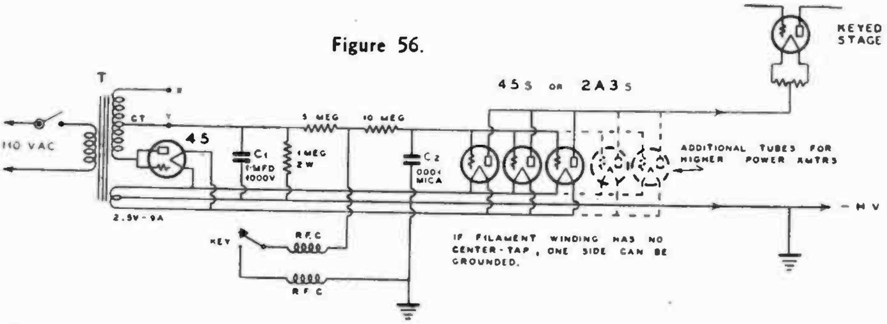
Vacuum Tube Keying

Center-tap keying as shown in figure 54 never should be used, because this circuit produces extremely bad key clicks. The key click filter in figure 53 always can be connected into the center-tap lead as an external unit. A more effective key click filter for the center-tap lead is made possible through the use of vacuum tubes. A simple vacuum tube keying circuit is shown in figure 55.

The keying tube is connected in series with the center-tap lead of the final r.f. amplifier. The grid of the keying tube is short-circuited to the filament when the key is closed, and the keying tube then acts as a low resistance in the center-tap lead. When the key is opened, the grid of the keying tube tends to block itself and the plate-to-filament resistance of the tube increases to a high value, which reduces the output of the r.f. amplifier approximately to zero. A more effective vacuum tube keying system is shown in figure 56.

In this system, the grids of the keying tubes are biased to a high negative potential when the key is open and to zero potential when the key is closed. The fixed bias supply to the keying tubes provides very effective keying operation. The degree of time-lag (key click elimination) can be adjusted to suit the individual operator, by varying both the capacity of the condenser which is shunted from grid to filament, and the values of the two high resistances in series with the

Figure 56.



T - PLATE AND FILAMENT TRANSFORMER 325 V EACH SIDE CENTER TAP

"Y" IS THE NORMAL TAP FOR KEYING MEDIUM POWER TRANSMITTERS AND USE "X" (ENTIRE SECONDARY) FOR HIGH POWER TRANSMITTERS

VACUUM - TUBE KEYING SYSTEM

grid and power supply leads. R.f. chokes can be connected in series with the key directly at the key terminals, to prevent the minute spark at the key contacts from causing interference in nearby broadcast receivers. These r.f. chokes are of the conventional b.c. type. There is no danger of shock to the operator when this keying circuit is used.

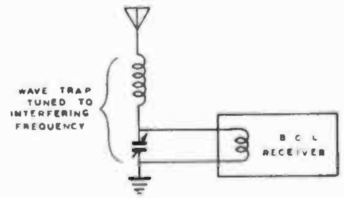
The small power supply for this keying circuit requires very little filter and can be of the half-wave rectifier type with a '45 tube as the rectifier. The negative voltage from this power supply only needs to be sufficient to provide cutoff bias to the type 45 keying tubes; potentials of from 100 to 300 volts are needed for this purpose. Approximately 50 milliamperes of plate current in the final amplifier should be allowed per type 45 keying tube. If the final amplifier draws 150 milliamperes, for example, three type 45 keying tubes will be required.

One disadvantage of vacuum tube keying circuits is a plate supply potential loss of approximately 100 volts, which is consumed by the keying tubes. The plate supply therefore should be designed to give an output of 100 volts more than ordinarily is needed for the r.f. amplifier. This loss of plate voltage is encountered because the plate-to-filament resistance of the type 45 tubes, at 50 milliamperes of current and zero grid potential, is approximately 2000 ohms.

Vacuum-tube keying is applicable to high-speed commercial transmitters, as well as for amateur use.

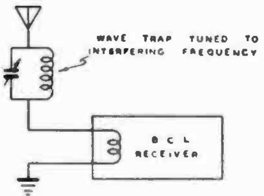
BROADCAST INTERFERENCE

Interference created by amateur transmitters in nearby broadcast receivers usually can be eliminated by means of shunt- or series-type wavetraps which are tuned to the frequency of the interfering signal. The method of connecting such wavetraps is shown in figures 57 and 58. The wavetrap coil should have a sufficient number of turns to resonate with a compression-type mica trimmer condenser of 30 or 70 $\mu\mu$fd. maximum capacity. The coil is similar to a short-wave receiver r.f. coil and should be tapped at several places along the winding to simplify adjustment. The wavetrap should be located as close as possible to the antenna post of the b.c. receiver. The series-type wavetrap usually is more effective than the shunt-type.



SERIES TYPE WAVE TRAP

Figure 57.



SHUNT TYPE WAVE TRAP

Figure 58.

Horizontal doublet transmitting antennas usually cause less local interference than those of the Marconi type. If a Marconi antenna is to be used, a counterpoise, rather than a ground connection, will often minimize the interference in broadcast receivers.

Floating Volume Control Shafts

Several sets have been encountered where there was only a slightly interfering signal; but, on placing one's hand up to the volume control, it would greatly increase. These proved to have volume controls with shafts insulated from ground and connected to a critical part of a circuit, especially the grid of a high-gain audio stage. The cure is to install a volume control with all the terminals insulated from the shaft, and then to ground the shaft.

Spray-Shield Tubes

Although they are not being made any more, there are quite a few sets still in use employing spray-shield tubes. These are used in both r.f. and in audio circuits. In their audio application, sometimes the cathodes, to which the shield is connected, are not at ground potential, being bypassed with a large-capacity electrolytic condenser. This type of condenser is a very poor r.f. filter and in a strong r.f. field some detection will take place causing interference. The best cure is to install a standard glass tube with a glove shield which is actually grounded and also to shield the grid leads to these tubes.

Coupling Loops

To increase the gain on the high-frequency end of the broadcast band, many sets use a loop of wire wound around the grid end of the input coil to provide some capacity coupling direct from the antenna to the grid. This, in conjunction with a high-impedance antenna primary, which is used to help the low-frequency end, allows the high-frequency signal to be passed directly to the grid. The basic cure is to move the coupling loop a little farther away from the end of the grid coil or to introduce a small capacity from antenna to ground. The use of a short receiving antenna will help reduce the interference. Especially avoid one which is any multiple of a half-wave long at the interfering frequency.

The antenna and ground system of the troubled b.c.l. set should be thoroughly checked for oxidized joints. Often there are so many connections where the wires are not thoroughly cleaned before connecting, or sometimes even just twisted together, that it is a wonder the sets work at all. These oxidized joints can cause rectification, resulting in two or more strong signals mixing and riding in on each other or appearing at remote parts of the dial. Either copper oxide or iron rust has the properties of rectification, and the rectifier element can be in another wire or metallic system in the vicinity of the receiving antenna. Iron pipes rubbing against each other or against stucco screen, poor contacts in the lighting circuits, or in fact, any two metallic objects in partial contact with each other may cause a cross modulation which is reradiated and can be picked up on any set in the immediate vicinity.

The antenna and ground connections should be checked to make sure that they are not reversed. This is easily taken for granted since the b.c. set will play, but a set is very much more susceptible to interference from a short-wave station when connected up wrong. Several cases have been cleared up by simply correcting these leads.

Harmonic Elimination

The second harmonics of some amateur frequencies fall outside amateur bands and cause illegal interference with commercial transmissions. Push-pull final amplifiers rarely cancel all the second harmonics in amateur transmitters, due to unbalanced circuits and insufficient tank circuit capacity to inductance ratio. Reference should be made to the *Chart of Tank Circuit Tuning Capacities* for proper circuit design. Sufficient tank circuit capacity will greatly minimize harmonic radiation.

Several circuits which will greatly reduce harmonic radiation are shown in chapter 17.

EIGHT

Radiotelephony Theory

A RADIOTELEPHONE transmitter differs but very little from a c.w. telegraph transmitter except for the audio-frequency system which is required in the radiophone transmitter. Both require a frequency determining stage, a series of frequency multipliers and power amplifiers to bring the output up to the desired frequency and amount of power, and a high-voltage direct current power supply for the various stages. This chapter will deal with the theory of various modulation systems and with the theory and design of the audio channel required in the transmitter which is to be used for radiophone.

MODULATION

Any type of continuous wave transmitter puts out a steady flow of radio-frequency energy which is varied in accordance with the intelligence which it is desired to transmit. This steady flow of r.f. energy is called the carrier or the carrier wave of the transmitter. If the outgoing carrier wave is broken up into short and somewhat longer pulses to conform with the international Morse code, the transmitter is said to be a c.w. radiotelegraph transmitter. However, if either the amplitude or the frequency of the outgoing carrier wave is varied in accordance with a voice or music waveform, the source of the signal is said to be a radio-telephone transmitter. Any variation in the output of a transmitter, either c.w. or phone, is called modulation. However, the term is much more generally applied to modulation as applied to a radiophone transmitter.

Frequency Modulation

Although frequency modulation has, until recently, been thought of only as the undesirable result of amplitude modulation of the plate voltage of a self-controlled oscillator, recent developments by Major E. H. Armstrong have shown that pure frequency modulation of an ultra-high-frequency carrier has many advantages over amplitude modulation from the standpoint of signal-to-noise ratio.

In the Armstrong system of frequency modulation the *frequency* of a u.h.f. transmitter is modulated in accordance with the voice or music to be transmitted. The *amplitude* of the carrier with and without modulation remains constant. A receiver which is receptive only to variations in the frequency of the incoming carrier discriminates to a very large extent against any variations in the amplitude of incoming signals. Since static crashes and manmade interference cause great variations in the amplitude of the carrier and only extremely small amounts of frequency modulation, this system of frequency modulation gives very high quality reception with an almost total absence of noise.

Although the Armstrong frequency modulation system has many advantages over amplitude modulation in the field of u.h.f. broadcasting, the complications of the system in its present state of development make it somewhat unsuited to use by amateurs. However, those advanced amateurs who are interested in the development of noise-free u.h.f. transmission and reception will find a considerable amount of material both of transmitters and receivers for frequency modulation published in the *Proceedings* of the Institute of Radio Engineers and in other advanced periodicals for the radio engineer.

Amplitude Modulation

The system of modulation almost universally employed at the present time for voice, music, television, facsimile, and c.w. transmission utilizes variation in the *amplitude* of the outgoing carrier in accordance with the intelligence to be transmitted. The most simple way of obtaining amplitude modulation is simply the shutting on and off of the transmitted carrier by means of a telegraph key or analogous device as used in c.w. telegraph transmission. Such keying systems are discussed in the chapter on *transmitter theory*. Systems of modulating the amplitude of a carrier in accordance with voice, music, or similar types of complicated waveforms are many and varied and will be discussed later on in this chapter.

Sidebands

When a carrier wave is modulated by an audio frequency tone (varied in amplitude at an audio frequency), a result of the process of modulation is the production of additional frequencies in the output of the transmitter which are equal to the *sum* of the carrier and the modulation frequency and the *difference* between the two frequencies. For example, if the carrier frequency is 14,200 kc. and it is being modulated by a frequency of 2 kc. (2000 cycles) there will be two sidebands formed, one on either side of the carrier frequency. One will be equal to the sum of the two frequencies, 14,202 kc., and the other will be equal to their difference, 14,198 kc. The frequency of the sidebands is independent of the amount of modulation of the carrier; it is determined only by the frequency of the modulating tone. This assumes, of course, that the maximum modulation capability of the transmitter is not being exceeded.

If the signal modulating the carrier consists of a number of different frequencies, as would be the case with voice or music modulation, sidebands will be formed by each of the modulating frequencies. The signal radiated by the transmitter will occupy a *band* of frequencies including the carrier and the highest modulation frequency on either side of the carrier. For example, if the highest modulation frequency is 5000 cycles, the signal emitted by the transmitter will occupy a band from 5000 cycles above to 5000 cycles below the carrier frequency. Thus the total band taken up by a carrier with 5000-cycle modulation will be *twice* the modulation frequency in width, or 10,000 cycles wide. This is true of any type of modulating waveform; the band taken up by the signal from the transmitter will be twice as wide as the highest modulation frequency.

Frequencies up to at *least* 2,500 cycles are required for good speech intelligibility, and frequencies as high as 5,000 or

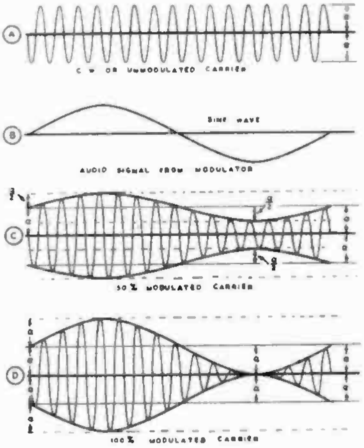


Figure 1.

GRAPHIC REPRESENTATION OF FOUR TYPES OF WAVE FORM.

Illustrating the difference between an unmodulated carrier, audio sine wave, 50 per cent modulated carrier and 100 per cent modulated carrier.

6,000 cycles are required for good music fidelity.

When audio frequencies as high as 5,000 cycles are to be transmitted, the radio-frequency channel would have to be 10,000 cycles (10 kilocycles) in width, since both the upper and lower side band frequencies are generated in the modulated r.f. stage.

Since the bands of frequencies available to amateurs for radiophone transmission are limited, and since the band of frequencies taken up by a transmitter which is being modulated by needless high frequencies is quite wide, it would be advisable if all amateurs would limit the maximum frequencies which their speech amplifiers would pass to about 3000 cycles. The passage of this frequency as maximum will give good intelligibility with a fair amount of crispness to the quality, and still the modulated carrier of the transmitter would occupy a maximum band only 6 kilocycles in width.

Mechanics of Modulation

A c.w. or unmodulated carrier wave is represented in A, figure 1. An audio-frequency wave is represented by curve B. When this audio-frequency wave B is applied to the modulated stage, the resultant wave may be represented as in C and D. The *average amplitude* of the carrier wave remains constant because the decrease in amplitude is the same as the increase (up to 100 per cent). In C. figure 1, the carrier wave is shown to be approximately 50 per cent modulated. and D shows a 100 per cent modulated wave.

In order to obtain 50 per cent modulation in a plate-modulated system, only one-fourth as much audio-frequency power is required as for 100 per cent modulation. However, the audio signal which is received at a distant point after being *demodulated* (detected) is in proportion to the percentage of modulation of the transmitter. If the peaks of modulation are reduced from 100 per cent down to 50 per cent, the result is a decrease in range of the transmitter.

The *average* amplitude of the carrier frequency wave is constant in most systems, but the *instantaneous power output* varies from approximately zero to four times that of the power of the unmodulated carrier wave. In a sinusoidally modulated wave, the antenna current increases approximately 22 per cent for 100 per cent modulation with a pure tone input; the r.f. meter in the antenna circuit indicates this increase in antenna current. The *average power* of the r.f. wave increases 50 per cent for 100 per cent modulation.

This indicates that in a plate-modulated radiotelephone transmitter the audio-frequency channel must supply this additional 50 per cent increase in average power. If the power input to the modulated stage is 100 watts, for example, this *average power* will increase to 150 watts at 100 per cent modulation, and this additional 50 watts of power must be supplied by the *modulator* when plate modulation is used. The actual antenna power is a constant percentage of the total value of input power.

Percentage of Modulation

The amount by which a carrier is being modulated may be expressed either as a modulation factor, varying from zero to 1.0 at maximum modulation, or as a percentage. The percentage of modulation is equal to 100 times the modulation factor. Figure 2A shows a carrier wave modulated by a sine-wave audio tone. A picture such as this might be seen on the screen of a cathode-ray oscilloscope with saw-tooth sweep on the horizontal plates and the modulated carrier impressed on the vertical plates. The same carrier without modulation would appear on the oscilloscope screen as figure 2B.

The percentage of modulation of the positive peaks and the percentage of modulation of the negative peaks can be determined from two oscilloscope pictures such as shown. In addition, the

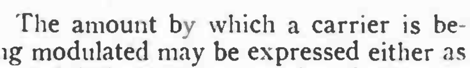


Figure 2.

presence or absence of carrier shift, or a change in the average amplitude of the carrier, can be determined from a picture such as figure 2A alone.

The modulation factor of the positive peaks may be determined by the formula:

$$M = \frac{E_{max} - E_{car}}{E_{car}}$$

The factor for negative peaks may be determined from this formula:

$$M = - \frac{E_{min} - E_{car}}{E_{car}}$$

In the two above formulas E_{max} is the maximum carrier amplitude with modulation and E_{min} is the minimum amplitude; E_{car} is the steady-state amplitude of the carrier without modulation. Since the deflection of the spot on a cathode-ray tube is linear with respect to voltage, the relative voltages of these various amplitudes may be determined by measuring the deflections, as viewed on the screen, wtih a rule calibrated in inches or centimeters. The percentage of modulation of the carrier may be had by multiplying the modulation factor thus obtained by 100.

Carrier shift, or a change in the *average* amplitude of the carrier with modulation, may be determined from a figure such as 2A through the use of the following formula:

$$\frac{E_{max} + E_{min}}{2} = E_{car}$$

This formula is a statement of the condition that should exist in a properly modulated carrier. If the result obtained from the left hand side of the equation is less than E_{car}, carrier shift is in a negative direction. If the result is more than E_{car}, carrier shift is in a positive direction. The latter usually occurs when the carrier is modulated in excess of 100 per cent.

Modulation Capability

The modulation capability of a transmitter is the maximum percentage to which that transmitter may be modulated before spurious sidebands are generated in the output or before the distortion of the modulating waveform becomes objectionable. The highest modulation capability which any transmitter may have is 100 per cent modulation on the negative peaks. The maximum permissible modulation of many transmitters is less than 100 per cent. The modulation capability of a transmitter may be limited by insufficient excitation or grid bias to a plate modulated stage, too light loading of any type of amplifier carrying modulated r.f., insufficient power output capability in the modulator, or too much excitation to a grid-modulated stage or a class-B linear amplifier. In any case the FCC regulations specify that no transmitter be modulated in excess of its modulation capability. Hence, it is desirable to make the modulation capability of a transmitter as near as possible to 100 per cent so that the carrier power may be used most efficiently.

Systems of Amplitude Modulation

There are many different systems and methods for amplitude modulating a carrier but they may all be grouped under two general classifications: *variable efficiency* systems, in which the average input to the stage remains constant with and without modulation and the variations in the efficiency of the stage in accordance with the modulating voltage accomplish the modulation; and *constant efficiency* systems in which the input to the stage is varied by one means or another to accomplish the modulation. The various systems under each classification have individual characteristics which make certain ones best suited to particular applications.

Variable Efficiency Modulation

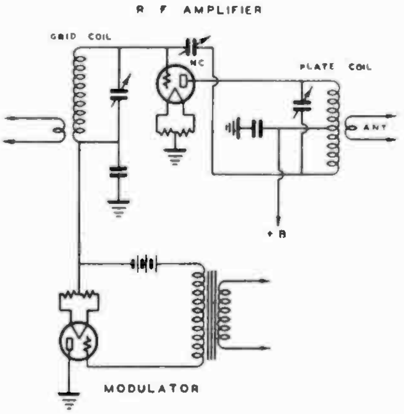
Since the average input remains constant in a stage employing variable efficiency modulation, and since the average power output of the stage increases with modulation, the limiting factor in such an amplifier is the plate dissipation of the tubes in the stage when they are in the unmodulated condition. Hence, for the best relation between tube cost and power output, the tubes employed should have as high a plate dissipation rating per dollar as possible.

The plate efficiency in such an amplifier is doubled when going from the unmodulated condition to the peak of the modulation cycle. Hence, the unmodulated efficiency of such an amplifier must always be less than 45 per cent, since the maximum peak efficiency obtainable in a conventional amplifier is in the vicinity of 90 per cent. Since the peak efficiency in certain types of amplifiers will be as low as 60 per cent, the unmodulated efficiency in such amplifiers will be in the vicinity of 30 per cent.

The various common systems of efficiency modulation are: grid-leak modulation, class BC grid modulation, class C grid modulation, screen-grid modulation, suppressor-grid modulation, and (a special case) cathode modulation. The class B linear amplifier also falls in this classification. Each of these various systems will be described individually.

Grid Leak Modulation

The several popular forms of grid modulation operate on the same general principle, but under somewhat different conditions. In all systems, the audio-frequency power is impressed upon the grid circuit, and the r.f. amplifier operates in a modified class C arrangement.



GRID LEAK MODULATION

Figure 3.

The simplest system employs a vacuum tube as a variable grid leak in a class C r.f. amplifier with a very small order of excitation. The modulator tube is driven by the speech amplifier, and its plate impedance varies in accordance with the speech input. The modulator tube receives its plate current from the rectified grid current of the r.f. amplifier. The grid bias of the modulator is adjusted to the point which gives best voice quality, and the r.f. excitation must be similarly adjusted for the same purpose. This system, shown in figure 3, does not give distortionless modulation and is critical in adjustment. The arrangement, however, is employed quite commonly in low-powered transmitters abroad, and is quite suitable for use in low-powered portable transmitters where it is not desired to carry heavy and bulky modulation equipment.

Class BC Grid Modulation

Figure 4 illustrates the class BC system of grid modulation. This is a system of grid modulation which can be adjusted to give exceptionally good voice quality due to the degeneration in the cathode circuit of the modulated stage.

The r.f. amplifier is operated with fixed bias equal to cutoff. This bias is supplied either from batteries or from a bias pack. Additional bias is obtained from a cathode resistor R_2 in the modulated stage. This resistor should be by-passed for r.f., but not for audio frequencies, by means of filament by-pass condensers no higher in value than .005 μfd.

When an audio voltage is applied from the modulator, it is amplified in the r.f. tube, and degenerative feedback occurs across resistor R_2. For this reason, the audio power requirements are somewhat greater than for other grid-modulated systems. This degenerative effect, however, produces a very linear modulation characteristic. The d.c. plate current which flows through R_2 should provide

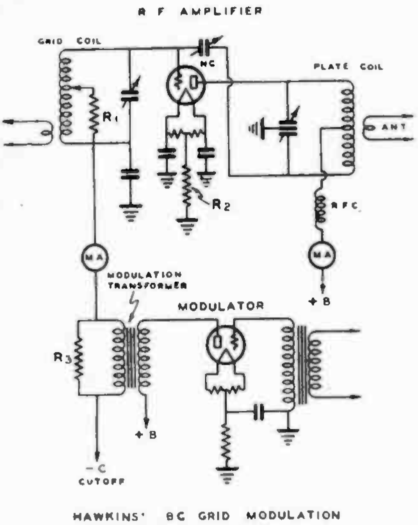


Figure 4.

an additional bias equal to at least half the theoretical cutoff bias. A higher value of R_2 will result in higher plate efficiency, but at a sacrifice in power output, which can be brought up by using higher plate voltage.

The r.f. grid excitation is adjusted to the point where grid current just starts to flow. Excess r.f. grid excitation can be absorbed by resistor R_1 (figure 4) connected across the grid circuit; this resistor also stabilizes the operation of the circuit and improves the quality.

Grid excitation can be conveniently controlled by means of a link-coupling adjustment. The antenna loading is greater than that required for plate modulation or c.w. operation. This coupling should be increased to a point somewhat beyond that at which maximum antenna or r.f. feeder current occurs for given excitation. The plate efficiency will be between 35 per cent and 40 per cent in a well-designed class BC amplifier.

The circuit constants can be calculated from a group of formulas given here:

(1) E_b = d.c. plate supply voltage, in volts.

(2) $W_{\text{plate loss}}$ = rated plate dissipation of the tube in watts.

(3) μ = amplification factor of the tube.

(4) W_{input} = d.c. plate input power, in watts.

(5) W_{output} = r.f. unmodulated carrier output in watts.

(6) I_p = d.c. plate current, amperes.

(7) E_{cco} = d.c. battery bias equal to theoretical cutoff bias (one-half total bias).

(8) R_k = cathode bias resistance, in ohms.

(9) $W_{\text{input}} = 1.66 W_{\text{plate loss}}$

(10) $W_{\text{output}} = .66\ W_{\text{plate loss}}$

$$(11)\quad I_p = \frac{1.66\ W_{\text{plate loss}}\,(1+\mu)}{\mu E_b}$$

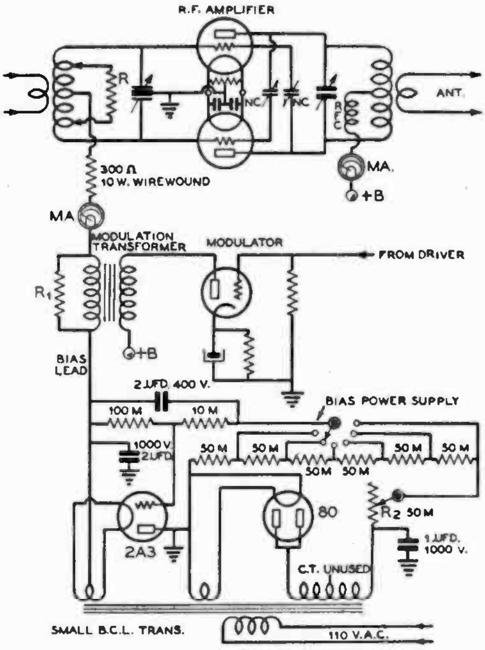
$$(12)\quad E_{cco} = \frac{E_b}{1+\mu}$$

$$(13)\quad R_k = \frac{E^2_b\mu}{1.66\ W_{\text{plate loss}}\,(1+\mu)^2}$$

The class BC amplifier shown for grid modulation can be operated as a linear r.f. amplifier at 40 per cent plate efficiency, which is somewhat better than the efficiency obtainable from a conventional linear amplifier (30 to 33 per cent). Slightly better efficiency with less audio driving power and fewer components may be obtained with class C grid modulation. However, if the quality of the latter system is to be improved to compare with class BC grid modulation a separate degenerative feedback circuit external to the amplifier should be employed.

Class C Grid Modulation

The most popular and probably the most satisfactory system of grid modulation is that which is commonly called class C grid bias modulation. Figure 5 illustrates the simple circuit employed; the amplifier can, of course, be either push-pull as indicated or single ended as shown for the other types of grid-modulated amplifiers. The most important difference between this system and the class BC arrangement is in the amount of grid bias employed. The bias on the class BC amplifier usually runs in the vicinity of 1½ to 2½ times cutoff; with



CLASS-C GRID MODULATION

Figure 5.

the class C grid bias modulation system the bias may run as high as 8 times cutoff under the carrier conditions.

Class C grid modulation requires high plate voltage on the modulated stage if maximum output is desired. The plate voltage is normally run about 50 per cent higher than for maximum output with plate modulation.

The driving power required for operation of a grid-modulated amplifier under these conditions is somewhat more than is required for operation at lower bias and plate voltage, but the increased power output and improved fidelity obtainable overbalances the additional excitation requirement. Actually, almost half as much excitation is required as would be needed if the same stage were to be operated as a class C plate-modulated amplifier. The resistor R across the grid tank of the stage is to serve as "swamping" to stabilize the regulation of the r.f. driving voltage. From 10 to 50 per cent of the output of the driving stage should be dissipated in this swamping resistor. If a reasonable amount of reserve excitation power is available and if a comparatively high-C grid tank is used on the grid-modulated stage, no swamping resistor will be required when the bias is at least 4 times cutoff.

A comparatively small amount of audio power will be required to modulate the amplifier stage 100 per cent. An audio amplifier having 10 watts output will be sufficient to modulate an amplifier with one kilowatt input. Proportionately smaller amounts of audio will be required for lower powered stages. However, the audio amplifier that is being used as the grid modulator should, in any case, either employ low plate resistance tubes such as 2A3's, or else employ degenerative feedback from the output stage to one of the preceding stages of the speech amplifier. This provision of low-plate-resistance output tubes in the grid modulator is to insure good regulation in the audio driver for the grid modulated stage. Good regulation of both the audio and the r.f. drivers of a grid modulated stage is quite important if distortion-free modulation approaching 100 per cent is desired.

With the normal amount of comparatively tight antenna coupling to the modulated stage, a non-modulated carrier efficiency of 40 to 45 per cent can be obtained with substantially distortion-free modulation up to practically 100 per cent. If the antenna coupling is decreased slightly from the condition just described and the excitation is increased to the point where the amplifier draws the same input, carrier efficiencies of 50 per cent are obtainable with tolerable distortion at 95 per cent modulation.

Tuning the Grid-Bias Modulated Stage

It will be noticed, by reference to figure 5, that a special type of bias supply for the grid-modulated stage has been incorporated as a part of the schematic of the stage. This was done purposely to make it more clear that a special type of high-voltage bias supply is required for best operation of such an amplifier. The arrangement shown has the advantage that the supply has very good regulation up to about 75 ma. of grid current (the maximum capability of a single 2A3) and that the voltage may be varied from nearly zero to about 700 volts. Aside from this, the supply may be constructed quite inexpensively.

The most satisfactory procedure for tuning the stage for grid-bias modulation of the class C type is as follows. The amplifier should first be neutralized and any possible tendency toward parasitics under any condition of operation should be eliminated. Then a reasonable amount of antenna coupling should be made to the plate circuit, the grid bias should be run up to the maximum available value, and the plate voltage and excitation should be applied. The grid bias voltage should then be reduced until the amplifier draws the approximate amount of plate current it is desired to run and modulation is then applied. If the plate current kicks up when a constant tone is applied, the grid bias should be reduced; if the plate meter kicks down, increase the grid bias. When the amount of bias voltage has been found (by adjusting the fine control, R_2, on the bias supply) where the plate meter remains constant with modulation, it is more than probable that the stage will be drawing either too much or too little input. The antenna coupling should then be either increased or decreased (depending on whether the input was too little or too much, respectively) until the input is more nearly the correct value. The bias should then be readjusted until the plate meter remains constant with modulation as before. By slight jockeying back and forth of antenna coupling and grid bias a point can be reached where the tubes are running at rated plate dissipation and where the plate milliammeter on the modulated stage remains substantially constant with modulation.

The linearity of the stage should then be checked by any of the conventional methods; the trapezoidal pattern method employing a cathode-ray oscilloscope is probably the most satisfactory. The check with the trapezoidal pattern will allow the determination of the proper amount of gain to employ on the speech amplifier. Incidentally, too much audio power on the grid of the modulated stage should not be used in the tuning-up process as the plate meter will kick quite erratically and it will be impossible to make a satisfactory adjustment.

Coupling Transformers for Grid Modulation

The transformer for coupling a single-ended modulator tube such as a 45 or a 2A3 into the grid circuit of the r.f. tube should preferably have a ratio of 1-to-1 or 1½-to-1 step-down. Class AB output transformers designed for operation from 2A3's or 42 triodes into a 5000-ohm load are suitable for push-pull modulators. The shunt resistance R_1 across the secondary of the modulation transformer should be of some value between 7500 and 10,000 ohms and should be rated at about 3 watts for the single-ended modulator and 10 watts for the push-pull class AB modulator.

Tubes for Grid Modulation

Medium-μ and high-μ triodes are most satisfactory as grid-bias modulated amplifiers. Low-μ tubes can be employed but the amount of grid bias voltage that is required by them for high efficiency class C grid modulation is almost prohibitive unless the plate voltage is comparatively low.

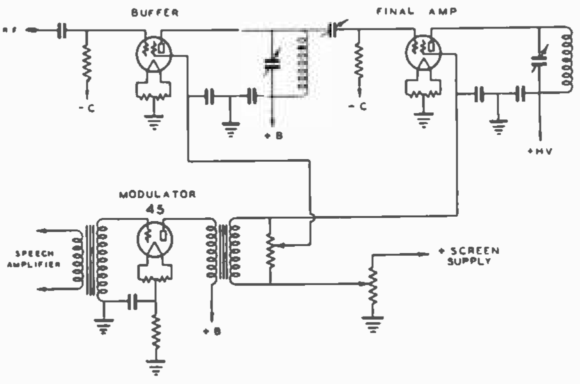
Screen-grid tubes and beam tetrodes can be grid-bias modulated quite satisfactorily. The efficiency will be somewhat lower than can be obtained with triodes, but less plate voltage and considerably less excitation power is required. A very satisfactory medium-power control grid modulated phone of great compactness can be built using one of the new, high-power-gain beam tubes.

Screen-Grid Modulation

Modulation can be accomplished by varying the screen-grid voltage at an audio-frequency rate in an r.f. screen-grid tube. The screen-grid voltage must be reduced to approximately one-fourth the value of that used for c.w. operation. The r.f. output is correspondingly reduced and the tube then operates as an efficiency-modulated device, somewhat similar to ordinary grid modulation.

The degree of modulation is limited to approximately 60 per cent when the screen-grid of a single stage is modulated. When two cascade stages are modulated, a level of 100 per cent can be reached, with good quality. The r.f. excitation and screen-grid voltages must be carefully adjusted in order to secure satisfactory results. The r.f. excitation to the grid of the final amplifier must be so low that this tube will act somewhat like a class B linear stage. It is possible to use dissimilar tubes in the cascade-modulated circuit shown in figure 6.

The buffer amplifier can be a type 6L6 or 807, the final amplifier one or two 814's or 813's. In any event, both stages should have the audio modulation voltage applied to the screens. This system of modulation is seldom used because of its complications and because only a few types of tubes are suitable for this application.



CASCADE SCREEN GRID MODULATION

Figure 6.

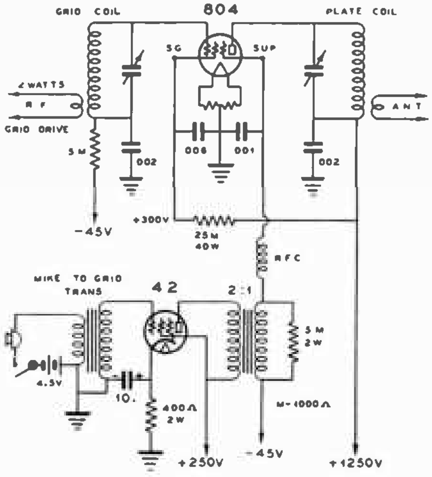
Suppressor Modulation

Still another form of efficiency modulation can be obtained by applying audio voltage to the suppressor-grid of a pentode tube which is operated class C. A change in bias voltage on the suppressor-grid will change the r.f. output of a pentode tube, and the application of audio voltage then provides a very simple method of obtaining modulation.

The suppressor-grid is biased negatively to a point which reduces the plate efficiency to somewhat less than 40 per cent. The peak efficiency at the time of complete modulation must reach twice this value. It is difficult to obtain 100 per cent modulation, though 90 per cent to 95 per cent can easily be obtained and with good linearity.

The same modulator design problems apply to the suppressor modulated transmitter as do to a grid-modulated amplifier. The control grid in the suppressor-modulator stage is driven to about the same degree as for c.w. or plate modulation. The r.f. excitation adjustment is not critical, but the excitation should be ample to allow distortionless modulation in this stage.

The quartz crystal should not be placed directly in the grid circuit of any suppressor-modulated stage because of a tendency for frequency modulation and



20 WATT SUPPRESSOR MODULATED PHONE

Figure 7.

because of poor quality due to insufficient r.f. grid excitation.

A medium powered suppressor modulated amplifier is shown in figure 7. An 804 is used as the amplifier and will supply about 20 watts of carrier. An 803 may be substituted for the 804 to increase the carrier output to about 50 or 60 watts. Either tube may be excited to full output by a 6L6 operating either as a frequency multiplier or as a crystal oscillator. A type 45 or a 42 will serve as modulator for either tube.

It is possible to operate a suppressor modulated amplifier stage as a doubler. The efficiency suffers somewhat but the voice quality will be found to be satisfactory.

Cathode Modulation

A special type of efficiency modulated amplifier is the cathode-modulated stage. A cathode-modulated amplifier may be classed primarily as efficiency modulated but it is also true that the amplifier is plate modulated to a certain extent by the existence of the modulating source in the cathode circuit. Cathode modulation offers certain advantages but it also has certain disadvantages as compared to other efficiency modulation systems.

The chief advantage of cathode modulation lies in the fact that comparatively high efficiency with reasonable power output for an efficiency modulated stage may be obtained at relatively low plate voltages. Although comparable efficiency may be obtained with class C grid bias modulation at high plate voltages, cathode modulation requires only about ⅔ the plate voltage for the same power output.

Under optimum operating conditions somewhat better plate efficiency may be obtained with cathode modulation than can be obtained with any other type of efficiency modulation. This is due to the fact that the amplifier is plate modulated to an extent in addition to the grid modulation. Efficiencies of 50 to 55 per cent are obtainable with ordinary operating conditions and under special conditions efficiencies as high as 60 per cent may be obtained. The peak efficiency of the stage under modulation will be in the vicinity of 80 to 85 per cent. It is possible to have the resting efficiency higher than half the peak efficiency because under the peak output conditions the stage is being plate modulated about 25 per cent.

The Cathode Modulator

The modulator which is used to feed the audio to the cathode circuit of the r.f. stage should have an audio power output capability of 10 to 15 per cent of the plate input to the modulated stage. The modulator tubes may operate class A, class AB, or class B; the actual method of operation of the modulator tubes is not critical so long as they have the requisite power output capability. The secondary impedance of the output transformer of the modulating stage (T in figure 8) should be from 300 to 500 ohms. However, this value is not particularly critical and higher or lower impedances (from 200 to 1000 ohms) may be used, although a slightly greater power output from the modulator will be required.

Excitation and Bias

The r.f. driver for a cathode-modulated stage should have about the same

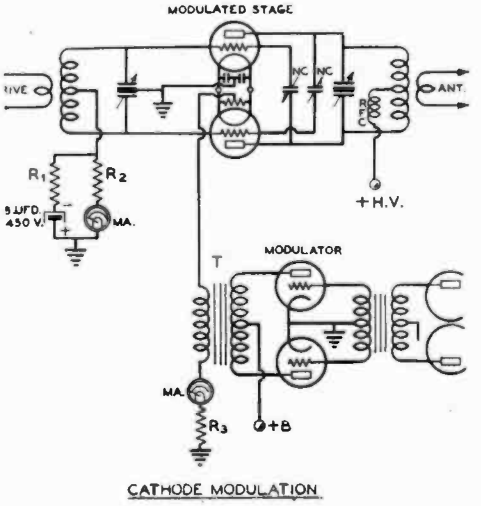


Figure 8.

power output capabilities as would be required to drive a c.w. amplifier to the same input as it is desired to drive the cathode-modulated stage. The grid leak, R_2 in figure 8, should be from 15,000 to 25,000 ohms for tubes with an amplification factor of 20 to 35. Medium-μ tubes will require a somewhat higher value of grid bias, hence a higher value of grid leak.

The proportioning of the three resistors R_1, R_2, and R_3 in figure 8 determines the modulation capability and the linearity of the cathode-modulated stage. The relative values of these resistors are determined by the amplification factor of the tubes, by the amount of excitation available and by the amount of audio power at hand. The most satisfactory adjustment of a cathode-modulated transmitter is that at which the plate dissipation of the tubes being modulated remains substantially the same with and without modulation. This condition of operation will normally be obtained with the stage operating at about 50 to 55 per cent efficiency and with a modulator power output of about 10 per cent of the input to the modulated stage.

The resistor R_1 serves to reduce the peak audio voltage on the grid as compared to that appearing at the plate. In a normal transmitter this resistor will have a value of 2500 to 5000 ohms, dependent primarily on the amplification factor of the tubes. The value of the grid leak, R_2, will vary from 10,000 to 30,000 ohms; when first placing the amplifier into operation it is best to vary the value of the grid leak until proper modulation is obtained, a higher value most commonly giving greater modulation. The cathode resistor R_3 acts mainly as a stabilizing influence due to the degenerative feedback which is developed as a result of its presence. In a conventional amplifier it may have a value from 100 to 500 ohms.

The Class B Linear Amplifier

The operation of the class B linear amplifier has been discussed in the chapter devoted to vacuum-tube theory and hence will only be covered quite generally here. The linear amplifier is not well suited for use in amateur stations since the value of unmodulated plate efficiency is quite low, varying from 30 to 39 per cent.

The grid circuit of a linear amplifier is fed modulated r.f. energy and the stage amplifies carrier and sidebands linearly. The stage is biased to cutoff with no excitation so that when excitation is applied the plate current flows in 180° pulses. This long period of plate current flow limits the theoretical peak efficiency to 78.5 per cent, the practical peak efficiency to about 65 per cent, and the average carrier efficiency to, as mentioned before, about 30 to 33 per cent.

The power output from a correctly operating linear amplifier will be about one half the maximum plate dissipation of the stage under the carrier conditions. The schematic of a linear amplifier is exactly the same as a conventional amplifier, whether single ended or push-pull, except that a swamping resistor is usually placed across the grid circuit of the stage. A linear amplifier generally requires from 5 to 10 per cent as much excitation power as will be obtained from its output circuit.

CONSTANT EFFICIENCY VARIABLE-INPUT MODULATION SYSTEMS

Constant efficiency variable-input modulation systems operate by virtue of the addition of external power to the modulated stage to effect the modulation. There are two general classifications that come under this heading, those systems in which the additional power is supplied as audio frequency energy from a modulator, usually called plate modulation systems, and those systems in which the additional power to effect modulation is supplied as direct current from the plate supply.

Under the former classification comes Heising modulation (probably the oldest type of modulation to be applied to a continuous carrier), class B plate modulation, and series modulation. These types of plate modulation are by far the easiest to get into operation and they give a very good ratio of power input to the modulated stage to power output. 65 to 80 per cent efficiency is the general rule. It is for these two important reasons that these modulation systems, particularly class B plate modulation, are at present the most popular among amateurs.

Modulation systems coming under the second classification are of comparatively recent development and have only quite recently been applied even to broadcast work. There are quite a few systems in this class but only two are really worthy of special consideration. These are: the Doherty linear amplifier, and the Terman-Woodyard high-efficiency grid modulator. Both systems operate by virtue of a carrier amplifier and a peak amplifier connected together by means of electrical quarter-wave lines. They will be described later on in this section.

Plate Modulation

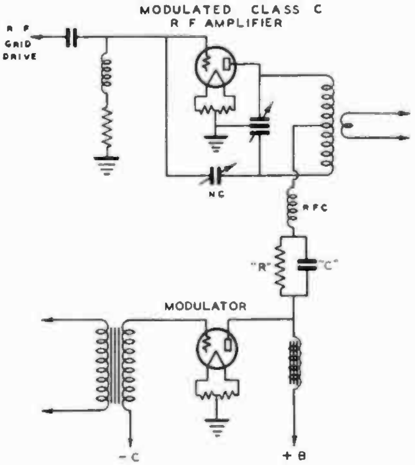
Plate modulation is the application of the audio power to the *plate circuit* of an r.f. amplifier. The r.f. amplifier must be operated class C for this type of modulation in order to obtain a radio-frequency output which changes in exact accordance with the variation in plate voltage. *The r.f. amplifier is* 100 *per cent modulated when the peak a.c. voltage from the modulator is equal to the d.c. voltage applied to the r.f. tube.* The positive peaks of audio voltage increase the instantaneous plate voltage on the r.f. tube to *twice* the d.c. value, and the negative peaks reduce the voltage to zero.

The instantaneous plate *current* to the r.f. stage also varies in accordance with the modulating voltage. The peak alternating current in the output of a modulator must be equal to the d.c. plate current of the class C r.f. stage at the point of 100 per cent modulation. This combination of change in audio voltage and current can be most easily referred to in terms of *audio power in watts.*

The plate efficiency of the plate-modulated stage is constant, and the additional power radiated in the form of sidebands is supplied by the modulator.

One of the advantages of plate (or power) modulation is the ease with which proper adjustments can be made in the transmitter. There is less plate loss in the r.f. amplifier for a given value of carrier power than with other forms of modulation, because the plate efficiency is higher.

By properly matching the plate impedance of the r.f. tube to the output of the modulator, the ratio of voltage and current swing to d.c. voltage and current is automatically obtained. The modulator should have a peak voltage output equal to the average d.c. plate voltage on the modulated stage. The modulator should also have a *peak power* output equal to the d.c. plate input power to the modulated stage. The *average* power output of the modulator will depend upon the type of waveform and upon the type of modulator. If the amplifier is being Heising modulated by a class A stage the modulator must have an average power output capability of one-half the input to the class C stage. If the modulator is a class B audio amplifier, the average power required of it may vary from one-quarter to one-half



HEISING OR PLATE MODULATION

"R" DROPS PLATE POWER INPUT AND VOLTAGE TO CLASS C STAGE IN ORDER TO OBTAIN HIGH DEGREES OF MODULATION. "C" IS FROM 2 TO 4 MFDS TO BY-PASS THE AUDIO SIGNAL TO THE CLASS C MODULATED AMPLIFIER.

Figure 9.

the class C input depending upon the waveform. However, the *peak* power output of any modulator must be equal to the class C input to be modulated. This subject is completely covered in the section Speech Waveforms.

Heising Modulation

Heising modulation is a system of plate modulation and usually consists of a class A audio amplifier coupled to the r.f. amplifier by means of a modulation choke coil, as shown in figure 9.

The d.c. plate voltage and plate current in the r.f. amplifier must be adjusted to a value which will cause the plate impedance to match the output of the modulator, since the modulation choke gives a 1-to-1 coupling ratio. A series resistor, by-passed for audio frequencies by means of a condenser, must be connected in series with the plate of the r.f. amplifier in order to obtain modulation up to 100 per cent. The a.c. or audio output voltage of a class A amplifier does not reach a value equal to the d.c. voltage applied to the class A amplifier and, consequently, the d.c. plate voltage impressed across the r.f. tube must be reduced to a value equal to the maximum available a.c. peak voltage.

A higher degree of distortion can be tolerated in low-power emergency phone transmitters which use a pentode modulator tube for securing sufficient audio output, and thus the series resistor and by-pass condenser are usually omitted.

Class B Plate Modulation

High-level class B plate modulation is probably the most satisfactory and least expensive method of plate modulating inputs of from 50 to 1000 watts. Since most amateur phone transmitters fall into this power range, considerable discussion will be given to the various problems associated with the design problems of class B modulators. Figure 10 shows a conventional class B plate-modulated class C amplifier.

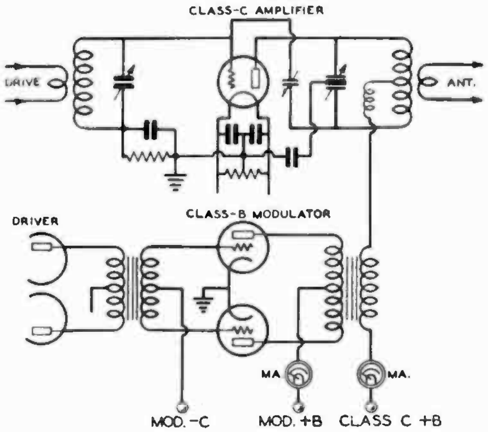


Figure 10.

The statement that the average modulator power must be one-half the class C input for 100% modulation is correct only if the waveform of the modulating power is a *sine wave*. For amateur purposes, where the modulator waveform is speech, the average modulator power for 100 per cent modulation is considerably less than one-half the class C input. If a modulator is to be used *only with speech*, it seems logical to assume that its design be based upon the peculiarities of speech rather than on the characteristics of the sine wave. The difference between speech and the sine wave is so pronounced that a 100-watt class-B modulator, *if properly designed for speech*, may be used to modulate fully an input of from 300 to 400 watts. The idea cannot be applied to Heising modulators (class A single ended) for reasons that will be apparent when it is recalled that such modulators run hottest when resting, and that the plate dissipation limits the peak output as well as the average output.

Power Relations in Speech Waveforms

It has been determined experimentally that speech is equivalent to two simultaneous equal amplitude tones of different frequencies, having a total amplitude equal to that of the sine wave with which the speech is being compared. It follows from this that, for speech, the *average* modulator plate current, plate dissipation and power output are just one-half the sine-wave values for a given *peak* power. In other words a 100-watt class-B modulator, if used to modulate 100 per cent an input of 200 watts, delivers an *average* power of only 50 watts and the average plate current and plate dissipation are only one-half the permissible values. In order to take full advantage of the tube ratings, the design should be altered so that the *peak* power output is increased until the average plate current or plate dissipation becomes the limiting factor.

Both peak power and average power are necessarily associated with waveform. *Peak* power is just what the name implies, the power at the peak of a wave. Peak power, although of the utmost importance in modulation, is of no practical significance in a.c. power work, except insofar as the *average* power may be determined from the peak value of a known wave form. There is no time element implied in the definition of peak power; peak power may be instantaneous —and for this reason average power, which is definitely associated with time, is the important factor in plate dissipation. It is possible that the peak power of a given wave form be several times the average value; for a sine wave the peak power is twice the average value, and for speech the peak power is approximately four times the *average* value. For 100 per cent modulation the *peak* (instantaneous) audio power must equal the class-C input, although the average power for this value of peak varies widely depending upon the modulator wave form, being 50% for a sine wave and about 25% for speech tones. The problem then of obtaining more speech power consists in obtaining as high a *peak* power as possible without exceeding the *average* plate dissipation or current rating of the tubes.

Since the power output varies as the square of the peak current, the most logical thing to do in order to obtain high peak power is to increase the peak current. This may be done by decreasing the class B modulator plate-to-plate load.

At this point it might be assumed that this increase in peak current is nothing more or less than a gross overload without regard for the manufacturer's ratings. However, a little reflection will show that the manufacturer's rating is given as *average* current and that the actual *peak* current (this cannot be read by a meter) varies widely with the mode of operation. An average plate current of 100 ma. in class C operation may call for a dynamic peak plate current of 1 ampere, whereas in class B service this same 100 ma. per tube represents a peak of only 315 ma. No ill effects will result if the peak plate current is increased to such a point that the average plate current with speech as read on the plate meter is equal to the sine-wave value as specified by the manufacturer. With this in mind the *peak* plate current may be safely doubled, assuming that the plate dissipation does not become the limiting factor.

Modulation Transformer Calculations

The modulation transformer is a device for matching the load impedance of the class C amplifier to the recommended load impedance of the class B or possibly class AB modulator tubes. Modulation transformers are usually designed to carry the class C plate current through their secondary windings as shown in figure 10. The manufacturer's ratings should be consulted to insure that the d.c. plate current being pulled through the secondary winding does not exceed the maximum rating.

The load resistance presented by the class C r.f. amplifier to the modulation transformer is calculated by dividing the d.c. plate-to-filament voltage by the plate current of the stage. For example, a pair of 75T tubes in a push-pull amplifier operating at 1200 volts and 250 milliamperes present a load impedance of 1200 divided by 0.25 amperes, or 4800 ohms.

$$Z = \frac{E}{I} = \frac{1200}{0.25} = 4800 \text{ ohms},$$

where Z is the load impedance of the class C r.f. amplifier.

The power input is 1200 times 0.25 or 300 watts.

Figure 11.

CLASS C INPUT THAT CAN BE FULLY SPEECH-MODULATED BY VARIOUS CLASS B TUBES

Class B Tubes	Class C Power Input	Class B P-P Load	Plate Voltage	Average Speech Plate Current	Class B Bias	Driver Tubes	Average Driving Power	Driver Transformer Ratio Pri. to ½ Sec.
TZ-20	250	4850	750	145	0	2-2A3	7	2.6:1
809	300	4800	750	165	—1½	2-2A3	5	4.5:1
809	400	7200	1000	150	—8	2-2A3	5	4.5:1
TZ-40	500	5100	1000	200	—5	2-2A3	8	2.6:1
TZ-40	600	7400	1250	182	—9	2-2A3	7	2.8:1
203Z	800	5500	1250	250	0	4-2A3	15	2.75:1

By reference to figure 11 we see that a pair of 809's operating at 750 volts will fully modulate an input of 300 watts to a class C amplifier with voice-waveform audio power. In other words, the peak audio output of the class B 809's when operated into a load impedance of 4800 ohms and at a plate voltage of 750 is 300 watts. It just so happens that the recommended plate-to-plate load resistance of the 809's under these operating conditions is the same as the load presented by the class C amplifier. Hence, the modulation transformer should have a primary-to-secondary ratio of 1-to-1. The other operating conditions for the 809 modulator will be found in figure 11. A modulation transformer rated to handle 125 watts of audio will be ample for the purpose.

Suppose we take as another example to illustrate the method of calculation the case of a pair of 54 Gammatrons operating at 2000 volts at 250 ma. This amplifier would present a load resistance of 2000 divided by 0.25 amperes or 8000 ohms. The plate power input would be 2000 times 0.25 amperes or 500 watts. By reference to figure 11 we see that a pair of TZ40's at 1000 volts will put out 500 peak audio watts and hence will modulate 500 watts input with speech waveform. The plate-to-plate load for these tubes is given as 5100 ohms; hence, our problem is to match a load of 8000 ohms to the proper load resistance of the TZ40's of 5100 ohms.

A 200-to-300 watt audio transformer will be required for the job. If the taps on the transformer are given in terms of impedances it will only be necessary to connect the secondary for 8000 ohms and the primary to 5100 ohms. If it is necessary to determine the turns ratio of the transformer it can be determined in the following manner. The square root of the impedance ratio is equal to the turns ratio, hence:

$$\sqrt{\frac{8000}{5100}} = \sqrt{1.57} = 1.25$$

The transformer must have a turns ratio of 1.25 to 1, step up. The transformer must be step-up since the higher impedance is on the secondary. When the primary impedance is the higher of the two impedances, the transformer must be connected step-down.

Bass Suppression

Not only can a smaller class B modulator be used for complete modulation of a given carrier power when voice only is to be used, but an increase in the effectiveness of the modulator power can be obtained by incorporation of a simple bass suppression circuit. Most of the audio power generated in a modulator is represented by the bass frequencies. As the frequencies below 200 or 250 cycles can be greatly attenuated without noticeably affecting the speech intelligibility, it is desirable to do so for communication work. Bass suppression permits a higher percentage modulation at the voice frequencies providing intelligibility, which is equivalent to a substantial increase in power. It is not necessary to suppress the bass frequencies completely; but only to attenuate them until, as the audio gain is increased, overmodulation first occurs at the voice frequencies that afford intelligibility rather than at the power-consuming bass frequencies.

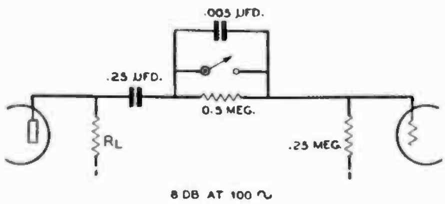


Figure 12.
Simple dialogue equalizer that can be installed in any speech amplifier.

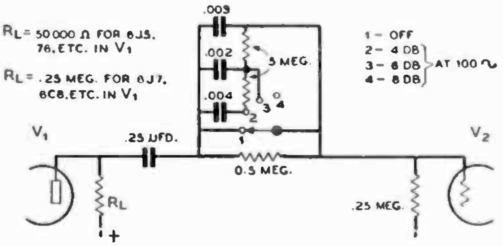


Figure 13.
Variable bass suppression.

In figures 12 and 13 are shown two simple systems for bass suppression. They are self-explanatory and can be placed between almost any two voltage amplifier tubes in your speech channel. They will work into or out of either triodes or pentodes, but *don't use inverse feedback around the suppressor* or you'll suppress the suppression!

The bass suppressor is an old idea in the talking picture field. It is really surprising how much it cleans up the average boomy ham quality on voice. One reason the new F-type telephone handset mikes sound so good on speech is that they cut off very sharply below 200 cycles.

The bass suppressor shown in figure 12 has a suppression of 6 db at 100 cycles while the arrangement of figure 13 has 0, 4, 6 and 8 db suppression in the four switch positions. The 5-megohm resistors merely eliminate the loud clicks which otherwise would be heard when varying the suppression.

In both of the arrangements, the suppression starts at about 500 cycles although the good work really begins below 200 cycles. The 1000-cycle gain of an amplifier equipped with this type of bass suppression is practically unchanged with the suppressor in or out.

Plate-and-Screen Modulation

When *only* the plate of a screen-grid tube is modulated, it is impossible to obtain high percentage linear modulation, except in the case of certain beam tubes. A dynatronic action usually takes place when the instantaneous plate voltage falls below the d.c. screen voltage, and this prevents linear modulation. However, if the screen is modulated simultaneously with the plate, the instantaneous screen voltage drops in proportion to the drop in the plate voltage, and linear modulation can then be obtained. A circuit for such a system is shown in figure 14.

The screen r.f. by-pass condenser, C_2, should not have a value greater than .01 µfd., preferably not larger than .005 µfd. It should be large enough to bypass effectively all r.f. voltage without short-circuiting high-frequency audio voltages. The plate by-pass condenser can be of any value from .002 µfd. to .005 µfd. The screen-dropping resistor, R_2, should reduce the applied high voltage to the value specified for operating

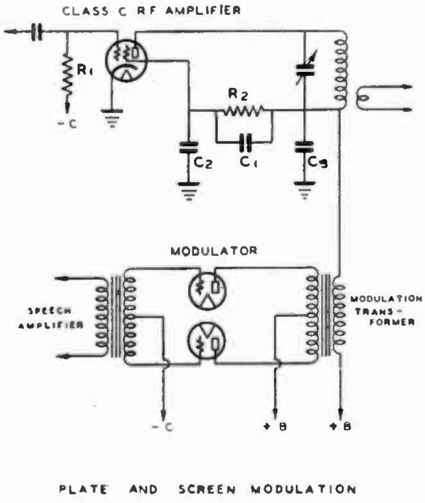


Figure 14.

the particular tube in the circuit. Condenser C_1 is seldom required, yet some tubes may require this condenser in order to keep C_2 from attenuating the high audio frequencies. Different values between .01 and .002 μfd. should be tried for best results.

Another method is to have a third winding on the modulation transformer, through which the screen-grid is connected to a low-voltage power supply. The ratio of turns between the two output windings depends upon the type of screen-grid tube which is being modulated. The latter arrangement is more economical insofar as modulator power is concerned, because there is no waste of audio power across a screen-grid voltage-dropping resistor. However, this loss is relatively small anyway with most tubes. The special transformer is not justified except perhaps for high power.

If the screen voltage for the beam tube is derived from a dropping resistor (*not* a divider) that is by-passed for r.f. but not a.f., it is possible to secure quite good modulation up to about 90% by applying modulation only to the plate, provided that the screen voltage and excitation are first run up as high as the tube will stand safely. Under these conditions the screen tends to modulate itself to an extent, the screen voltage varying over the audio cycle as a result of the screen impedance increasing with plate voltage, and decreasing with a decrease in plate voltage.

The modulation transformer for plate-and-screen-modulation, when utilizing a dropping resistor, is similar to the type of transformer used for any plate-modulated phone. In figure 14, the combined screen and plate current is divided into the plate voltage in order to obtain the class C amplifier load impedance. The audio power required to obtain 100 per cent sine-wave modulation is one-half the d.c. power input to the screen, screen resistor and plate of the modulated r.f. stage.

Quite good linearity at high percentage modulation can be obtained with some of the *beam*-type transmitting tetrodes by modulating the plate voltage alone.

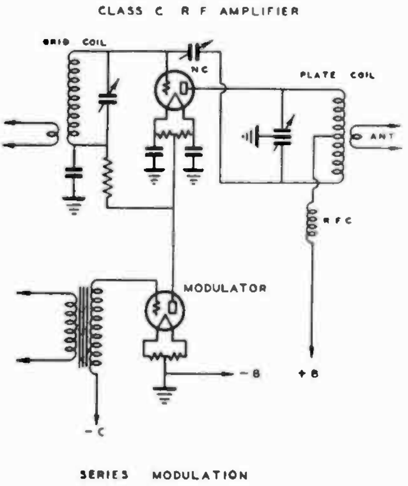


Figure 15.

Series Modulation

Another form of plate modulation is known as *series modulation*, in which the r.f. tube and modulator are in series across the d.c. plate supply, as shown in figure 15.

Series modulation eliminates the modulation choke required in the usual form of Heising modulation. Although this system is capable of very good voice quality, the antenna coupling must be carefully adjusted simultaneously with the C bias in the modulator in order to maintain at least 20 per cent more plate voltage across the modulator than that which is measured from positive B to r.f. tube filament. It is difficult to obtain a high degree of modulation unless a portion of the total plate current is shunted by the r.f. tube through a resistor in series with a high-inductance choke coil. Series modulation is seldom used today except for television work.

The Doherty Linear Amplifier and the Terman-Woodyard Grid-Bias Modulated Amplifier

These two new-design amplifiers will be described collectively since they operate upon a very similar principle. Figure 16 shows a greatly simplified schematic diagram of the operation of both types

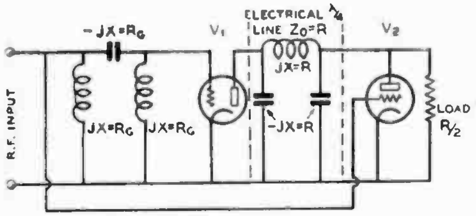


Figure 16.

Both systems operate by virtue of a carrier tube (V_1 in both figures 16 and 17) which supplies the unmodulated carrier and whose output is reduced to supply negative peaks, and a peak tube (V_2 in figures 16 and 17) whose function is to supply approximately half the positive peak of the modulation cycle and whose additional function is to lower the load impedance on the carrier tube so that it will be able to supply the other half of the positive peak of the modulation cycle.

The peak tube is enabled to increase the output of the carrier tube by virtue of an impedance inverting line between the plate circuits of the two tubes. This line is designed to have a characteristic impedance of one half the value of load into which the carrier tube operates under the carrier conditions. Then a load of one half the characteristic impedance of the quarter-wave line is coupled into the output. By experience with quarter-wave lines in antenna-matching circuits we know that such a line will vary the impedance at one end of the line in such a manner that the geometric mean between the two terminal impedances will be equal to the characteristic impedance of the line. Thus if we have a value of load of *one-half* the characteristic impedance of the line at one end, the other end of the line will present a value of *twice* the characteristic impedance of the line to the carrier tube V_1.

This is the situation that exists under the carrier conditions when the peak tube merely floats across the load end of the line and contributes no power. Then, as a positive peak of modulation comes along the peak tube starts to contribute power to the load until at the peak of the modulation cycle it is contributing enough power so that the impedance at the load end of the line is equal to R, instead of the R/2 that is presented under the carrier conditions. This is true because at a positive modulation peak (since it is delivering full power) the peak tube subtracts a negative resistance of R/2 from the load end of the line.

Now, since under the peak condition of modulation the load end of the line is terminated in R ohms instead of R/2, the impedance at the *carrier-tube* will be *reduced* from 2R ohms to R ohms. This again is due to the impedance inverting action of the line. Since the load resistance on the carrier tube has been reduced to half the carrier value, its output at the peak of the modulation cycle will be doubled. Thus we have the necessary condition for a 100 per cent positive modulation peak; the amplifier will deliver four times as much power as it does under the carrier conditions.

On negative modulation peaks the peak tube does not contribute; the output of the carrier tube is reduced until on a 100 per cent negative peak its output is zero.

While an electrical quarter-wave line (consisting of a pi network with the inductance and capacity legs having a reactance equal to the characteristic impedance of the line) does have the desired impedance-inverting effect, it also has the undesirable effect of introducing a 90° phase shift across such a line. If the shunt elements are capacitances, the phase shift across the line leads by 90°; if they are inductances, the phase shift lags by 90°. Since there is an undesir-

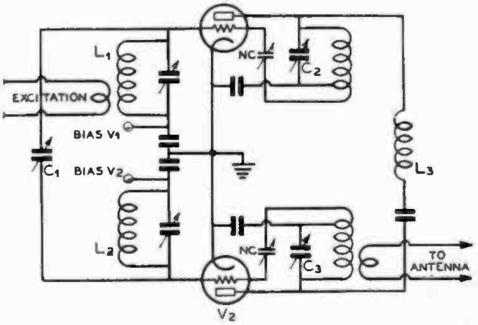


Figure 17.

able phase shift of 90° between the plate circuits of the carrier and peak tubes, an equal and opposite phase shift must be introduced in the exciting voltage to the grid circuits of the two tubes so that the resultant output in the plate circuit will be in phase. This additional phase shift has been indicated in figure 16 and a method of obtaining it has been shown in figure 17.

The difference between the Doherty linear and the Terman-Woodyard grid modulator is the same as the difference between a linear and a grid-modulated stage. Modulated r.f. is applied to the grid circuit of the Doherty linear with the carrier tube biased to cutoff and the peak tube biased to the point where it draws substantially zero plate current at the carrier condition. In the Terman-Woodyard grid modulated amplifier the carrier tube runs class C with comparatively high bias and high plate efficiency while the peak tube again is biased so that it draws almost no plate current. Unmodulated r.f. is applied to the grid circuits of the two tubes and the modulating voltage is inserted in series with the fixed bias voltages. From one-half to two-thirds as much *audio* voltage is required at the grid of the peak tube as is required at the grid of the carrier tube.

The resting carrier efficiency of the grid-modulated amplifier may run as high as is obtainable in any class C stage, 80 per cent or better. The resting carrier efficiency of the linear will be about as good as is obtainable in any class B amplifier, 60 to 65 per cent. The overall efficiency of the bias-modulated amplifier at 100 per cent modulation will run about 75 per cent; of the linear, about 60 per cent.

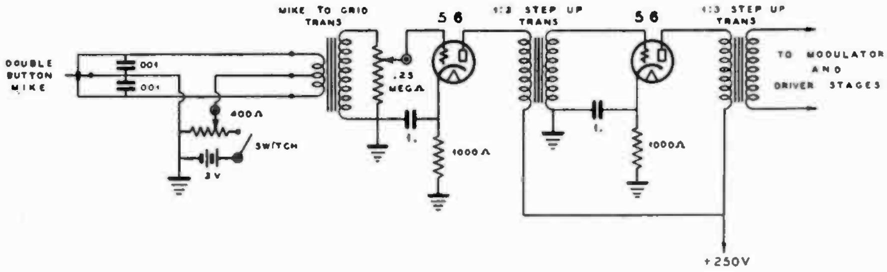
The effect of the quarter-wave line in the plate and grid circuits of the amplifier shown in figure 17 is obtained by detuning the circuits enough to give the shunt element of the networks. At resonance, the coils L_1 and L_2 in the grid circuits of the two tubes have each an inductive reactance equal to the capacitive reactance of the condenser C_1. Thus we have the effect of a pi network consisting of shunt inductances and series capacitance. In the plate circuit we want a phase shift of the same magnitude but in the opposite direction; so our series element is the inductance L_3 whose reactance is equal to the characteristic impedance desired of the network. Then the plate tank condensers of the two tubes C_2 and C_3 are increased an amount past resonance so that they have a capacitive reactance equal to the inductive reactance of the coil L_3. It is quite important that there be no coupling between inductors in an amplifier of this type.

Although both these types of amplifiers are highly efficient and require no high-level audio equipment, they are difficult to adjust—particularly so on the higher frequencies—and it would be an extremely difficult problem to design a multi-band rig employing the circuit. However, the grid-bias modulation system has advantages for the high-power transmitter that may make some amateurs interested more than academically in the circuit. For those who are, discussion of the design and adjustment of the circuit has been given in recent issues of the technical radio magazines and in the *Proceedings* of the I.R.E.

SPEECH EQUIPMENT-MICROPHONES

The microphone, which changes sound into electrical energy, usually consists of a diaphragm which moves in accordance with the compressions and rarefactions of the air called *sound waves*. The diaphragm then actuates some form of device which changes its electrical properties in accordance with the amount of physical movement.

If the diaphragm is very tightly stretched, the natural period of its vibration can be placed at a frequency which will be out of range of the human voice. This obviously reduces the sensitivity of the microphone, yet it greatly improves the uniformity of response to the wide range encountered for voice or musical tones. If the natural mechanically resonant period of the diaphragm falls within the voice range, the sensitivity is greatly increased near the resonant frequency. This results in distorted output,



TYPICAL SPEECH AMPLIFIER FOR DOUBLE BUTTON CARBON MICROPHONE OR 200Ω LINE INPUT

Figure 18.

a familiar example being found in the old-type land-line telephone microphone.

A good microphone must respond equally to all voice frequencies; it must not introduce noise, such as hiss; it must have sufficient sensitivity to eliminate the need of excessive audio amplification; its characteristics should not vary with changes in temperature or humidity, and its characteristics should remain constant over a useful period of life.

The Carbon Microphone

Carbon microphones can be divided into two classes: (1) *Single-button,* (2) *Double-button.* The single-button microphone consists of a diaphragm which exerts a mechanical pressure on a group of carbon granules. These granules are placed behind the diaphragm between two electrodes, one of which is secured directly to the diaphragm and moves in accordance with the vibration of the diaphragm. This vibration changes the pressure on the carbon granules, resulting in a change of electrical resistance to current flowing between the electrodes, the direct current being supplied from an external source. The variation in resistance causes a change in the current which flows through the primary winding of a coupling transformer, thereby inducing a voltage in the secondary winding of this transformer; this voltage is then amplified by means of vacuum tube amplifiers.

Single-button microphones are useful for operation in portable transmitters because their sensitivity is greater than that of other types of microphones, thereby requiring less audio amplification to supply audio modulating power for the transmitter. The objectionable feature of the single-button microphone is its high hiss level. Another is that the diaphragm generally resonates within the voice range, resulting in mediocre tone quality. The better microphones of this type, however, are highly intelligible even though lacking somewhat in fidelity.

Double-Button Microphones

The double-button microphone has two groups of carbon granules arranged in small containers on either side of the diaphragm. This push-pull effect reduces the even-harmonic distortion, resulting in more intelligible modulation. The diaphragm is normally stretched to such an extent that its natural period may be as high as 8,000 cycles per second, which is beyond the range of the human voice. This reduces the sensitivity of the microphone and greater audio amplification is needed to secure the same output as from a single-button carbon microphone. On the other hand, the tone quality from the double-button microphone is better, though the hiss is still present.

The cost of a double-button microphone is a satisfactory index of its performance when purchased from a reliable concern. The output from a *high-quality* two-button microphone is about 45 db below that of a standard single-button microphone.

Condenser Microphones

A condenser microphone has a better

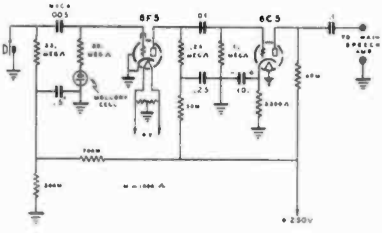


Figure 19.

CONDENSER MICROPHONE PRE-AMPLIFIER.

This preamplifier is used with a condenser microphone in order to increase its output to a sufficient level to work directly into the grid of a speech amplifier, such as one which was originally designed for carbon microphone input. No transformer is needed for coupling between the 6F5 and the speech amplifier. The 0.1-μfd. coupling condenser and the speech amplifier grid leak should be located at the speech amplifier.

frequency response than a carbon microphone and it does not produce a hiss. This type of microphone consists of a highly damped or stretched diaphragm mounted very close to a metal plate, but insulated from the plate. The movement of the diaphragm changes the spacing between the two electrodes, resulting in a change in electrical capacity. When a d.c. polarizing voltage is applied across the plates, an a.c. voltage will be generated when the diaphragm is actuated by reason of the change in capacity between the plates; this voltage can then be amplified by means of vacuum tubes. The diaphragm of a typical condenser microphone is made of duralumin sheet, approximately 1/1000 in. thick, with approximately the same spacing between the diaphragm and the rear heavy plate electrode. The output is approximately 75 db below an ordinary single-button carbon microphone with unstretched diaphragm.

The condenser microphone has a low output level, which necessitates at least two stages of preamplification, the first stage being located very close to the microphone. The output impedance is extremely high and the unit must, therefore, be well shielded in order to prevent r.f. and 60-cycle a.c. hum pickup. It is sensitive to changes in barometric pressure and humidity. More modern types of microphones are replacing the condenser type, although the latter are still widely used.

Crystal Microphones

The crystal microphone operates on the principle that a change in dimensions of a *piezoelectric* material, such as *Rochelle salt crystals,* generates a small a.c. voltage which can be amplified by means of vacuum tubes. No d.c. polarizing voltage or current or coupling transformer is required for the crystal type of microphone; thus, it becomes a very simple device to connect into an audio amplifier.

Crystal microphones can be divided into two classifications: (1) the diaphragm type, (2) the grille type.

The diaphragm type is relatively inexpensive and consists of a semifloating diaphragm which subjects the crystal to deformation in accordance with the applied sound pressure. The fidelity is equal to that of most two-button carbon microphones and there is no background noise or hiss generated in the microphone itself.

The grille type consists of a group of crystals connected in series or series-parallel for the purpose of obtaining high electrical output without aid of a diaphragm.

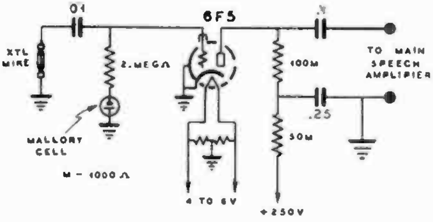


Figure 20.

This preamplifier can be used with an inductive microphone by changing the resistance network in the input to a transformer of the correct design. If the preamplifier is far removed from the main speech amplifier, a plate-to-500-ohm-line transformer should be connected in the output, with a corresponding 500 ohm-to-grid transformer at the speech amplifier.

The output level varies between —55 db and —80 db for various types of crystal microphones. The grille type is less directional to sound pickup than most other types and is capable of almost perfect fidelity. However, they have the disadvantage of a high thermal-agitation noise level.

Velocity or Ribbon Microphones

The inductive or ribbon-type microphone has a thin, corrugated, metal strip diaphragm which is loosely supported between the poles of a horseshoe magnet. A minute current is induced in this strip when it moves in a magnetic field, and this current can be fed to the primary of a step-up-ratio transformer of high ratio because of the very low impedance of the ribbon.

The microphone output must be amplified by means of a very high gain pre-amplifier, because the output level of the older types of ribbon microphones is —100 db and even the newer ones are around —85 db. The inductive type of microphone is rugged and simple in construction. Unfortunately, it cannot be used for close talking without overemphasizing the lower frequencies. It is a velocity, rather than a pressure-operated, microphone and should therefore be placed at least two feet from the source of sound. It is very sensitive to a.c. hum pickup, and this is one of the principal reasons why it is not widely used in amateur practice.

The impedance of the ribbon is so low that it is difficult to design a ribbon-to-grid transformer with good fidelity. Therefore, for best quality, two transformers are usually used in cascade: ribbon-to-200 ohms and 200 ohms-to-grid.

The Dynamic Microphone

The dynamic (moving coil) type of microphone operates on the same principle as the inductive microphone. A small coil of wire, actuated by a diaphragm, is suspended in a magnetic field, and the movement of the coil in this field generates an alternating current. The output impedance is approximately 30 ohms as against approximately one ohm for the ribbon type of microphone. The output level of the high fidelity types is about —85 db, the level varying with different makes. The output level of the p.a. types is somewhat higher and the fidelity is almost as good. This type of microphone is quite rugged, but has the disadvantage of picking up hum when used close to any power transformers.

An inexpensive and very satisfactory dynamic microphone for amateur transmitters can be made from a small, permanent-magnet type, dynamic loudspeaker. One of the newer 5-in. types with alloy magnet will give surprising fidelity at relatively high output level.

A shielded cable and plug are essential to prevent hum pickup. The unit can be mounted in any suitable type of container. The circuit diagram is shown in figure 21.

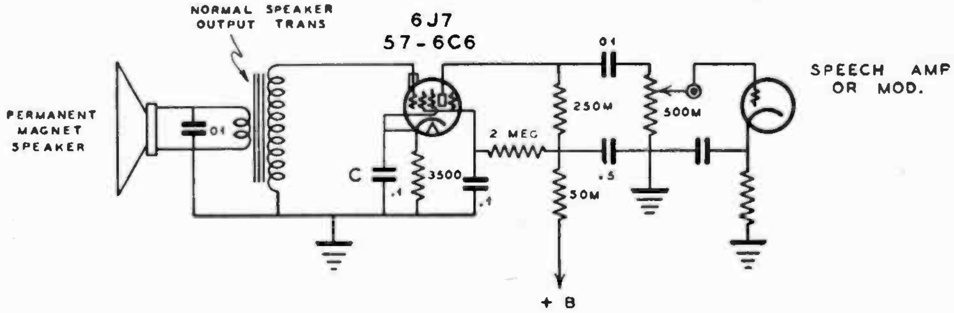


Figure 21.

LOW COST DYNAMIC MICROPHONE INPUT AMPLIFIER.

Directional Effects

Crystal microphones, as well as those of some other types, can be mounted in a spherical housing with the diaphragm oriented horizontally in order to secure a non-directional effect. Decidedly directional effects may be required, on the other hand, and microphones for this purpose are commercially available.

SPEECH AMPLIFIERS

That portion of the audio channel between the microphone or its preamplifier and the power amplifier or driver stage can be defined as the *speech amplifier*. It consists of from one to three stages of *voltage amplification* with resistance, impedance or transformer coupling between stages. The input level is generally about —50 db in the case of a speech amplifier designed for a double-button carbon microphone or preamplifier input. The input level is approximately —70 db when the speech amplifier is designed for operation from a diaphragm-type crystal microphone. Some conventional speech amplifier circuits are shown in the preceding pages. Other speech amplifier circuits are shown in the chapter on *Speech and Modulation Equipment*.

It is possible to dispense with the preamplifier with certain types of low-level microphones by designing the speech amplifier input to work at —100 db or so, but it is better practice and entails less constructional care if a speech amplifier with less gain is used, in conjunction with a preamplifier to make up the required overall amplification. Less trouble with hum and feedback will be encountered with the latter method.

Designing a speech amplifier to work at —70 db is comparatively easy, as there is little trouble from power supply hum getting into the input by stray capacitive or inductive coupling.

Amplifier Gain

The power gain in amplifiers or the power loss in attenuators can be conveniently expressed in terms of db *units*, which are an expression of ratio between two power levels.

A formula for the calculation of db gain or loss is here given:

$$DB = 10 \times \log_{10} \frac{P_2}{P_1}$$

Since power is equal to the product of voltage times current when the power factor is unity, db units can be used to express voltage gain. In this case the formula is:

$$DB = 20 \times \log_{10} \frac{E_1}{E_2}$$

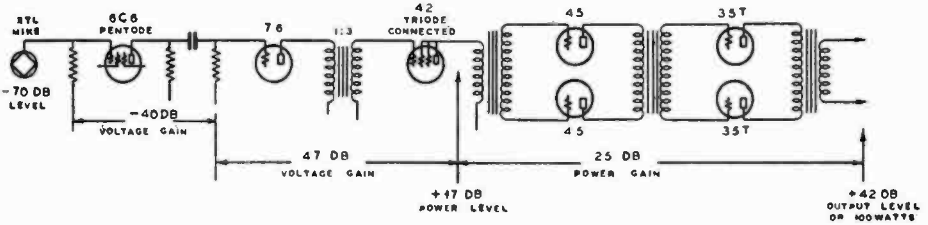
This provides a useful means for computing the overall voltage gain of a preamplifier and the speech amplifier. When adding the gain of several stages, the db units are added or subtracted, which greatly simplifies the calculations.

For example: if a preamplifier has 35 db gain, and the speech amplifier has 65 db gain, the total gain is 35 + 65, equals 100 db. One hundred db corresponds to a voltage gain of 100,000 times. Thus, for example, if the microphone level is —100 db the speech amplifier output will be —100 db + 100 db, or zero db level. Zero level corresponds to a power level of 6 milliwatts.

In order to obtain 60 watts of audio power output, a power gain of 6,000 times will be required, which corresponds to a power gain of approximately 38 db. This amplification can be considered as part of the main power amplifier or modulator, or as part of the speech amplifier, depending upon the particular transmitter under consideration. The important point to remember is that power ratios use the expression: 10 × log, whereas voltage gain between similar impedances is computed by the expression: 20 × log.

Let us take a typical example of radiophone transmitter with a class C amplifier input of 200 watts. For 100 per cent plate modulation, the audio power requirement is 100 watts. This corresponds to a db power level of + 42 db. Zero db level is 6 milliwatts or .006 watt. (Refer to db power table in chapter 21.)

Therefore, the formula:



COMPUTATION OF GAIN FOR AUDIO CHANNEL OF RADIO TRANSMITTER

Figure 22.

$$DB = 10 \times \log_{10} \frac{P_1}{P_2} =$$

$$10 \times \log_{10} \frac{100}{.006} = 42$$

The amateur may desire to use a diaphragm type crystal microphone which is rated at —70 db for average sound levels. This extremely low output must be brought up to a value of 100 watts or +42 db. The total gain required will be 112 db.

No preamplifier would be necessary, because this amount of gain can be built into a good speech amplifier and modulator. A typical audio channel which meets these requirements is shown in the skeleton circuit, figure 22.

The first speech amplifier consists of a 6C6 connected as a high-gain pentode, resistance-coupled to a 76 speech amplifier which, in turn, is coupled through a step-up transformer into a 42 tube which operates as a triode. The latter is connected to a push-pull 45 class AB driver for the final power amplifier or modulator consisting of a pair of 35T's.

The 6C6 stage is capable of producing a voltage amplification of 100 times, which corresponds to 40 db.

$$DB = 20 \times \log_{10} \frac{100}{1} = 40$$

The 76 and 42 triodes with a 3-to-1 stepup interstage transformer will produce a voltage gain of 240.

$$DB = 20 \times \log_{10} \frac{240}{1} = 47$$

Actually, the db voltage gain must be measured between like impedances in order to be correct.

The total speech amplifier gain is 40 + 47, equals 87 db. If the output level of the microphone is —70 db, the output level of the 42 triode will be 87 — 70, equals +17 db. This level corresponds to approximately 300 milliwatts, which is well within the rating of a 42 triode driver, and is sufficient to drive the 45 tubes in class AB.

$$17 = 10 \times \log_{10} \frac{P}{.006}$$

Therefore, P equals 0.3 watt or 300 milliwatts.

$$DB = 10 \times \log_{10} \frac{100}{0.3} = 25$$

This can be checked by subtracting 17 from 42, which is 25 db, the power gain between the grids of the 45 tubes and the output of the class B modulator.

With 0.3 watt input to the 45 stage, 9 watts of output can be obtained.

$$DB = 10 \times \log_{10} \frac{9}{0.3} = 15$$

The power gain through the 45 stage is 15 db. leaving a power gain of 10 in the 35T class B stage. More power gain could be secured in the 35T stage, thus requiring less gain in the 45 driver stage, and therefore the class B input transformer could have a greater stepdown ratio than in the case of a circuit design in which no leeway in voltage and power gain is provided for.

Modulators

A *modulator* supplies audio power to the particular r.f. stage in the transmitter which is being modulated. A speech amplifier does not deliver sufficient power output for modulating a conventional form of r.f. stage delivering more than a very few watts power. The modulator is an audio amplifier which delivers ample power output for completely modulating the d.c. input to the modulated stage. Power requirements of audio amplifiers vary from a fraction of a watt up to 500 watts, for amateur purposes. Low-power transmitters of the grid-modulated or suppressor-grid-modulated types require less than one watt of audio power, whereas a 1-kw. plate-modulated phone transmitter requires 500 watts of audio power for 100% sine-wave modulation.

Class A amplifiers are suitable for low-power grid-modulated, or suppressor-modulated phone transmitters; class AB audio amplifiers for high-power grid-modulated or for low-power plate-modulated phones, and class B audio amplifiers for most economical operation of transmitters in which the audio requirements are greater than about 50 watts. Class AB or class B modulators require a *driver* stage, which can be considered part of the modulating system proper rather than part of the speech amplifier. The complete modulator essentially consists of a device for converting speech-amplifier output *voltage* into audio *power*.

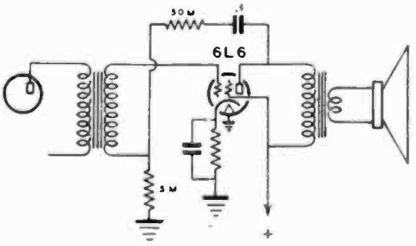
Complete information on receiver and transmitter type tubes for modulator service, as well as for any other portion of a radiotelephone transmitter, will be found in chapters *Five* and *Nine*.

DEGENERATIVE FEEDBACK

A system of taking energy from the output of an amplifier or transmitter and feeding it back into the input circuit 180° out of phase with the incoming voltage has come into quite wide usage in recent years. Inverse feedback or degeneration, as it is called, allows greatly improved operation of audio amplifiers and radiophone transmitters to be obtained. It has been found that the proper application of degeneration in an amplifier can be made to reduce greatly the harmonic distortion and otherwise to improve the fidelity. The inclusion of inverse feedback causes a reduction in the gain of an amplifier which can be offset by the addition of a stage of speech amplification. The disadvantage of the additional stage of amplification is far more than compensated for by the reduction in three kinds of distortion commonly known as frequency distortion (change in gain with respect to frequency), harmonic distortion, and delay or phase distortion.

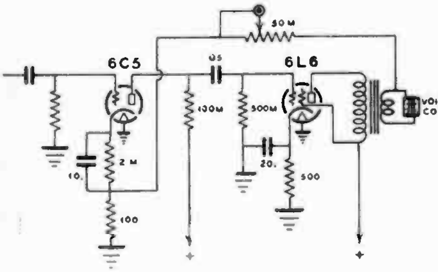
The Inverse Feedback Principle

The principle involved in inverse feedback systems is to select a portion of the amplifier output voltage and feed it back into one of the previous circuits, exactly out of phase with the input voltage. In figure 23, a simple method of applying inverse feedback to an audio amplifier is shown. With the values of resistance as indicated, the reverse feedback is approximately 10 per cent. This reduces the gain of the audio amplifier; however, it still has approximately twice the sensitivity of a triode amplifier with similar plate circuit characteristics. The plate circuit impedance of the 6L6 is greatly



INVERSE FEEDBACK FOR SINGLE STAGE AMPLIFIER

Figure 23.



INVERSE FEEDBACK FOR 2 STAGE AMPLIFIER
Figure 24.

reduced, an advantage when working into a loudspeaker (because a loudspeaker is not a constant impedance device).

Inverse feedback can be applied in a somewhat different manner, as shown in figure 24, for a two-stage amplifier. This method is particularly desirable, in that feedback produces better results when the feed-back circuit is connected from the output back to the grid of one of the *preceding* amplifier stages.

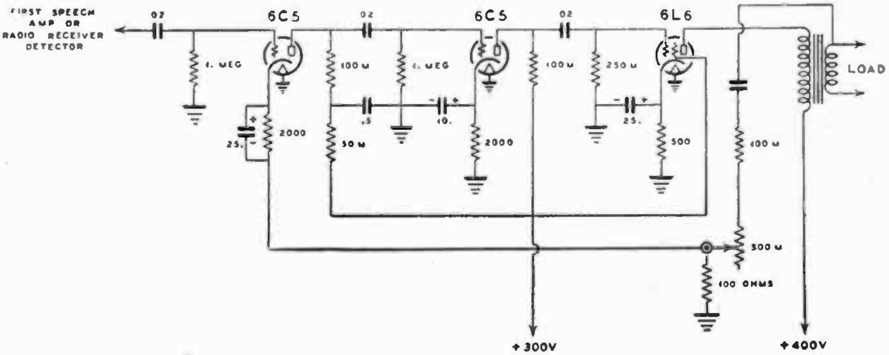
The polarity of the secondary winding of the output transformer, in all cases where the feed-back connection is made to the secondary, should be that which will produce degeneration and reduction in amplifier gain, rather than regeneration and howl or increase of gain.

The circuits in figures 25 and 26 indicate methods for applying inverse feedback to three stages of amplification. These two systems are suitable for operation as speech amplifiers and modulators for grid-modulated radio-telephones, or low-power plate-modulated transmitters. The 100-ohm cathode resistor should be located as near as possible to the 6C5 tube cathode terminal in order to prevent undesirable pickup and feedback at frequencies other than those desired.

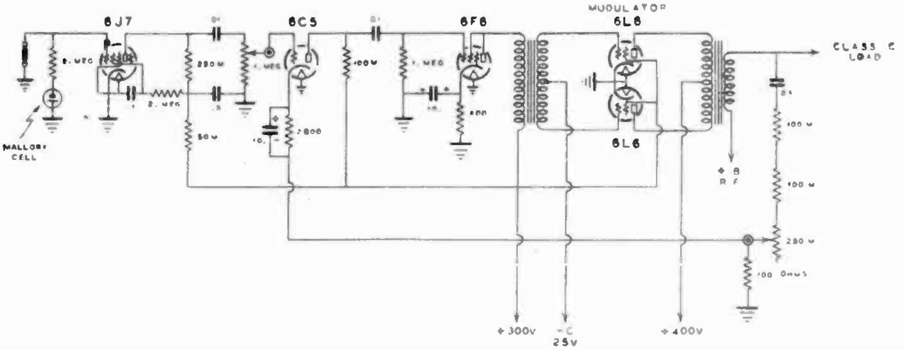
R. F. Inverse Feedback

Modulation distortion, noises and hum level which are present on the carrier of a radiotelephone station can be reduced by inverse feedback applied as in many broadcast transmitters, but modified for amateur applications. The method consists of rectifying a small amount of the carrier signal and feeding back the audio component in reverse phase into some part of the speech amplifier. This arrangement will reduce the hum level and improve the voice quality of most amateur radiotelephone transmitters.

The amount of inverse feedback that can be applied in this manner will depend upon the available amount of excess speech amplification and the degree to which it can be carried without oscillation. The process of inverse feedback is to utilize voltages 180° out of phase over the band of frequencies of operation. Sometimes the feed-back voltage may be considerably less than 180° out of phase for frequencies outside of the voice range, resulting in oscillation above the



DEGENERATIVE FEEDBACK AMPLIFIER
Figure 25.



DEGENERATIVE FEEDBACK AMPLIFIER

Figure 26.

audible range, and the amount of feedback which can be applied is limited by this effect.

Two inverse feedback rectifier circuits are shown in figures 27 and 28.

Figure 27 is a simple diode rectifier which incorporates a phase-reversing switch which must be thrown to that position which will cause a slight reduction in speech amplifier gain. The actual gain of the speech amplifier can be increased by means of the manual gain control. The undesired noise or hum which is audible in the phone monitor will generally be reduced with the correct adjustment of the r.f. pickup coil and phase-reversing switch. Once adjusted, no additional changes are necessary unless the transmitter power output or frequency is varied.

In figure 28, a type 84 rectifier tube is connected so that one side serves as an inverse feed-back rectifier, and the other side is a standard overmodulation indicator and phone monitor.

The circuits in figures 29 and 30 show methods of connection from the feedback rectifier in to the speech amplifier.

The Diode Feedback Rectifier

The diode feedback rectifier rectifies the carrier, and any hum or noise modulation on the carrier appears as an audio voltage across the 100,000-ohm feedback control to the grid of the speech amplifier. A portion of this voltage is fed back into the speech amplifier so as to be out of phase, and thus buck out the hum or noise in the output of the radio transmitter. This may actually introduce distortion in a portion of the speech amplifier in which there is otherwise none present (commonly spoken of as being within the feedback "loop") but the final result is that the distortion or hum is cancelled out in the carrier signal of the radiotelephone transmitter. This system may be appiled to transmitters which use

Figure 27.

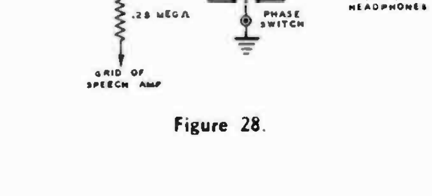


Figure 28.

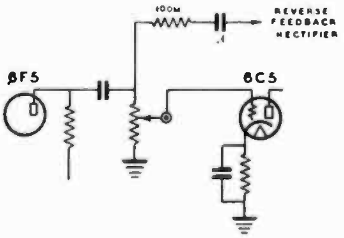


Figure 29.

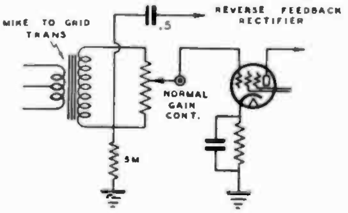


Figure 30.

plate, suppressor or control grid modulation. It is especially suited to transmitters employing grid modulation.

Automatic Modulation Control and Automatic Peak Limiting

It is possible to increase the average modulation level without danger of overmodulation by designing the speech amplifier to have a nonlinear amplification above a threshold value corresponding to approximately 80 per cent modulation. In other words, the gain of the amplifier is constant until a signal is impressed upon it that would ordinarily modulate the transmitter over 80 per cent; then the gain of the amplifier goes down rapidly as the input signal is increased.

To increase the modulation percentage in a conventional transmitter from 80 per cent to 100 per cent requires an increase in the input signal of 2 db. Broadcast stations commonly employ a compressor or peak limiter which requires 5 db increase in the audio input voltage to the amplifier in order to raise the modulation from 80 to 100 per cent. This gives 3 db compression and permits running of the gain control, without danger of overmodulation, at a setting 3 db higher than would otherwise be possible. This is equivalent to doubling the transmitter power.

Somewhat more than 3 db compression can be employed in a voice transmitter designed for communication work, but an attempt to incorporate too much compression will result in distortion so great as to affect the intelligibility.

Automatic modulation control is similar to a peak-limiting audio amplifier in effect, though the method of accomplishing the compression is somewhat different. In the a.m.c. system the output of the modulator itself is used to actuate the compression circuit, and it is somewhat more positive in action and easier to adjust. The chief disadvantage of the latter system is that it can be used only with plate modulation, while a peak-limiting a.f. amplifier can be used with either plate modulation or any type of grid modulation.

Practical application of peak-limiting and a.m.c. systems will be found in the chapter, *Speech and Modulation Equipment.*

NINE

Transmitting Tubes

SOME of the necessary information for determining the operating conditions of transmitter vacuum tubes is not generally found in technical bulletins which are supplied by tube manufacturers. For this reason it was necessary to compute certain of these data in RADIO's laboratory; the findings are included along with the manufacturer's specifications in the pages which follow.

The typical operating conditions for class-B audio amplifiers or modulators and for r.f. amplifier service, are included for many popular tubes. From this data the reader can tell at a glance what type of driver stage is needed, what the power supply requirements must be, the approximate output that can be expected and how the tube constants vary under certain operating conditions.

The ratings in the *Tube Tables* are for *safe values* of plate voltage and current. Amateurs who operate their transmitters at higher than normal tube ratings, without exceeding the actual plate dissipation ratings of the tubes, should remember that this condition of operation sometimes can be tolerated for *c.w. telegraphy only,* and with consequent increase in the required grid driving power, so that the tube can be operated over a lesser angle of plate current flow during each r.f. cycle. The d.c. grid current never should exceed the maximum rated value, yet the grid bias voltage may be increased to such an extent that from two to four times as much grid driving power is applied to the grid (or grids) of the tube (or tubes) in the final amplifier stage. This practice results in greater *plate efficiency* (within limits), but with a sacrifice in *power gain.*

In extreme cases, 200 watts of grid driving power would be required to obtain 600 watts of antenna power from the final r.f. amplifier stage. Thus, it can be seen that the foregoing does not represent economy in design; for this reason the *Tube Tables* in this *chapter* in general are based on a power gain of approximately 10, with plate efficiencies of from 66 per cent to 75 per cent. Radiation of harmonics will not be so troublesome when the class-C amplifier operates in this range of efficiencies, particularly when the C-to-L ratio of the tank circuit is chosen correctly.

The values of *grid driving power* shown in the *Tables* are those actually used by the grid of the tube plus the power loss in the C-bias supply or grid leak. Circuit losses should be given consideration when designing buffer or amplifier stages for all-band operation. The tuned circuit losses are appreciably higher in the 10- and 20-meter bands than for operation at 80- or 160-meters. These circuit losses cannot be given in a tube table; only the actual grid driving power can be listed. The driving stage should be capable of supplying some excess of power to compensate for circuit losses, especially at the higher frequencies.

The actual power required to drive a tube for class-C r.f. use (neglecting tank circuit losses) can be determined with quite good accuracy by multiplying the d.c. grid current (average) by the *peak* r.f. exciting voltage. The method of calculating the exact amount of power required is rather involved, but fortunately this simple empirical formula gives results sufficiently accurate for most purposes.

THE TUBE TABLES

With the exception of small receiver-type tubes, all tubes for transmitter, modulator and audio application are listed in the tables by manufacturer and type number. Frequency range, interelectrode capacities, grid driving power, power output and average operating conditions are given. Power output and grid driving power requirements are given for average conditions where class-C amplifiers operate at an angle between 120° and 140°. The class-C plate efficiency will be between 66 per cent and 75 per cent under these conditions. Greater output and higher efficiency sometimes can be secured when more grid drive is available. The amplification factor (μ) determines the value of d.c. grid bias needed for the particular type of amplifie circuit in which the tube operates.

*Asterisk Explanation

Types marked with an asterisk are especially recommended by the editors to amateurs designing new equipment. The tubes thus indicated offer the best performance per dollar and are somewhat better suited to the purposes for which they were designed than are older or more costly tubes of similar power output.

Cross Index To Transmitting Tubes

PLATE DISSIPATION RATING—IN WATTS (Manufacturer's Rating)	TRANSMITTING VACUUM TUBE TYPES
8	Raytheon RK-23, RK-25, RK-44, RK-45 pentodes, RK-56 beam tetrode.
10	Raytheon RK-34 twin triode; RCA 802 pentode.
12	RCA 10 (210), 842, 1602 triodes, 837 pentode.
15	Hytron HY-60 triode; Raytheon RK-59 twin triode; RCA 841, 843 triodes, 865 tetrode, 6L6 (G), 1619, 1624 beam tetrodes, 844 pentode; Western Electric WE-307A pentode.
20	Amperex 801 triode; RCA 801, 1608 triodes; Taylor T-20, TZ-20 triodes; United 310 triode.
21	Raytheon, RK-39, RK-41 beam tetrodes; RCA 807 beam tetrode; Taylor T-21 beam tetrode.
25	Heintz & Kaufman 24 triode; Hytron 6L6-GX beam tetrode, HY-25 triode, HY-61 beam tetrode; Raytheon RK-11, RK-12 triodes; RCA 809 triode; Western Electric WE-254B tetrode.
30	Western Electric WE-316A triode.
35	Eimac 35-T triode; Raytheon RK-30, RK-35, RK-37 triodes; RCA 800 triode.
40	Amperex 830 triode, Hytron HY-40 (Z), HY-57 triodes; Raytheon RK-18, RK-20, RK-31 triodes, RK-46 pentode; RCA 804 pentode; Taylor T-40, TZ-40, 756, 825 triodes; United 930 triode; Western Electric WE-300A (a.f. only) triode.
50	Heintz & Kaufman HK-54, HK-154 triodes; Raytheon RK-32 triode, RK-47 beam tetrode; RCA 808 triode, 814 beam tetrode, 834 triode; Taylor 841A triode; Western Electric 304B, WE-356A triode.

Cross Index to Transmitting Tubes, Continued

PLATE DISSIPATION RATING— IN WATTS (Manufacturer's Rating)	TRANSMITTING VACUUM TUBE TYPES
55	Taylor T-55, 203 B; RCA 811, 812 triodes.
60	Amperex 830B triode; Raytheon RK-51 triode; RCA 830B triode; United 930B triode; Western Electric WE-305A tetrode.
62.5	Raytheon RK-52 triode.
65	Hytron HY-51A (B, Z) triodes; Taylor 203-Z triode
70	Western Electric WE-282A tetrode.
75	Amperex HF-100, ZB-120 triodes; Eimac 75-T triode; Heintz & Kaufman HK-55 Gridless Gammatron.
85	Western Electric WE-242A triode
100	Amperex 211C, 849, 851, 852 triodes; Eimac 100-TL (TH) triodes; Heintz & Kaufman HK-254 triode; Raytheon RK-28 (A) tetrodes; RK-36, RK-38 triodes; RK-48 beam tetrode; RCA 203A, 211, 838, 845, 852 triodes; 813, 850, 860 tetrodes; United 211C, 849, 851, 852 triodes.
120	Amperex 203H, 211H triodes.
125	RCA 803 pentode, 805, 810 triodes; Taylor T-125 triode.
150	Amperex HF-200 triode; Heintz & Kaufman HK-155 Gridless Gammatron, HK-354 (C, D, E & F) triodes; RCA 806 triode; Taylor HD-203A (C), HD-211C, TW-150 triodes.
155	Taylor T-155 triode.
200	Amperex HF-300 triode; Taylor T-200, 814, (not same as RCA 814), 822 triodes.
250	Eimac 250-TL (TH) triodes; Heintz & Kaufman HK-255 Gridless Gammatron; RCA 204A triode.
275	Western Electric WE-212E triode.
300	Heintz & Kaufman HK-654 triode; RCA 833 triode.
350	Western Electric WE-270A, WE-357A triodes.
400	Amperex 831 triode; RCA 831 triode, 849 triode, 861 tetrode.
450	Eimac 450-TL (TH) triodes.
500	Heintz & Kaufman HK-255 Gridless Gammatron.
600	RCA 887, 888 triodes.
750	Eimac 750-TL (TH) triodes; Heintz & Kaufman HK-1554 triode; RCA 851 triode.
1000	Western Electric WE-251A triode.
1200	Western Electric WE-279A triode.
1500	Eimac 1500-T triode; Heintz & Kaufman HK-3054 triode.
2000	Eimac 2000-T triode.

AMPEREX

HF-100*

AMPEREX triode. H.f. and u.h.f. frequency doubler, amplifier or oscillator down to 2 meters in wavelength. Class-B modulator, though superseded by ZB120 for this purpose.

CHARACTERISTICS:

Filament Voltage	10 to 10.5 volts
Filament Current	2 amps.
Amplification Factor	23
Grid-to-Plate Capacitance	4.5 μμfds.
Grid-to-Filament Capacitance	3.5 μμfds.
Plate-to-Filament Capacitance	1.4 μμfds.
Maximum Plate Dissipation	75 watts
Maximum D.C. Plate Voltage	1500 volts
Maximum D.C. Plate Current	150 ma.
Maximum D.C. Grid Current	30 ma.
Base	UX 4-pin

Plate Out Top, Grid Out Side of Envelope. Carbon plate.

CLASS-C R.F. Service:	30 Mc. or Lower	120 Mc.
D.C. Plate Voltage	1500	1000 volts
D.C. Grid Voltage	—200	—110 volts
D.C. Plate Current	150	120 ma.
D.C. Grid Current	20	20 ma.
Grid Drive (Approx.)	7	6 watts
Grid Bias Loss	4	2.2 watts
Power Output (Approx.)	170	70 watts
Maximum Plate Dissipation	75	50 watts

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ZB-120*

AMPEREX Zero bias triode. Especially designed for class-B audio amplification. Can be used as linear r.f. power amplifier. Is capable of delivering up to 150 watts in class-C r.f. service. Its high amplification factor makes it an efficient frequency doubler.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	2 amps.
Amplification Factor	90
Maximum Plate Dissipation	75 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum A.F. Power Output (2 Tubes)	300 watts
Transconductance at 100 ma. Plate Current	5000 μmhos
Base	Standard 50-watt. Plate: Carbon

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HF-200*

AMPEREX general purpose high-frequency triode. Suitable for u.h.f. oscillators.

Note: Grid excitation requirements vary greatly due to plate load, efficiency required and circuit design.

Frequency Range: 100% ratings up to 45 Mc.

CHARACTERISTICS:

Filament Voltage	10 to 11 volts
Filament Current	3.4 amps.
Amplification Factor	18
Grid-to-Plate Capacitance	5.8 μμfds.
Grid-to-Filament Capacitance	5.2 μμfds.
Plate-to-Filament Capacitance	1.2 μμfds.
Maximum Plate Dissipation	150 watts
Maximum D.C. Plate Voltage	2000 volts
Maximum D.C. Plate Current	200 ma.
Maximum D.C. Grid Current	60 ma.
Base	Standard 4-pin. 50-watt

Plate at top, grid at side of envelope.

CLASS-C R.F. AMPLIFIER:		
D.C. Plate Voltage	1500	2000 volts
D.C. Grid Voltage	—210	—300 volts
D.C. Plate Current	200	200 ma.
D.C. Grid Current	35	35 ma.
Grid Driving Power	13	19 watts
Grid Bias Loss	7.5	10 watts
Power Input	300	400 watts
Power Output	180	260 watts

203H

AMPEREX r.f. amplifier or oscillator, especially useful at high frequencies.

Note (1): The grid r.f. excitation requirements vary with efficiency, plate load and circuit design; thus, the driver must be designed to allow for these factors.

(2): The plate lead is through the top of the tube; thus, it will stand higher plate voltages and operate more efficiently at higher frequencies than a regular type 203-A.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Grid-to-Plate Capacitance	9 μμfds.
Grid-to-Filament Capacitance	6 μμfds.
Plate-to-Filament Capacitance	1.8 μμfds.
Maximum Plate Dissipation	120 watts
Maximum D.C. Plate Voltage	1500 volts
Maximum D.C. Plate Current	180 ma.
Maximum D.C. Grid Current	50 ma.
Amplification Factor	25
Base	Standard 50-watt

CLASS-C AMPLIFIER	At 60 Mc.	Less Than 20 Mc.
D.C. Plate Voltage	1200	1500 volts
D.C. Grid Voltage	—150	—180 volts
D.C. Plate Current	175	175 ma.
D.C. Grid Current	40	40 ma.
Grid Driving Power	14	17 watts
Grid Bias Loss	6	7.3 watts
Power Input	210	263 watts
Power Output (Approx.)	100	180 watts

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211H

AMPEREX r.f. amplifier for radio transmitters.

Note (1): The grid input and plate output powers will vary greatly with different values of load impedance and frequency. The values listed are typical operating conditions.

(2): At high frequencies, circuit and dielectric losses increase and thus the grid driver should have available approximately twice as much output as shown in the table below for grid drive.

(3): This tube has the plate lead out through the top of the envelope and thus it will operate more efficiently at higher frequencies than a standard type 211 tube.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Grid-to-Plate Capacitance	8.0 μμfds.
Grid-to-Filament Capacitance	5.5 μμfds.
Plate-to-Filament Capacitance	2.0 μμfds.
Amplification Factor	12
Mutual Conductance at 100 ma. I_b	4000 micromhos
Maximum Allowable Plate Dissipation	120 watts
Base	Standard 4-pin, 50-watt

CLASS-C AMPLIFIER	Single Tube at 60 Mc.	Less Than 20 Mc.	Telegraphy
D.C. Plate Voltage	1200*	1500*	2000 volts
D.C. Plate Current	175	175	180 ma.
D.C. Grid Bias	—200	—300	—300
D.C. Grid Current	30	30	50 ma.
Grid Driving Power (Approx.)	11	14	20 watts
Grid Bias Supply Loss	6	9	15 watts
Power Output (Approx.)	100	190	250 watts
Power Input	216	263	360 watts
Plate Loss	116	73	110 watts
Approx. A.C. Load Imped.	3500	4300	5500 ohms
Modulator D.C. Load	6850	8500	11,100 ohms

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* Maximum.

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HF-300*

AMPEREX general purpose triode for high-frequency and u.h.f. amplifiers or oscillators.

Note: Grid excitation requirements vary greatly due to circuit design, plate load, and required efficiency.

Frequency Range: 100% ratings up to 45 Mc.

CHARACTERISTICS:

Filament Voltage	11 to 12 volts
Filament Current	4 amps.
Amplification Factor	23
Grid-to-Plate Capacitance	6.5 μμfds.
Grid-to-Filament Capacitance	6.0 μμfds.
Plate-to-Filament Capacitance	1.4 μμfds.
Maximum Plate Dissipation	200 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D.C. Plate Current	275 ma.
Maximum D.C. Grid Current	75 ma.
Base	Standard 4-Pin 50-Watt Plate through top, grid through side of envelope.

CLASS-C R.F. AMPLIFIER

D.C. Plate Voltage	1500	2500	volts
D.C. Grid Voltage	—200	—300	volts
D.C. Plate Current	275	275	ma.
D.C. Grid Current	60	60	ma.
Grid Driving Power	27	33	watts
Grid Bias Loss	12	18	watts
Power Input	420	700	watts
Power Output	260	500	watts

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930

UNITED ELECTRONICS triode. Amperex (830). Oscillator, modulator, r.f. amplifier, generally as a neutralized r.f. amplifier or buffer stage in high-frequency transmitters.

Note: Intermediate between 211 and 210 or 801 in operation.

Frequency Range: 100% ratings up to 6 Mc.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	2 amps.
Amplification Factor	8
Grid-to-Plate Capacitance	9.9 μμfds.
Grid-to-Filament Capacitance	4.9 μμfds.
Plate-to-Filament Capacitance	2.2 μμfds.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	750 volts
Maximum D.C. Plate Current	110 ma.
Maximum D.C. Grid Current	18 ma.
Base	UX 4-pin

R.F. SERVICE:	Class-B Telephony	Class-C Plate-Mod. Telephony	Class-C Telegraphy	
D.C. Plate Voltage	750	600	750	max. v.
D.C. Grid Voltage	—95	—180	—180	volts
D.C. Plate Current	80	100	110	ma.
D.C. Grid Current	...	15	15	ma.
Grid Driving Power	...	5	5	watts
Grid Bias Loss	...	2.7	2.7	watts
Power Input	60	60	82.5	watts
Power Output	20	40	55	watts

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EIMAC

35-T*

EIMAC high-mu triode. Crystal oscillator for plate voltages up to 1200 volts. Class-B modulator or a.f. amplifier. Class-C buffer or doubler. Class-C telephony. U.h.f. oscillators with quarter-wave line frequency control. U.h.f. r.f. amplifiers.

Frequency Range: 100% ratings up to 100 Mc.

Note (1): For plate modulation, the values of grid bias should be increased at least 50%, and the grid drive will be approximately doubled.

Note: (2): Values of grid bias and grid drive may be reduced with regenerative doubler circuits. The above values are for values of efficiencies between 58% and 68%. Lower grid bias and drive give lower efficiencies. With regeneration, the bias may be reduced to approximately ⅓ of the above values without loss of output. The bias should never be less than 3½ times cutoff bias when doubling.

CHARACTERISTICS:

Filament Voltage	5 to 5¼ volts
Filament Current	4 amps.
Amplification Factor (Average)	30
Maximum Normal Plate Dissipation	35 watts
Grid-to-Plate Capacitance	1.9 μμfds.
Maximum D.C. Plate Voltage	1500 volts
Maximum D.C. Plate Current	150 ma.
Maximum D.C. Grid Current	25 ma.
Base	UX 4-pin. Plate at top of envelope.

CLASS-B AUDIO AMPLIFIER (2 Tubes):

D.C. Plate Voltage	500	750	1000	1250	1500	volts
D.C. Grid Voltage	0	—10	—22.5	—40	—50	volts
Zero Signal D.C. Plate Current	65	50	40	20	16	ma.
Maximum Signal D.C. Plate Current	200	200	188	158	140	ma.
Load Resistance (Plate to Plate)	4000	7000	11000	17200	23600	ohms
Driving Power	6.5	8.5	7.5	5.5	4.5	watts
Output Power	50	90	120	130	140	watts

CLASS-C R.F. AMPLIFIER TELEGRAPHY (Buffer Service):

D.C. Plate Voltage	400	750	1000	1500	volts
D.C. Grid Voltage	—20	—38	—50	—100	volts
D.C. Plate Current	90	90	90	90	ma.
D.C. Grid Current	15	18	20	20	ma.
Grid Driving Power (Approx.)	2	3.0	3.5	4.5	watts
Grid Bias Loss	.3	.7	1	2	watts
Power Input	36	67.5	90	135	watts
Power Output (Approx.)	20	47.5	62	101	watts
A.C. Load Resistance	1700	3500	5200	8400	ohms

FREQUENCY DOUBLER (Without Regeneration):

D.C. Plate Voltage	750	1250	1500	volts
D.C. Grid Voltage	—445	—502	—530	volts
D.C. Plate Current	87	85	87	ma.
D.C. Grid Current	10	10	10	ma.
Grid Driving Power	5	6.5	6.8	watts
Grid Bias Loss	4.5	5	5.3	watts
Power Input	65	106	130	watts
Power Output	37.5	72	90	watts
A.C. Load Resistance	4000	7600	9500	ohms

REGENERATIVE FREQUENCY DOUBLER:

D.C. Plate Voltage	750	1000	volts
D.C. Grid Voltage	—90	—150	volts
D.C. Plate Current	100	80	ma.
D.C. Grid Current	20	20	ma.
Grid Driving Power	4.5	5.5	watts
Grid Bias Loss	1.8	3	watts
Power Input	75	80	watts
Power Output (Approx.)	40	50	watts

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75-T*

Low capacity triode designed for high output at moderate plate voltages. Modulator, class B. Class C buffer or doubler. Class C telegraphy or telephony amplifier. U.h.f. oscillator or r.f. amplifier.

CHARACTERISTICS:

Filament Voltage	5 volts
Filament Current	6.5 Amperes
Amplification Factor	10.6
Grid-Plate Capacity	2.3 μμfds.
Grid-Filament Capacity	2.2 μμfds.
Maximum Plate Current	175 milliamperes
Plate Dissipation	75 watts

Tube must be operated vertically with ample ventilation provided. Seals should be cooled by Radiator Connectors.

MAXIMUM RATINGS:	Intermittent Service Telegraphy Class "B" Audio	Continuous Service Class "C" Telephony
Grid Current (milliamperes)	30	30
Plate Current (milliamperes)	175	175
Plate Dissipation (watts)	75	75
Plate Voltage	3000	3000

As frequency is increased circuit inefficiencies may necessitate a reduction of plate voltage or plate current so that maximum dissipation ratings are not exceeded.

TYPICAL OPERATING CONDITIONS FOR CLASS "C" TELEPHONY AND TELEGRAPHY

Plate Volts	750	1000	1500
Plate Current (milliamperes)	135	175	175
Grid Current (milliamperes)	30	30	30
Grid Bias (volts)	—150	—200	—300

Power Output (watts)	70	125	200

Excitation power roughly 1/10 the input power.

CLASS "B" AUDIO

Plate Voltage	Recommended Plate to Plate Impedance	Power Output
2000	12,500 ohms	400 watts
1500	10,000 ohms	300 watts
1250	9,000 ohms	250 watts
1000	6,800 ohms	200 watts
750	6,000 ohms	100 watts

Plate is designed to operate at a cherry-red color on its normal dissipation rating of 75 watts. A perceptible red color is noted at 25 watts. These temperatures are perfectly permissible and no damage will result from such operation.

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100TL*

EIMAC u.h.f. triode with medium amplification factor. Designed primarily for diathermy service and as replacement for original Eimac 50T.

CHARACTERISTICS:

Filament Voltage	5 to 5.1 volts
Filament Current	6.5 amps.
Grid-to-Plate Capacitance	2.3 μμfds.
Grid-to-Filament Capacitance	2.0 μμfds.
Plate-to-Filament Capacitance	0.4 μμfd.
Normal Plate Dissipation	100 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	225 ma.
Maximum D.C. Grid Current	35 ma.
Amplification Factor	12
Base	Standard UX 4-pin

Plate through top, grid through side of envelope.

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	1000	2000	3000	volts
D.C. Plate Current	200	150	135	ma.
D.C. Grid Current	30	30	30	ma.
D.C. Grid Bias	—200	—400	—600	volts
Power Output	120	225	300	watts
Approx. Grid Driving Power	7.5	13.5	21	watts
Grid Bias Loss	6	12	18	watts

CLASS-B AUDIO AMPLIFIER:

D.C. Plate Voltage	1000	2000	3000	volts
Load Impedance (Plate-to-Plate)	5200	16000	30000	ohms
Power Output, 2 Tubes	170	350	465	watts

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100TH*

EIMAC high-mu u.h.f triode. Especially suitable for class C r.f amplification and class B audio service.

CHARACTERISTICS:

Filament Voltage	5 to 5.1 volts
Filament Current	6.5 amps.
Amplification Factor	30
Grid-to-Plate Capacitance	2 μμfds.
Grid-to-Filament Capacitance	2.2 μμfds.
Plate-to-Filament Capacitance	0.3 μμfd.
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	225 ma.
Maximum D.C. Grid Current	50 ma.
Normal Plate Dissipation	100 watts
Base	Standard UX 4-pin, Isolantite

Plate through top, grid through side of envelope.

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	1000	2000	3000	volts
D.C. Plate Current	200	150	135	ma.
D.C. Grid Current	45	45	45	ma.
D.C. Grid Bias	—70	—140	—210	volts
Approx. Grid Driving Power	4.5	8	10	watts
Grid Bias Loss	3.2	6.3	9.5	watts
Approximate Power Output	120	225	300	watts

CLASS-B AUDIO AMPLIFIER:

D.C. Plate Voltage	1000	2000	3000	volts
Load Impedance (Plate-to-Plate)	5200	16000	30000	ohms
Power Output, (2 Tubes)	210	380	500	watts

250TL*

EIMAC. u.h.f. triode with medium amplification factor. Designed for diathermy service and for replacement of older type Eimac 150-T.

CHARACTERISTICS:

Filament Voltage	5 to 5.1 volts
Filament Current	10.5 amps.
Amplification Factor	13
Grid-to-Plate Capacitance	3.5 μμfds.
Grid-to-Filament Capacitance	3.0 μμfds.
Plate-to-Filament Capacitance	0.5 μμfd.
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	50 ma.
Normal Plate Dissipation	250 watts
Base	Standard 50-watt

Plate through top, grid through side of envelope.

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	1000	2000	3000	volts
D.C. Plate Current	300	350	330	ma.
D.C. Grid Current	45	45	45	ma.
D.C. Grid Bias	—200	—400	—600	volts
Approx. Grid Driving Power	11	22	33	watts
Grid Bias Loss	9	18	27	watts
Approximate Power Output	200	500	750	watts

CLASS-B AUDIO AMPLIFIER:

D.C. Plate Voltage	1250	2000	3000	volts
Load Impedance, (Plate-to-Plate)	3280	6000	12400	ohms
Power Output (2 Tubes)	540	900	1180	watts

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250TH*

EIMAC, high-mu u.h.f. triode. Designed primarily for r.f. amplification and class-B audio service.

CHARACTERISTICS:

Filament Voltage	5 to 5.1 volts
Filament Current	10.5 amps.
Amplification Factor	32
Grid-to-Plate Capacitance	3.3 μμfds.
Grid-to-Filament Capacitance	3.5 μμfds.
Plate-to-Filament Capacitance	0.3 μμfd.
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	65 ma.
Normal Plate Dissipation	250 watts
Base	Standard 50-watt

Grid through side, plate through top of envelope.

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	1000	2000	3000	volts
D.C. Plate Current	300	350	330	ma.
D.C. Grid Current	55	55	55	ma.
D.C. Grid Bias	—70	—140	—210	volts
Approx. Grid Driving Power	8	16	25	watts
Grid Bias Loss	3.9	7.7	11.6	watts
Approximate Power Output	200	500	750	watts

CLASS-B AUDIO AMPLIFIER:

D.C. Plate Voltage	1000	1500	3000	volts
Load Imped. (Plate-to-Plate)	2360	4200	12400	ohms
Power Output (2 Tubes)	350	630	1180	watts

Grid Bias: Zero for plate potentials up to 1400 volts.

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450TL*
450TH*

EIMAC high-power triodes. the 450TH has an amplification factor of 32; the 450TL has an amplification factor of 16. These tubes are especially designed for broadcast and commercial transmitters. Tantalum plates and grids.

Filament Voltage	7.5 volts
Filament Current	12 amps.
Maximum D.C. Plate Current	500 ma.
D.C. Plate Voltage	4000 volts
Normal Plate Dissipation	450 watts
Grid-to-Plate Capacitance	4.5 μμfds.
Base	Standard 50-watt type

Plate out through top and grid through side of glass envelope.

750-TH
750-TL

EIMAC general-purpose triodes. Tantalum grid and plate, low interelectrode capacitances and heavy leads permitting satisfactory operation at high frequencies. Used primarily in broadcast, experimental and commercial transmitters.

CHARACTERISTICS:

Filament Voltage (A.C.)	7.5 to 7.7 volts
Filament Current (Approx.)	21 amps.
Amplification Factor 750-TH	30
Amplification Factor 750-TL	13.5
Grid-to-Plate Capacitance	4.5 μμfds.
Grid-to-Filament Capacitance	6.0 μμfds.
Plate-to-Filament Capacitance	0.8 μμfd.
Base	special
Overall Height	16½ inches
Maximum Diameter	7 inches

Tube must be operated vertically with ample ventilation provided.

MAXIMUM RATINGS BELOW 40 MEGACYCLES:

Plate Voltage	6000 volts
Plate Current	1000 ma.
Grid Current (D.C.) 750-TH	175 ma.
Grid Current (D.C.) 750-TL	125 ma.
Normal Plate Dissipation	750 watts

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1500-T

The 1500-T must be cooled by a draft of air such as is provided by a fan or blower. Provision has been made so that the seals can be cooled by a draft of air such as that provided by a small dental blower. Such cooling must be used above 20 Mc. On the lower frequencies a large radiator-connector having cooling fins similar to cylinder design for air-cooled gas engines will provide adequate seal cooling.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	26.0 amps.
Amplification Factor	18.5
Grid-Plate Capacity	7.0 μμfds.
Grid-Filament Capacity	10.0 μμfds.
Filament-Plate Capacity	0.9 μμfd.
Bulb	Nonex GT 56
Base	Special
Overall Height	16.5 inches
Maximum Diameter	7.0 inches

MAXIMUM RATINGS:

D.C. Plate Voltage	6000 volts
D.C. Plate Current	1.25 amperes
D.C. Grid Current	175 ma.
Plate Dissipation	1500 watts

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2000-T

The 2000-T must be cooled by a draft of air such as is provided by a fan or blower. See discussion under type 1500-T.

CHARACTERISTICS:

Filament Voltage	10.0 volts
Filament Current	26.0 amperes
Amplification Factor	18.5
Grid-Plate Capacity	9.0 μμfds.
Grid-Filament Capacity	13.0 μμfds.
Filament-Plate Capacity	1.0 μμfds.
Bulb	Pyrex GT 64
Base	Special
Overall Height	17.5 inches
Maximum Diameter	8.0 inches

MAXIMUM RATINGS:

D.C. Plate Voltage	6000 volts
D.C. Plate Current	1.75 amperes
Grid Current	200 ma.
Plate Dissipation	2000 watts

HEINTZ and KAUFMAN

HK-24 *

HEINTZ AND KAUFMAN general purpose triode, especially suited to u.h.f. applications. Very low interelectrode capacities and short electron transit time.

CHARACTERISTICS:

Plate Dissipation	25 watts
Amplification Factor	25
Filament Voltage	6.3 volts
Filament Current	3.0 amps.

INTERELECTRODE CAPACITIES:

Grid—Plate	1.7 μμfd.
Grid—Filament	2.5 μμfd.
Plate—Filament	0.4 μμfd.

PHYSICAL DATA:

Plate	Cylindrical Tantalum
Grid	Vertical Bar Tantalum
Filament	Thoriated Tungsten
Base	Small, 4-pin Ceramic
Envelope	Nonex Glass

RADIO-FREQUENCY POWER AMPLIFIER CLASS "C" UNMODULATED:

	MAXIMUM RATING PER TUBE	TYPICAL OPERATION, 1 TUBE		
D.C. Plate Voltage	1500	1500	1250	1000 volts
D.C. Plate Current	75	75	75	75 ma.
D.C. Grid Current	30	20	20	20 ma.
D.C. Grid Voltage	—250	—120	—110	—100 volts
Peak R.F. Grid Voltage	..	240	230	220 volts
Grid Driving Power	..	3.8	3.7	3.6 watts
Plate Dissipation	25	25	21	18 watts
Plate Efficiency	..	80	78	76%
Power Output	..	90	73	57 watts

RADIO-FREQUENCY POWER AMPLIFIER CLASS "C" PLATE MODULATED:
(Carrier Conditions for use with 100% Modulation)

	MAXIMUM RATING PER TUBE	TYPICAL OPERATION, 1 TUBE		
D.C. Plate Voltage	1250	1250	1000	750 volts
D.C. Plate Current	60	60	60	60 ma.
D.C. Grid Current	30	30	30	30 ma.
D.C. Grid Voltage	—250	—125	—105	—90 volts
Peak R.F. Grid Voltage	..	230	210	190 volts
Grid Driving Power	..	6.2	5.7	5.1 watts
Plate Dissipation	17	15	13	11 watts
Plate Efficiency	..	80	78	75%
Power Output	..	60	47	34 watts

AUDIO FREQUENCY POWER AMPLIFIER— CLASS "B" MODULATOR:

	MAXIMUM RATING PER TUBE	TYPICAL OPERATION, 2 TUBES	
D.C. Plate Voltage	1500	1250	1000 volts
D.C. Plate Current— Maximum Signal	75	136	150 ma.
D.C. Plate Current— Zero Signal	..	24	30 ma.
D.C. Grid Voltage	—250	—42	—29 volts
Peak A.F. Grid Voltage	..	128	124 volts
Load Resistance— (Plate to Plate)	..	21200	15000 ohms
Plate Dissipation	25	50	45 watts
Plate Efficiency	..	70	69%
Driving Power— (Nominal)	..	4.2	4.5 watts
Power Output	..	120	105 watts

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HK-54*

HEINTZ & KAUFMAN general purpose high-mu triode for high-frequency service. Tantalum plate and grid. Standard 4-pin base, plate through top and grid through side of glass envelope.

CHARACTERISTICS:

Filament Voltage	5.0 volts
Filament Current	5.0 amps.
Amplification Factor	27
Grid-to-Plate Capacitance	1.9 μμfd.
Grid-to-Filament Capacitance	1.9 μμfd.
Plate-to-Filament Capacitance	0.3 μμfd.
Normal Plate Dissipation	50 watts
Max. D.C. Plate Voltage	2000 volts
Max. D.C. Plate Current	150 ma.
Max. D.C. Grid Current	30 ma.

CLASS-B AUDIO AMPLIFIER (TWO TUBES):

D.C. Plate Voltage	750	1000	1500 volts
D.C. Grid Voltage	—15	—25	—45 volts

Zero Sig. D.C. Plate Current	40	40	40	ma.
Max. Sig. D.C. Plate Current	226	233	200	ma.
Load Resistance (Plate-to-Plate)	6000	8500	16800	ohms
Power Output	95	140	200	watts

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	750	1250	2000	volts
D.C. Grid Voltage	—90	—140	—270	volts
D.C. Plate Current	135	135	130	ma.
D.C. Grid Current	20	20	20	ma.
Effective R.F. Grid Voltage	185	223	330	volts
Driving Power (Approx.)	5	6.5	9	watts
Power Output	70	125	210	watts

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HK55, HK155, HK255

HEINTZ & KAUFMAN Gridless Gammatrons.

CHARACTERISTICS:	TYPE 55	TYPE 155	TYPE 255	
Filament Voltage	6.0	5	14	volts
Filament Current	3	10	30	amps.
Normal Plate Dissipation	75	150	500	watts
Amplification Factor	3.5	2	3	
Maximum D.C. Plate Current	150	300	1000	ma.
Maximum D.C. Plate Voltage	1250	3000	5000	volts
Plate Impedance	1200	1100	1000	ohms

Unusual Features: Control element is a gamma plate of tantalum.

Filament is between regular plate and gamma plate.

Uses: Oscillators, audio and radio-frequency amplifiers. Nearly complete current variation may be secured without driving the control (gamma plate) element positive.

TYPE 255, INTERELECTRODE CAPACITANCES:

Gamma Plate to Power Plate	5 μμfds.
Filament to Gamma Plate	12 μμfds.
Filament to Power Plate	7 μμfds.

TYPE 255 CLASS-A AUDIO AMPLIFIER (SINGLE TUBE WITH NO GRID CURRENT):

D.C. Plate Voltage	1500	2000	2500	3000	volts
D.C. Grid Voltage	—350	—570	—800	—1000	volts
D.C. Plate Current	340	250	200	170	ma.
Load Resistance	5000	6000	8000	20000	ohms
Output Power	60	125	175	180	watts
Efficiency	12	25	35	36%	
Harmonic Distortion (Approx.)	5	5	5	5%	

TYPE 255 CLASS-B AUDIO AMPLIFIER (2 TUBES. "GRIDS" SWING TO ZERO AND DRAW NO CURRENT):

D.C. Plate Voltage	2000	3000	5000	8000	volts
D.C. Grid Voltage	—800	—1200	—2100	—3300	volts
D.C. Plate Current	600	830	900	750	ma.
Power Output	450	1100	2500	4000	watts
Plate Efficiency	38	44	56	67%	
Load Resistance (Plate-to-Plate)	4000	5000	10000	23000	ohms
Plate Loss	750	1400	2000	2000	watts

TYPE 255 CLASS-B R.F. AMPLIFIER (SINGLE TUBE. NO "GRID" CURRENT):

D.C. Plate Voltage	2000	3000	5000	8000	volts
D.C. Grid Voltage	—800	—1200	—2100	—3300	volts
D.C. Plate Current	120	155	142	97	ma.
Load Resistance	1500	2000	4500	12000	ohms
Plate Loss	188	347	490	500	watts
Power Input	240	465	710	775	watts
Power Output	52	118	220	275	watts
Efficiency	21.5	25	31	36%	

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HK-154

HEINTZ & KAUFMAN. General purpose u.h.f. and h.f. triode tantalum plate and grid.

Note: Grid drive requirements vary widely under different operating conditions.

CHARACTERISTICS:

Filament Voltage	5.0 volts
Filament Current	6.5 amps.
Amplification Factor	6.7
Grid-to-Plate Capacitance	5 μμfd.
Maximum Plate Dissipation	50 watts
Maximum D.C. Plate Voltage	1500 volts
Maximum D.C. Plate Current	175 ma.
Maximum D.C. Grid Current	30 ma.
Base	UX 4-pin

Grid and Plate leads through opposite sides of glass Envelope

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HK-254*

HEINTZ & KAUFMAN general purpose high-mu triode for high-frequency or class-B audio service. Tantalum plate and grid. 50-watt base. Plate through top, grid through side of glass bulb.

CHARACTERISTICS:

Filament Voltage	5.0 volts
Filament Current	7.5 amps.
Amplification Factor	25
Grid-to-Plate Capacitance	3.4 μμfds.
Grid-to-Filament Capacitance	3.3 μμfds.
Plate-to-Filament Capacitance	1.1 μμfd.
Normal Plate Dissipation	100 watts
Max. D.C. Plate Voltage	3000 volts
Max. D. C. Plate Current	200 ma.
Max. D.C. Grid Current	40 ma.

CLASS-B AUDIO AMPLIFIER (2 TUBES):

D.C. Plate Voltage	1000	2000	3000	volts
D.C. Grid Voltage	0	—65	—100	volts
Zero Sig. D.C. Plate Current	160	50	40	ma.
Max. Sig. D.C. Plate Current	344	261	245	ma.
Load Resistance (Plate-to-Plate)	4000	16000	30000	ohms
Power Output	146	328	550	watts

R.F. AMPLIFIER SERVICE, CLASS-C:

D.C. Plate Voltage	1000	2000	3000	volts
D.C. Grid Voltage	—40	—165	—251	volts
D.C. Plate Current	200	200	167	ma.
D.C. Grid Current	40	40	40	ma.
Effective R.F. Grid Voltage	178	284	335	volts
Driving Power (Approx.)	10	16	19	watts
Power Output	126	300	400	watts

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HK-354

HEINTZ & KAUFMAN triode. Tantalum plate and grid. Class-B modulator. Class-C. r.f. amplifier. Maximum d.c. plate voltage for plate modulation is 3000 volts. Primarily for replacement. Superseded by HK-354C and HK-354D.

With forced ventilation, the plate dissipation may be increased to as high as 250 watts.

Frequency Range: 100% ratings up to 15 Mc. Reduced ratings at u.h.f. (above 30 Mc.).

CHARACTERISTICS:

Filament Voltage	5.0 volts
Filament Current	10 amps.
Amp. Factor (Avg.)	14
Normal Plate Dissipation	150 watts
Grid-to-Plate Capacitance	4 μμfds.
Grid-to-Filament Capacitance	9 μμfds.
Plate-to-Filament Capacitance	0.2 μμfd.
Maximum D.C. Plate Voltage	3500 volts
Maximum D.C. Plate Current	300 ma.
Maximum D.C. Grid Current	50 ma.

Plate through top of envelope. Base Standard 4-Pin 50-watt.

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HK-354C*

HEINTZ & KAUFMAN triode. Ultra-high-frequency amplifier. tantalum plate and grid. Suitable for use as class-B modulator and class-C amplifier. All characteristics are the same as those for HK-354, except for lower grid-to-filament capacitance. The grid comes out through the side of the glass envelope, rather than through the base of the tube as in the HK-354, which makes the tube more suitable for high-frequency operation. Refer to HK-354 for characteristics and operating data.

HK-354D*

HEINTZ & KAUFMAN triode. Ultra-high-frequency amplifier, doubler and class-B audio amplifier. Similar to HK-354C except for amplification factor. Best of the "354" types for all-around use.

CHARACTERISTICS:

Filament Voltage	5.0 volts
Filament Current	10.0 amps.
Amplification Factor	22
Normal Plate Dissipation	150 watts
Maximum D.C. Plate Voltage	4000 volts
Maximum D.C. Plate Current	300 ma.
Maximum D.C. Grid Current	50 ma.

Base: Standard 50-watt. Plate through top, grid through side of envelope.

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	1500	2000	2500	3000	3500 volts
D.C. Grid Voltage	—236	—242	—317	—424	—490 volts
D.C. Plate Current	300	297	274	255	240 ma.
D.C. Grid Current	50	50	50	50	50 ma.
Grid Driving Power	24	26	30	35	38 watts
Grid Bias Loss	12	12	16	21	25 watts
Approx. Power Output	316	445	535	614	690 watts

R.F. DOUBLER:

D.C. Plate Voltage	1000	1500	2000 volts
D.C. Grid Voltage	—361	—458	—619 volts
D.C. Plate Current	250	200	175 ma.
D.C. Grid Current	50	50	50 ma.
Grid Driving Power	32	36	44 watts
Grid Bias Loss	16	22	32 watts
Approximate Power Output	100	150	200 watts

CLASS-B AUDIO AMPLIFIER (2 TUBES):

D.C. Plate Voltage	1500	2000	2500	3000 volts
D.C. Grid Voltage	—60	—87	—112	—135 volts
Zero Signal D.C. Plate Current	50	50	50	50 ma.
Maximum Signal D.C. Plate Current	277	362	290	327 ma.
Plate-to-Plate Load Resistance	12000	20000	20000	21000 ohms
Power Output	302	469	519	692 watts

Suggested Driver: Four 6A5 or 45, with fixed bias and 350 volts plate supply.

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HK-354E*

HEINTZ & KAUFMAN triode. Similar to HK-354C and HK-354D except for mu, which is 35.

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HK-354F*

HEINTZ & KAUFMAN triode. Similar to HK-354C and HK-354D except for mu, which is 50.

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HK-654

HEINTZ & KAUFMAN triode for class-B modulator and high-frequency r.f. service. Especially suitable for class-B r.f. and grid-modulated telephony. Tantalum plate and grid. 100% ratings up to 15 Mc.; reduced ratings above 30 Mc.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	15 amps.
Amplification Factor	25
Normal Plate Dissipation	300 watts
Maximum D.C. Plate Voltage	5000 volts
Maximum D.C. Plate Current	450 ma.
Maximum D.C. Grid Current	100 ma.
Base	Standard 4-pin, 50-watt

Plate through top, grid through side of envelope.

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HK-1554

HEINTZ & KAUFMAN general purpose triode. Designed for commercial transmitters in the high-frequency range.

Note: Air-cooled plate. With forced ventilation, plate dissipation may be increased to 1500 watts.

CHARACTERISTICS:

Filament Voltage	11 volts
Filament Current	17 amps.
Normal Plate Dissipation	750 watts
Amplification Factor	14.5 watts
Grid-to-Plate Capacitance	11 $\mu\mu$fds.
Grid-to-Filament Capacitance	15.5 $\mu\mu$fds.
Plate-to-Filament Capacitance	1.2 $\mu\mu$fds.
Base	Special HK

Plate through top of envelope.

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HK-3054

HEINTZ & KAUFMAN general purpose triode for commercial application. Largest standard glass envelope tube made.

Note: Plate dissipation may be increased to 3 kw. by forced ventilation. Air cooled h.f. tube construction.

CHARACTERISTICS:

Filament Voltage	16 volts
Filament Current	50 amps.
Normal Plate Dissipation	1500 watts
Amplification Factor	20
Grid-to-Plate Capacitance	15 $\mu\mu$fds.
Grid-to-Filament Capacitance	25 $\mu\mu$fds.
Plate-to-Filament Capacitance	2.5 $\mu\mu$fds.
Maximum D.C. Plate Voltage	5000 volts
Maximum D.C. Plate Current	2000 ma.
Maximum D.C. Grid Current	500 ma.

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HYTRON

6L6-GX*

Beam-Tetrode, Power Amplifier. Similar to Taylor T-21 except for octal base. (Low-loss replacement for 6L6 and 6L6G.)

Heater Voltage (A.C. or D.C.)	6.3 volts
Heater Current	0.9 amp.
Plate Voltage	500 max. volts
Screen Voltage	300 max. volts
Plate Resistance	22500 ohms
Mutual Conductance	6000 μmhos
Amplification Factor	135
Plate Dissipation	25 watts max.
Plate Current	90 max. ma.
Screen Current	6 max. ma.

Ceramic Base

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HY25*

General purpose triode, R.F. power amplifier, oscillator. Class "B" modulator, frequency doubler with thoriated-tungsten filament. Ceramic base. Plate cap.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	2.25 amps.
Plate Voltage	800 max. volts
Plate Current	75 ma. max.
Plate Dissipation	25 watts
Grid Current	25 ma.
Amplification Factor	55
Mutual Conductance	3000 mhos.

INTERELECTRODE CAPACITANCES:

Grid-to-plate	4.6 $\mu\mu$fd.
Grid-to-fil.	4.2 $\mu\mu$fd.
Plate-to-fil.	1.0 $\mu\mu$fd.

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HY-40*

General purpose triode, R.F. power amplifier, oscillator, Class "B" modulator.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	2.25 amps.
Plate Voltage	100 v. max.
Plate Current	115 ma. max.

Plate Dissipation	40 watts
Grid Current	25 ma.
Amplification Factor	25
Mutual Conductance	3800 mhos.

INTERELECTRODE CAPACITANCES:

Grid-to-plate	6.3 μμfd.
Grid-to-fil.	5.8 μμfd.
Plate-to-fil.	1.8 μμfd.

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HY-40Z

Zero-bias Class "B" modulator, R.F. power amplifier, oscillator, high-μ triode. Similar to HY-40 except higher μ.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	2.5 amps.
Plate Voltage	1000 volts
Plate Current	115 ma.
Plate Dissipation	40 watts
Grid Current	30 ma.
Amplification Factor	80
Mutual Conductance	4200 mhos.

Averaged over any Audio Frequency Cycle.

TYPICAL OPERATING CONDITIONS:
A.F. Power Amplifier and Modulator Class "B"

D.C. Plate Voltage	1000 max. volts
Maximum Signal D.C. Plate Current	115 max. ma.
Maximum Signal Plate Input	115 max. watts
Plate Dissipation	40 max. watts

TYPICAL OPERATION, TWO TUBES:
(Unless otherwise specified, values are for 2 tubes)

D.C. Plate Voltage	800	1000		volts
D.C. Grid Voltage	0	0		volts
Static Plate Current	36	48		ma.
Peak A.F. grid to grid voltage	150	175	approx.	volts
Maximum Signal D.C. Plate Current	280	280		ma.
Load Resistance per Tube	1375	1725		ohms
Effective Load Resis. Pl.-Pl.	5500	6900		ohms
Maximum Signal Driving Power	2.5	3	approx.	watts
Maximum Signal Power Output	140	180	approx.	watts

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HY-51A,* HY-51B

R.F. Class "B" and "C" power amplifier, oscillator, Class "B" modulator. General-purpose triode with thoriated-tungsten filament. Ceramic base. Graphite anode. Lava insulation.

CHARACTERISTICS:

	HY-51A	HY-51B
Filament Voltage	7.5 volts	10.0 volts
Filament Current	3.5 amps.	2.25 amps.
Plate Voltage	1000 v. max.	
Plate Current	155 ma. max.	
Plate Dissipation	65 watts	
Grid Current	25 ma.	
Amplification Factor	25	
Mutual Conductance	6500 mhos	

INTERELECTRODE CAPACITANCES:

Grid to plate	7.5 μμfd.
Grid to fil.	6.0 μμfd.
Plate to fil.	2.0 μμfd.

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HY-51Z*

Zero-bias Class "B" modulator, R.F. Class "B" and "C" power amplifier, frequency doubler. High-μ triode with thoriated-tungsten filament. Ceramic base. Graphite anode. Lava insulation.

CHARACTERISTICS:

Filament voltage	7.5 volts
Filament current	3.5 amps.
Plate voltage	1000 max. volts
Plate current	175 max. ma.
Grid current	35 max. ma.
Plate dissipation	65 max. watts
Average amplification factor	85
Mutual conductance	7200 μmhos

INTERELECTRODE CAPACITANCES:

Grid to plate	7.5 μμfd.
Grid to fil.	6.0 μμfd.
Plate to fil.	2.0 μμfd.

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HY-57*

General purpose triode, somewhat similar to RCA 809.

CHARACTERISTICS:

Filament Voltage	6.3 volts
Filament Current	2.25 amps.
Plate Voltage	800 volts max.
Plate Dissipation	40 watts max.
Max. Plate Current	110 ma.
Max. Grid Current	25 ma.
Average Amp. Factor	50
Mutual Conductance	4500 μmhos

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HY-60

Isolantite base beam-power tube. Requires no neutralization when used for r.f. service, if external shielding is used.

CHARACTERISTICS:

Heater Voltage	6.3 volts
Heater Current	0.5 amps.
Mutual Conductance	4100 μmhos
Amplification Factor	218
Plate Dissipation	15 watts

AS CLASS-C POWER AMPLIFIER:
(Carrier conditions per tube for use with a max. modulation factor of 1.0.)

D.C. Plate Voltage—C.W.	425 max. volts
D.C. Plate Voltage—Phone	325 max. volts
D.C. Screen Voltage (Grid No. 2)	225 max. volts
D.C. Grid Voltage (Grid No. 1)	—150 max. volts
D.C. Plate Current	60 max. ma.
D.C. Grid Current	5 max. ma.
Plate Input	20 max. watts
Screen Input	2.0 max. watts
Plate Dissipation	12 max. watts

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HY-61*

Isolantite base beam-power tube, Hytron equivalent of RCA 807. See 807 data for characteristics and applications.

RAYTHEON

RK-11

RAYTHEON general purpose triode with standard 4-pin base and plate lead through top of bulb. Max. ratings up to 60 Mc.

CHARACTERISTICS:

Filament Voltage	6.3 volts
Filament Current	3.0 amps.
Amplification Factor	20
Grid-to-Plate Capacitance	7 μμfds.
Grid-to-Filament Capacitance	7 μμfds.
Plate-to-Filament Capacitance	0.9 μμfd.
Maximum Plate Dissipation	25 watts
Maximum D.C. Plate Voltage	750 volts
Maximum D.C. Plate Current	105 ma.
Maximum D.C. Grid Current	35 ma.

CLASS-C AMPLIFIER SERVICE:

	GRID-MOD.	PLATE-MOD.	TELEGRAPHY
D.C. Plate Voltage	750	600	750 volts
D.C. Grid Voltage	—130	—120	—120 volts
D.C. Plate Current	38	85	105 ma.
D.C. Grid Current	1.2	24	21 ma.
Driving Power	2.7 (peak)	3.7	3.2 watts
Power Output	12	38	55 watts

RK-12

RAYTHEON zero-bias class-B audio amplifier tube which may also be used for r.f. service such as frequency doubling. 4-pin standard base with plate out through top of glass bulb. Maximum ratings up to 60 Mc. Similar to RK-11 except for mu of 80.

CLASS-B AUDIO AMPLIFIER (2 TUBES):

D.C. Plate Voltage	750 volts
D.C. Grid Voltage	0 volts
Zero Sig. D.C. Plate Current	50 ma
Max. Sig. D.C. Plate Current	200 ma
Max. Sig. D.C. Grid Current	65 ma.
Peak A.F. Grid-to-Grid Voltage	129 volts
Driving Power	3.4 watts
Power Output	100 watts

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RK-18

RAYTHEON h.f. triode class-B modulator. Class-C r.f. amplifier or oscillator Buffer or doubler. Superseded by newer Raytheon types.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	3.0 amps.
Amplification Factor	18
Grid-to-Plate Capacitance	4.8 μμfds.
Grid-to-Filament Capacitance	4.6 μμfds.
Plate-to-Filament Capacitance	2.9 μμfds.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	1000 volts
Maximum D.C. Plate Current	85 ma.
Maximum D.C. Grid Current	25 ma.
Base	UX 4-pin. Plate at top of envelope.

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RK-20

RAYTHEON r.f. amplifier. Frequency doubler. Oscillator. Suppressor-, Grid- or Plate-modulated amplifier.

Caution: Do not apply screen voltage without simultaneous application of plate voltage.

Frequency Range: 100% ratings up to 20 Mc.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	3.0 amps.
Grid-to-Plate Capacitance	0.12 μμfd.
Input Capacitance	11 μμfds.
Output Capacitance	10 μμfds.
Maximum Plate Dissipation	40 watts
Maximum Screen Dissipation	15 watts
Base	UX 5-pin Isolantite. Plate at top of envelope.

R.F. SERVICE:

	CLASS-B TELE-PHONY	SUP-PRESSOR MODU-LATION	CLASS-C TELEGRAPHY	
D.C. Plate Voltage	1250	1250	1250	1250 volts
D.C. Screen Voltage	300	300	300	300 volts
D.C. Suppressor Voltage	0	—45	0	—45 volts
D.C. Grid Bias	—30	—100	—100	—100 volts
Peak R.F. Grid Volts	70	175	175	175 volts
Peak A.F. Grid Volts	..	75	..	.. volts
D.C. Plate Current	43	43	80	92 ma.
D.C. Screen Current	15	36	37	32 ma.
D.C. Grid Current	..	5	5	5 ma.
Grid Driving Power	.5	.9	.9	.9 watt
Grid Bias Loss	..	.5	.5	.5 watt
Power Output (Approx.)	16	18	64	80 watts
Screen Resistor	60,000	25,000	26,000	29,000 ohms

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RK-23-25

RAYTHEON r.f. amplifier, frequency doubler, oscillator, suppressor-, control grid- or plate-modulated amplifier. As a doubler, approx. 12 watts can be obtained. This tube has large 7-pin base. Plate at top of tube.

Frequency Range: 100% ratings up to 30 Mc.

CHARACTERISTICS	RK-23	RK-25
Heater Voltage	2.5	6.3 volts
Heater Current	2.0	0.8 amp.

Grid-Plate Cap.	0.2 μμfds.
Input Capacitance	10 μμfds.
Output Capacitance	10 μμfds.
Max. Plate Dissipation	8 watts

R.F. SERVICE:

	CONTROL GRID MODU-LATION	SUPP. MOD.	CLASS-C TELEGRAPHY	
D.C. Plate Voltage	500	500	500	500 volts
D.C. Screen Voltage	200	200	200	200 volts
D.C. Suppress. Voltg.	45	—45	0	45 volts
D.C. Grid Voltage	—125	—90	—90	—90 volts
Peak R.F. Grid Vltg.	150	135	135	135 volts
Peak A.F. Grid Voltg.	45	75	..	.. volts
D. C. Plate Current	34	32	50	55 ma.
D.C. Screen Current	20	40	40	35 ma.
D.C. Grid Current	1.5	6	6	6 ma.
Grid Driving Power	1.3	.8	.8	.8 watts
Grid Bias Loss	.2	.5	.5	.5 watts
Pwr. Output (Approx.)	6.5	5.5	18	24 watts
Screen Resistor	20,000	7500	7500	8500 ohms

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RK-28
RK-28A

RAYTHEON pentode tube for suppressor-modulated telephony. Buffer or final amplifier in radio transmitters. Since it is a screen grid tube no neutralization is needed. May be used as a crystal oscillator or doubler at reduced inputs and outputs of approx. 60%. The RK-28A is similar except for carbon plate and hard glass bulb.

Precaution: Input and output circuits should be shielded and all circuits carefully by-passed for r.f. Screen voltage should not be applied when plate voltage is connected.

Frequency Range: 100% ratings up to 20 Mc. The RK-28 has a lower output capacitance than the 803, so can be operated more effectively at higher frequencies, such as 14 and 30 Mc.

Note: Combined plate and screen modulation may be applied for a carrier output of 100 watts with a maximum plate supply of 1500 volts. With 400 volts d.c. on screen, 300 volts peak a.f., on it, and 1500 peak volts on the plate will provide 100% modulation.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	5 amps.
Grid-to-plate Capacitance	0.02 μμfd.
Input Capacitance	15.5 μμfds.
Output Capacitance	5.5 μμfds.
Maximum Plate Dissipation	100 watts
Maximum Screen Dissipation	35 watts
Base	5-pin, 50-watt. Plate at top of envelope.

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RK-30

RAYTHEON equivalent of type RCA 800. Characteristics substantially the same except max. plate current rating of 115 ma.

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RK-31

RAYTHEON high mu triode. Primarily a class-B audio amplifier. May be used for r.f.

Note: R.f. grid excitation requirements vary widely; thus the driver stage should be designed with ample factor of safety for output needs.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	3.0 amps.
Amplification Factor Varies with Input	high mu.
Mamimum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	85 ma.
Base	Plate at top of envelope UX 4-pin.

CLASS-B MODULATOR OR A.F. AMPLIFIER:

D.C. Plate Voltage	1000	1250 volts (max.)
D.C. Grid Voltage	0	0 volts
Grid Driving Power (2 Tubes)	900	900 milliwatts
Zero Signal D.C. Plate Current (Per Tube)	12	15 ma.

Maximum Signal D.C. Plate Current (Per Tube)	80	80 ma.
Load Resistance (Plate to Plate)	13,600	17000 ohms
Power Output (2 Tubes)	110	140 watts

R.F. SERVICE:

	CLASS-C TELEGRAPHY	FREQUENCY DOUBLER
D.C. Plate Voltage	1250	1000 volts
D.C. Grid Voltage	—90	—300 volts
D.C. Plate Current	85	85 ma.
D.C. Grid Current	25	15 ma.
Grid Driving Power	5.25	6 watts
Grid Bias Loss	2.25	4.5 watts
Power Input	106	85 watts
Approximate Power Output	76	52 watts
Approximate A.C. Load Impedance	7250	5400 ohms

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RK-32

RAYTHEON U.h.f. triode. Substantially similar to RCA 834 in all respects. See 834 data.

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RK-34

RAYTHEON twin-triode power amplifier. Designed primarily for u.h.f. amplifier or oscillator service. May be used efficiently up to 240 Mc., providing the plate dissipation is not allowed to exceed 10 watts.

Note: A fixed bias of —15 volts is desirable in case of failure of r.f. excitation.

Unusual Feature: Two plate leads are brought through the top of the tube envelope, thus reducing interelectrode capacities for u.h.f. service.

CHARACTERISTICS:

Heater Voltage	6.3 volts
Heater Current	0.8 amps.
Amplification Factor	13
Grid-to-Plate Capacitance	2.7 μμfd.
Input Capacitance	4.2 μμfd.
Output Capacitance	2.1 μμfd.
Max. Plate Dissipation	10 watts
Max. D.C. Plate Voltage	300 volts
Max. D.C. Plate Current	80 ma.
Max. D.C. Grid Current	25 ma.

R.F. SERVICE—CLASS C AMPLIFIER:

D. C. Plate Voltage	300 volts
D.C. Grid Voltage	—45 volts
D. C. Plate Current	75 ma.
D.C. Grid Current	15 ma.
Grid Driving Power	1.8 watts
Grid Bias Loss	0.67 watts
Power Input	14 watts
Approx. A.C. Load Impedance	1600 ohms

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RK-35

RAYTHEON U.h.f. triode. General purpose triode with tantalum plate. Class-B audio r.f. amplifier or oscillator.

Frequency Range: 80% of full ratings at 56 Mc., 60% at 112 Mc.

Note: Grid driving power requirements vary over wide limits, depending upon plate load, circuit losses and type of circuit.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Amplification Factor	8
Grid-to-Plate Capacitance	2.7 μμfds.
Grid-to-Filament Capacitance	3.5 μμfds
Plate-to-Filament Capacitance	0.4 μμfd
Maximum Plate Dissipation	35 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	100 ma.
Maximum D.C. Grid Current	20 ma.

Base. .UX 4-pin. Plate at top, grid at side of envelope.

R.F. SERVICE:

	CLASS-B R.F.	GRID-MOD. R.F.	CLASS-C
D.C. Plate Voltage	1000	1000	1000 volts
D.C. Grid Voltage	160	240	320 volts
D.C. Plate Current	52	50	96 ma.
D.C. Grid Current	..	..	15 ma.
Grid Driving Power	6	2.6	6.5 watts
Grid Bias Loss	..	..	5 watts
Power Input	52	50	96 watts
Power Output (Approx.)	17	16	70 watts

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RK-36

RAYTHEON r.f. amplifier or oscillator for h.f. and u.h.f. applications.

Frequency Range: 100% ratings up to 56 Mc.

Note: Grid drive may vary widely under different operating conditions.

CHARACTERISTICS:

Filament Voltage	5.0 volts
Filament Current	8.0 amps.
Amplification Factor	11
Grid-to-Plate Capacitance	5 μμfds.
Grid-to-Filament Capacitance	4.5 μμfds.
Plate-to-Filament Capacitance	1.0 μμfd.
Maximum Plate Dissipation	100 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	165 ma.
Maximum D.C. Grid Current	35 ma.

4-prong med. base. Plate out top and grid out side of envelope. Tantalum plate.

R.F. SERVICE:

	CLASS-B	GRID MOD.	CLASS-C
D.C. Plate Voltage	2000	2000	2000 volts
D.C. Grid Voltage	—180	—270	—360 volts
D.C. Plate Current	75	72	150 ma.
D.C. Grid Current	..	..	30 ma.
Grid Driving Power (Approx.)	10*	3.5*	15 watts
Grid Bias Loss	..	..	5.4 watts
Power Output (Approx.)	50	42	200 watts

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* Peak

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RK-37*

RAYTHEON high-mu triode, tantalum plate. Oscillator, doubler, or amplifier for very high frequency operation. 100% ratings up to 30 Mc. 80% ratings at 56 Mc. 60% ratings at 112 Mc. Class-B modulator.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Maximum Plate Dissipation	35 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	100 ma.
Maximum D.C. Grid Current	25 ma.
Grid-to-Plate Capacitance	2.9 μμfds.
Grid-to-Filament Capacitance	3.2 μμfds.
Plate-to-Filament Capacitance	0.3 μμfd.

Standard UX 4-pin base. Plate through top, grid through side of envelope.

R.F. SERVICE:

	CLASS-B R.F.	GRID MOD. TELEPHONY	CLASS-C
D.C. Plate Voltage	1000	1000	1000 volts
D.C. Grid Voltage	—45	—52.5	—70 volts
D.C. Plate Current	50	50	95 ma.
D.C. Grid Current	..	..	20 ma.
Peak R.F. Grid Power	2.3	2.3	3.0 watts
Peak Audio Voltage	..	45	.. volts
Carrier Output Power	15	15	60 watts

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RK-38*

RAYTHEON high-mu triode. Tantalum plate. Designed for class-B audio amplifier, r.f. amplifier or oscillator service. 100% ratings up to 56 Mc.

CHARACTERISTICS:

Filament Voltage	5.0 volts
Filament Current	8 amps.
Grid-to-Plate Capacitance	4.5 μμfds.
Grid-to-Filament Capacitance	3.9 μμfds.

Plate-to-Filament Capacitance	1.0 μμfd.
Maximum Plate Dissipation	100 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	165 ma.
Maximum D.C. Grid Current	40 ma.

Standard UX 4-pin base. Plate through top, grid through side of envelope.

R.F. SERVICE:

	CLASS-B R.F.	GRID-MOD. TELEPHONY	CLASS-C
D.C. Plate Voltage	2000	2000	2000 volts
D.C. Grid Voltage	—100	—150	—200 volts
D.C. Plate Current	75	80	150 ma.
D.C. Grid Current	..	..	30 ma.
Peak R.F. Grid Power	7	4	11.5 watts
Peak Audio Voltage	..	100	.. volts
Carrier Power Output	55	60	225 watts

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RK-39*

RAYTHEON beam power tetrode, designed for frequency doubler, amplifier, or crystal oscillator service. Frequency range: full voltage ratings up to 30 Mc. Maximum plate voltage at 60 Mc., 400 volts.

CHARACTERISTICS:

Heater Voltage	6.3 volts
Heater Current	0.9 amp.
Grid-to-Plate Capacitance	0.15 μμfd.
Input Capacitance	13 μμfds.
Output Capacitance	10.5 μμfds.
Maximum Plate Dissipation	21 watts
Maximum Screen Dissipation	3.5 watts
Maximum D.C. Plate Voltage	500 volts
Maximum D.C. Screen Voltage	300 volts
Maximum D.C. Screen Current	20 ma.
Maximum D.C. Plate Current	100 ma.
Maximum D.C. Control Grid Current	5 ma.
Base	Standard 5-Pin Isolantite

Plate Through Top of Envelope.

R.F. SERVICE:	CLASS-B R.F.	CLASS-C
D.C. Plate Voltage	500	500 volts
D.C. Plate Current	65	95 ma.
D.C. Screen Voltage	250	250 volts
D.C. Screen Current	3	12 ma.
D.C. Control Grid Current	0.3	3 ma.
Carrier Power Output	11	35 watts

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RK-41

RAYTHEON beam power pentode, identical with RK-39, except for heater which is 2.5 volts at 2.4 amps.

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RK-42

RAYTHEON triode for portable sets. Similar to type 30, except for filament.

Filament Voltage	1.5 volts
Filament Current	.06 amp.

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RK-43

RAYTHEON high-mu twin triode for class-B service. Each triode is somewhat similar to RK-42, except for higher mu.

Filament Voltage	1.5 volts
Filament Current	.12 amp.

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RK-44

RAYTHEON pentode, similar to RK-25, except for somewhat higher ratings. Designed for aircraft and mobile service.

Heater Voltage	12.6 volts
Heater Current	0.7 amps.
Maximum D.C. Plate Voltage	650 volts
Maximum D.C. Plate Current	80 ma.
Class-C Output	30 watts

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RK-45

RAYTHEON pentode, identical to RK-25, except for heater which operates at 12.6 volts and 0.45 amps. Designed for aircraft and mobile transmitters.

RK-46

RAYTHEON pentode, similar to RK-20, except for filament and envelope, which are heavier in construction. Filament is rated at 12.6 volts at 2.5 amps. Designed for mobile and aircraft transmitters.

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RK-47*

RAYTHEON equivalent of RCA 814 beam power tetrode, designed for r.f. amplifier-doubler service. Somewhat similar to RK-20, except for special grid structure; slightly higher plate efficiency than in similar types of pentode tubes.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Screen Voltage	300 volts
Maximum Plate Dissipation	50 watts
Maximum Screen Dissipation	15 watts
Maximum D.C. Grid Current	10 ma.
Grid-to-Plate Capacitance	0.12 μμfd.
Input Capacitance	13 μμfds.
Output Capacitance	10 μμfds.
Base	Standard UX 5-pin

Plate through top of envelope.

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RK-48

RAYTHEON beam-power tetrode, designed for r.f. amplifier service. Requires very low grid excitation. Somewhat similar to RK 28, but without suppressor grid. Easier to drive than RK-28 for slightly higher power output.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	5 amps.
Maximum D.C. Plate Voltage	2000 volts
Maximum D.C. Screen Voltage	400 volts
Maximum Plate Dissipation	100 watts
Maximum Screen Dissipation	35 watts
Maximum D.C. Grid Current	25 ma.
Average Required D.C. Grid Current	10 ma. for normal output.
Base	5 prong, 50-watt

Plate through top of envelope.

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RK-51

RAYTHEON general purpose triode with 4-pin standard base and plate through top of bulb. Maximum ratings up to 60 Mc.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	3.75 amps.
Amplification Factor	20
Grid-to-Plate Capacitance	6 μμfds.
Grid-to-Filament Capacitance	6 μμfds.
Plate-to-Filament Capacitance	2.5 μμfds.
Max. Plate Dissipation	60 watts
Max. D.C. Plate Voltage	1500 volts
Max. D.C. Plate Current	150 ma.
Max. D.C. Grid Current	40 ma.

CLASS-C R.F. AMPLIFIER:

	GRID. MOD.	PLATE MOD.	TELEGRAPHY
D.C. Plate Voltage	1500	1250	1500 volts
D.C. Grid Voltage	—130	—200	—250 volts
D.C. Plate Current	60	105	150 ma.
D.C. Grid Current	0.4	17	31 ma.
Driving Power	2.3 (Peak)	4.5	10 watts
Power Output	32	96	170 watts

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RK-52

RAYTHEON zero-bias modulator tube with standard 4-pin base and plate through top of bulb. May be used as a frequency doubler. Maximum ratings up to 60 Mc.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	3.75 amps.
Amplification Factor (Approx.)	150
Grid-to-Plate Capacitance	12 μμfds.
Grid-to-Filament Capacitance	6.6 μμfds.

Plate-to-Filament Capacitance	2.2 μμfds.
Maximum Plate Dissipation	52.5 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	150 ma.
Maximum D.C. Grid Current	50 ma.

CLASS-B AUDIO AMPLIFIER (2 TUBES):

D.C. Plate Voltage	1250 volts
D.C. Grid Voltage	0 volts
Zero Sig. D.C. Plate Current	40 ma.
Maximum Sig. D.C. Plate Current	300 ma.
Maximum Sig. D.C. Grid Current	100 ma.
Peak A.F. Grid-to-Grid Voltage	180 volts
Driving Power	7.5 watts
Load Resistance (Plate-to-Plate)	10,000 ohms
Power Output	250 watts

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RK-56

RAYTHEON heater type aligned grid beam power amplifier tube having an isolantite base. The deflector plates in the RK-56 are connected internally to the cathode.

HEATER RATING:

Heater Voltage	6.3	volts
Heater Current	0.55	amp.

DIRECT INTERELECTRODE CAPACITANCES:

Grid to Plate	0.2 max.	μμfd.
Input	10	μμfd.
Output	9	uuμμ.

R.F. POWER AMPLIFIER OR OSCILLATOR—CLASS-C MAXIMUM RATINGS:

D.C. Plate Voltage—Telegraphy	300	volts
D.C. Plate Voltage—Telephony		
With Control Grid Modulation	300	volts
With Plate or Plate & Screen Modulation	350	volts
D.C. Screen Voltage—Telegraphy	300	volts
D.C. Screen Voltage—Telephony	300	volts
With Control Grid Modulation	300	volts
With Plate or Plate & Screen Modulation	200	volts
D.C. Plate Current	65	ma.
Plate Dissipation	8	watts
Screen Dissipation	4.5	watts

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RK-59

RAYTHEON coated filament type twin triode power amplifier tube having an isolantite base. It is designed for use as a power amplifier, oscillator or frequency multiplier:

FILAMENT RATING

Filament Voltage	6.3 volts
Filament Current	1 amp.

DIRECT INTERELECTRODE CAPACITANCES—EACH TRIODE

Grid to Plate	.9 μμfd.
Input	.5 μμfd.
Output	.1 μμfd.

MAXIMUM RATINGS

D.C. Plate Voltage	500 volts
D.C. Plate Current (both triodes)	90 ma.
Plate Dissipation (both triodes)	15 watts

RCA

6L6-6L6G*

Purpose: Designed primarily for push-pull amplifier in radio receivers but also widely used in crystal oscillators and r.f. amplifiers for radio transmitters.

Unusual Characteristic: Has two beam-forming plates internally connected to the cathode. Has no physical suppresor grid. The beam action suppresses secondary emission and results in a more ideal pentode operation.

Precautionary Measures: Good air ventilation is desirable because the tube shell becomes very hot under normal operation. In push-pull circuits, balanced tubes are necessary, as well as balanced transformers if second harmonic elimination is desired.

Audio Amplifier Application: If not over 34 watts of audio output is required, a single 6C5 audio amplifier or power detector will drive a pair of 6L6 tubes in push-pull. A 1-to-2 or 1-to-3 stepup interstage transformer is suitable. For outputs of over 34 watts, push-pull 6C5 tubes are suitable for drivers, with a 1-to-½ ratio interstage transformer (primary to ½ secondary.) The output transformer should be of large size in order to handle up to 60 watts of audio power without core saturation. May be used as a modulator for phone transmitters.

Feedback Amplifier Application: Reverse feedback operation in a receiver amplifier will damp out low-frequency loudspeaker resonance. The result is similar in action to a triode, but the d.c. efficiency of a pentode is retained without much sacrifice in power sensitivity. Part of the output is fed back to the grid circuits in reverse phase in order to produce the effect of lower plate impedance.

Crystal Oscillator Application: The crystal r.f. current is very low due to the high power sensitivity of this tube. Outputs of 15 watts can be obtained as a crystal oscillator without exceeding tube ratings.

R.f. Applications: The 6L6 is suitable for a low-power frequency doubler in transmitters. Due to high sensitivity and harmonic output, only a small amount of power is required to drive the grid as a doubler for outputs of 20 watts and more for frequencies as high as 15 Mc.

Single-ended Amplifier: Because of its inherent characteristics, the 6L6 produces bad harmonic distortion when used as a single-ended audio amplifier at high volume levels. This distortion may be minimized by deliberately generating out-of-phase distortion in the preceding audio amplifier stage or by using inverse feedback.

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10

Triode. Class-C amplifier or doubler. Class-B power amplifier and modulator for medium-power transmitters. Crystal oscillator in commercial transmitters (at 250 volts max. plate supply). Often operated at 750 to 900 volts plate supply and 75 ma. per tube in class-C telegraphy, amateur service.

Frequency Range: Up to 15 Mc. at normal ratings. May be operated on frequencies as high as 60 Mc. at reduced plate voltage (400 volts) if tube is equipped with ceramic base, or if molded bakelite bases are cross-slotted with hack-saw cut.

CHARACTERISTICS:

Filament Voltage		7.5 volts
Filament Current		1.25 amps
Plate Voltage	350	425 max. volts
Grid Voltage	—31	—39 max. volts
Plate Current	16	18 ma.
Plate Resistance	5150	5000 ohms
Amplification Factor	8	8
Mutual Conductance	1550	1600 micrombos.
Load Resistance	11.000	10.200 ohms
Self-Bias Resistance	1950	2150 ohms
Power Output	0.9	1.6 watts
Plate-Grid Cap.		7 μμfds.
Input Capacities		4 μμfds.
Output Capacitance		3 μμfds.
Base		Medium 4-pin

CLASS-C AMPLIFIER (TELEGRAPHY):

D.C. Plate Voltage	400	500	600 v.
D.C. Plate Current	65	65	65 ma.
D.C. Grid Voltage	—100	—125	—150 v.
D.C. Grid Current	10	10	12 ma.
Approx. A.C. Load Imped.	3000	3800	4600 ohms
Approx. Power Output	16	21	27 watts
R.F. Grid Excitation	2.7	3.0	3.8 watts
Grid Bias Loss	1.0	1.25	1.8 watts
Plate Loss	10	11.5	12 watts

CLASS-B A.F. AMPLIFIER:

Plate Voltage	400	600 v.
Grid Bias	—50	—75 v.
Zero Sig. Plate Current (Per Tube)	4	4 ma.
Max. Sig. Plate Current (Per Tube)	65	65 ma.
Load Resistance (Plate to Plate)	6000	10,000 ohms
Approx. Power Output (2 Tubes)	27	45 watts

203A

Class-B audio service and as an r.f. amplifier.

Frequency Range: 100% ratings up to 6 Mc., 50% at 30 Mc.

Note: The grid drive requirements vary with load impedance, circuit design and high-frequency circuit losses; thus, the driver should be able to deliver twice as much power as listed for grid drive.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	25
Maximum Plate Dissipation	100 watts
Grid-to-Plate Capacitance	14.5 μμfds.
Grid-to-Filament Capacitance	6.5 μμfds.
Plate-to-Filament Capacitance	5.5 μμfds.
Base	4-pin, 50 watt

CLASS-B MODULATOR OR A.F. AMPLIFIER (2 TUBES):

D.C. Plate Voltage	1000	1250 volts
D.C. Grid Bias	—35	—45 volts
Zero Signal D.C. Plate Current (Per Tube)	13	13 ma.
Maximum Signal D.C. Plate Current (Per Tube)	160	160 ma.
Load Resistance (Plate-to-Plate)	6900	9000 ohms
Power Output	200	260 watts

R.F. SERVICE:

	CLASS-B R.F.	CLASS-C TELE-PHONY	CLASS-C TELEG-RAPHY	FRE-QUENCY DOUBLER
D.C. Plate Voltage	1250	1000	1250	1000 volts
D.C. Plate Current	106	150	160	126 ma.
D.C. Grid Bias	—45	—135	—130	—495 volts
D.C. Grid Current	..	50	25	20 ma.
Grid Drawing Power (Approx.)	..	7	7	13 watts
Grid Bias Loss	..	6.8	3.3	5 watts
Power Input	133	150	200	126 watts
Approx. Power Output	42.5	90	125	80 watts
Approx. A.C. Load Impedance	..	3300	3900	4200 ohms
Modulator D.C. Load Resistance	..	6666	..	.. ohms

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204A

RCA - AMPEREX - UNITED. Triode Oscillator or amplifier for frequencies below 3000 kc. Used primarily in broadcast transmitters. Newer u.h.f. types such as 833, T-200, HF 300, etc., are more suitable for high-frequency work.

Frequency Range: 100% ratings up to 3 Mc. 50% at 15 Mc.

Note: Grid excitation requirements vary with plate impedance, circuit design and circuit losses, so the driver stage should be able to supply approximately twice as much output as listed for grid drive.

CHARACTERISTICS:

Filament Voltage	11 volts
Filament Current	3.85 amps.
Amplification Factor	25
Grid-to-Plate Capacitance	15 μμfds.
Grid-to-Filament Capacitance	12.5 μμfds.
Plate-to-Filament Capacitance	2.3 μμfds.
Maximum Plate Dissipation	250 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D.C. Plate Current	275 ma.
Maximum D.C. Grid Current	80 ma.
Base	Standard 250-watt

Plate through top.

CLASS-B MODULATOR:

D.C. Plate Voltage	1500	2000 volts
D.C. Grid Bias (Approx.)	—40	—60 volts
Zero Signal Plate Current (Per Tube)	37	37 ma.
Max. Signal Plate Current (Per Tube)	250	250 ma.
Load Resistance (Plate-to-Plate)	7800	8800 ohms
Power Output (2 Tubes)	400	600 watts

R.F. SERVICE:

	CLASS-B TELE-PHONY	PLATE MOD.-TELE-PHONY	CLASS-C TELEGRAPHY	
D.C. Plate Voltage	2000	1800	1500	2500 volts
D.C. Grid Bias	—70	—250	—150	—200 volts
D.C. Plate Current	160	250	250	250 ma.
D.C. Grid Current	..	70	50	50 ma.
Power Output (Approx.)	100	300	225	400 watts
Grid Driving Power	..	35	17	22 watts
Grid Bias Loss	..	17.5	7.5	10 watts

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211

Class-B modulator. Class-B and C r.f. amplifier for telephony or telegraphy. Occasionally used as a frequency doubler.

Frequency Range: Full ratings up to 6 megacycles. 50% ratings at 30 Mc.

Note (1): Grid driving requirements vary with load impedance, frequency of operation (due to losses), and type of circuits; thus, the driver stage should be capable of supplying twice as much power output as listed for grid drive.

Note (2): The WE 242A is similar in characteristics and operation to the 211. The 211D (do not confuse with old WE-211D) is similar to the 211 but it also has slightly lower interelectrode capacitances.

CHARACTERISTICS:

Filament Voltage	10.0 volts
Filament Current	3.25 amps.
Amplification Factor	12
Grid-to-Plate Capacitance	14.5 μμfds.
Grid-to-Filament Capacitance	6 μμfds.
Plate-to-Filament Capacitance	5.5 μμ fds.
Maximum Plate Dissipation	100 watts
Base	4-pin. 50-watt

CLASS-B MODULATOR (A.F.):

D.C. Plate Voltage	1000	1250 volts
Zero Signal Plate Current (Per Tube)	10	10 ma.
Zero Grid Bias	—77	—100 volts
Maximum Signal Plate Current (Per Tube)	160	160 ma.
Load Resistance (Plate-to-Plate)	6900	9000 ohms
Power Output (2 Tubes)	200	260 watts

R.F. AMPLIFIER SERVICE:

	CLASS-B TELE-PHONY	CLASS-C TELE-PHONY	CLASS-C TELEG-RAPHY	DOUBLER
D.C. Plate Voltage	1250	1000	1250	1250 volts
D.C. Plate Current	106	150	165	145 ma.
D.C. Grid Bias	—100	—260	—215	—712 volts
D.C. Grid Current (Approx.)	zero	35	20	30 ma.
Grid Driving Power (Approx.)	..	14	7.3	26 watts
Grid Bias Loss	..	9	4.3	21 watts
Power Input	133	150	208	180 watts
Approx. Power Output	42.5	100	150	120 watts
Approx. A.C. Load Impedance	..	3300	3800	4870 ohms
Modulator D.C. Load Resistance	..	6666	..	.. ohms

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211C

THE 211C tubes of various manufacturers (Amperex, Taylor, United) are similar to 211 tubes in operation, except for lower grid-to-plate capacitance. They are somewhat more effective at the higher frequencies down towards the u.h.f. region. *See 211 tube data.*

Note: The WE 261A and WE 276A are somewhat similar to the 211C in characteristics and operation.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Maximum Plate Dissipation	100 to 120 watts
Maximum D.C. Plate Voltage	1350 volts
Maximum D.C. Plate Current	180 ma.
Maximum D.C. Grid Current	50 ma.
Grid-to-Plate Capacitance	7 to 9 μμfds.
Grid-to-Filament Capacitance	5.5 μμfds.
Plate-to-Filament Capacitance	5 μμfds.
Base	Standard 4-pin 50-watt

800

RCA or AMPEREX triode. Class-B Modulator. Class-C r.f. amplifier. Frequency doubler. U.h.f. oscillator and amplifier. Primarily for replacement; superseded by 834 and 808.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Amplification Factor	15
Maximum Plate Dissipation	35 watts
Grid-to-Plate Capacitance	2.5 μμfds.
Grid-to-Filament Capacitance	2.75 μμfds.
Plate-to-Filament Capacitance	1.0 μμfd.
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	80 ma.
Maximum D.C. Grid Current	25 ma.
Base	UX 4-pin

Plate and grid at top of envelope.

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801

RCA, AMPEREX, UNITED 310. Triode, Class C R-f amplifier for phone or c.w. Class-B modulators. Frequency doubler. An improved type 10.

Caution: The values given for grid driving power and power output vary with frequency and load circuit impedance. The driving stage should be designed to have twice as much power output as needed for grid driving power.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	1.25 amps.
Amplification Factor	8
Grid-to-Plate Capacitance	6.0 μμfds.
Grid-to-Filament Capacitance	4.5 μμfds.
Plate-to-Filament Capacitance	1.5 μμfd.
Maximum Plate Dissipation	20 watts
Maximum D.C. Plate Voltage	600 volts
Maximum D.C. Plate Current	70 ma.
Maximum D.C. Grid Current	15 ma.
Base	UX 4-pin Isolantite

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802

RCA pentode. R.F. amplifier, frequency doubler. oscillator; suppressor, grid or plate-modulated amplifier. Plate at top of tube.

Frequency Range: 100% up to 30 Mc., 55% at 60 Mc.

Note: The internal shield should connect to cathode at the socket, in most circuits.

CHARACTERISTICS:

Heater Voltage	6.3 volts
Heater Current	0.8 amps.
Grid-to-Plate Capacitance	0.15 μμfd.
Input Capacitance	12 μμfds.
Output Capacitance	8.5 μμfds.
Max. Plate Dissipation	10 watts
Max. Screen Dissipation	6 watts
Base	7-pin, large

R.F. SERVICE:

	GRID MODULATION	SUPP. MOD.	CLASS-C TELEG.		
D.C. Plate Voltage	500	500	500	500	volts
D.C. Screen Voltage	200	200	200	200	volts
D.C. Suppres. Voltg.	0	—45	0	40	volts
D.C. Grid Voltage	—130	—90	—100	—100	volts
Peak R.F. Grid Volt.	145	125	155	135	volts
Peak A.F. Grid Volt.	50	65	...	...	
D.C. Plate Current	25	22	45	45	ma.
D.C. Screen Current	8	28	22	12	ma.
D.C. Grid Current	1	4.5	6	2	ma.
Grid. Driv. Power	.8	.5	.9	.25	watts
Grid Bias Loss	.13	.4	.6	.2	watts
Pwr. Output (App.)	4	3.5	14	16	watts
Screen Resistor	37,500	10,700	13,700	20,000	ohms

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803

RCA. Suppressor - modulated telephony. Buffer or final amplifier in radio transmitters. Since it is a screen grid tube, no neutralization is needed. May be used as a crystal oscillator or doubler at approximately 60% output.

Frequency Range: 100% ratings up to 20 Mc. High interelectrode capacities also tend to reduce output circuit efficiencies at higher frequencies such as 30 Mc.

Precaution: Input and output circuits should be shielded and all circuits carefully by-passed for r.f. Screen voltage should not be applied unless plate voltage is connected.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Mutual Conductance at I_b=55	4000 micromhos
Grid-to-Plate Capacitance	0.15 μμfd.
Input Capacitance	15.5 μμfds.
Output Capacitance	28.5 μμfds.
Maximum Plate Dissipation	125 watts
Maximum Screen Dissipation	30 watts
Base	5-pin, 50-watt

Plate lead at top of envelope.

R.F. SERVICE:

	CLASS-B TELEPHONY	SUPPRESSOR-MOD. TELEPHONY		CLASS-C TELEGRAHPY		
D.C. Plate Volt.	2000	1500	2000	1250	2000	volts
D.C. Screen Volt.	600	500	500	500	500	volts
D.C. Sup. Volt.	40	—110	—135	40	40	volts
D.C. Grid Bias Volt.	—40	—50	—50	—30	—30	volts
Peak R.F. Grid Volt.	55	120	120	150	150	volts
Peak A.F. Grid Volt.	...	150	175	...	...	
D.C. Plate Current	80	80	80	160	160	ma.
D.C. Screen Current	15	55	55	45	42	ma.
D.C. Grid Current	3	15	15	18	16	ma.
Grid Driv. Power (Approx.)	1.5	1.6	1.6	1.8	1.6	watts
Grid Bias Loss	0.1	.75	.75	.5	.5	watts
Power Output (App.)	53	40	53	130	210	watts
Screen Resistor	100,000	18,000	27,000	17,000	36,000	ohms

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804

RCA pentode r.f. amplifier. Frequency doubler. Oscillator. Suppressor, grid or plate-modulated amplifier.

Caution: Do not apply screen voltage without simultaneous application of plate voltage.

Frequency Range: 100% ratings at 15 Mc. 75% at 35 Mc. and 50% at 80 Mc. Special attention should be given to shielding and by-passing at high frequencies.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	3.0 amps.
Grid-to-Plate Capacitance	0.1 μμfd.
Input Capacitance	16 μμfds.
Output Capacitance	14.5 μμfds.
Maximum Plate Dissipation	40 watts
Maximum Screen Dissipation	15 watts
Mutual Conductance	3250 micromhos
Base UX 5-pin	Plate at top of envelope

R.F. SERVICE:

	CLASS-C TELEPHONY	SUPPRESSOR-MOD. TELEPHONY		PENTODE CLASS-C TELEGRAPHY	TETRODE CLASS-C TELEGRAPHY	
D.C. Plate Voltage	1250	1000	1250	1250	1250	volts
D.C. Screen Voltage	300	300	300	300	180	volts
D.C. Suppressor Volt.	45	—35	—50	45	180	volts
D.C. Grid Bias	—115	—100	—100	—100	—100	volts
Peak R.F. Grid Volts	135	140	140	150	160	volts
Peak A.F. Grid Volts	35	60	70	..	...	volts

D.C. Plate Current ...	45	45	48	92	92 ma.
D.C. Screen Current ..	11	33.5	35.5	27	23 ma.
D.C. Grid Current ..	2	5.5	7	7	8 ma.
Grid Driving Power ...	.85	.7	.85	.9	1.2 watts
Grid Bias Loss	..	.6	.7	.7	.8 watt
Power Output (App.)	21	16	21	80	80 watts
Screen Resistor ..	....	21,000	27,000	35,000	.... ohms

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805*

RCA high-mu type tube for class-B audio service. May also be used for r.f. service.

Note (1): Plate lead out top of tube reduces flash-over danger.

Frequency Range: 100% ratings up to 30 Mc., 75% at 45 Mc. and 50% at 85 Mc.

Note (2): The class-B input transformer between push-pull 2A3's (fixed bias) and class-B 805 tubes should have a turns ratio of $\frac{\text{primary}}{\frac{1}{2}\text{ Sec.}} = 3.0.$

Note (3): The grid excitation and bias may vary widely for class-C operation. It is desirable that the driver be capable of supplying approximately twice as much output as listed for grid drive.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor Varies with Input Signal.	
Grid-to-Plate Capacitance	6.5 μμfds.
Grid-to-Filament Capacitance	8.5 μμfds.
Plate-to-Filament Capacitance	10.5 μμfds.
Maximum Plate Dissipation	125 watts
Maximum D.C. Plate Voltage	1500 volts
Maximum D.C. Plate Current	210 ma.
Maximum D.C. Grid Current	70 ma.
Base	Standard 4-pin 50-watt

Plate at top of envelope.

CLASS-B MODULATOR OR A.F. AMPLIFIER:

D.C. Plate Voltage	1250	1500 volts
D.C. Grid Bias	0	—16 volts
Peak A.F. Grid-to-Grid Voltage..	235	280 volts
Zero Sig. D.C. Plate Current (Per Tube)	74	42 ma.
Max. Sig. D.C. Plate Current (Per Tube)	200	200 ma.
Load Resistance (Plate-to-Plate) ..	6700	8200 ohms
Maximum Signal Driving Power ..	6	7 watts
Maximum Signal Power Output..	300	370 watts

R.F. SERVICE:

	CLASS-B TELE-PHONY	PLATE-MOD. TELE-PHONY	CLASS-C TELEG-RAPHY	FRE-QUENCY DOUBLER	
D.C. Plate Voltage	1250	1250	1500	1250	volts
D.C. Grid Voltage	0	—160	—100	—400	volts
Peak R.F. Grid Voltage	75	300	230	625	volts
D.C. Plate Current	135	160	200	135	ma.
D.C. Grid Current	15	60	40	25	ma.
Grid Driving Power (Approx.)	11	16	9.2	12.5	watts
Grid Bias Loss	...	9.6	4	10	watts
Power Input	169	200	300	169	watts
Approx. Power Output..	55	140	215	85	watts
Approx. A.C. Load Imped. .		3900	3600	3800	ohms
Mod. D.C. Load Resist..	...	7800	...	...	

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806*

RCA u.h.f. power triode for general use in either r.f. or audio service. Frequency range: 100% of rating up to 56 Mc.

CHARACTERISTICS:

Filament Voltage	5.0 volts
Filament Current	10.0 amps.
Amplification Factor	12.6
Grid-to-Plate Capacitance	3.4 μμfds.
Grid-to-Filament Capacitance	6.1 μμfds.
Plate-to-Filament Capacitance	1.1 μμfds.
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	200 ma.
Maximum D.C. Grid Current	50 ma.
Normal Plate Dissipation	150 watts

Base: Standard 50-watt; grid through side, plate through top of envelope.

CLASS-B AUDIO AMPLIFIER (TWO TUBES):

D.C. Plate Voltage	2000	3000 volts
D.C. Grid Voltage	—150	—240 volts
Zero Signal Plate Current	20	20 ma.
Max. Signal Plate Current	390	330 ma.
Load Res. (Plate-to-Plate)	11500	21500 ohms
Max. Signal Driving Power	14	10 watts
Power Output	500	660 watts

R.F. AMPLIFIER SERVICE:

	CLASS-B	R.F.	CLASS-C PLATE-MOD.	CLASS-C TELEGRAPHY		
D.C. Plate Volt.	2000	3000	2500	2000	3000	volts
D.C. Grid Volt.	—150	—240	—600	—400	—600	volts
D.C. Plate Cur.	110	70	195	195	195	ma.
D.C. Grid Cur..	1	0	40	25	25	ma.
Driving Power (Approx.) ...	8	5	32	15	20	watts
Grid Bias Loss..	0.15	0	24	10	15	watts
Power Output ..	70	70	390	280	450	watts

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807*

R.C.A. beam power pentode transmitter tube. R.f. buffer or doubler for frequencies up to 60 Mc. at full rated input. 50% ratings at 150 Mc. Also useful as crystal oscillator with external capacity connected between grid and plate. Class-AB audio amplifier with 60 watts output for two tubes (see 6L6 characteristics). If care is taken in placement of parts and if shield is placed around tube and if the input circuits are shielded from the output circuits, no neutralization will be required for r.f. circuits.

CHARACTERISTICS:

Heater Voltage	6.3 volts
Heater Current	0.9 amp.
Grid-to-Plate Capacitance	0.2 μμfd.
Input Capacitance	11.6 μμfds.
Output Capacitance	7 μμfds.
Maximum Plate Dissipation	21 watts
Maximum D.C. Plate Voltage	600 volts

Plate lead at top of envelope.
Standard 5-pin ceramic base.

R.F. AMPLIFIER:	C.W.	PHONE
D.C. Plate Voltage	600	475 volts
D.C. Screen Voltage	250	225 volts
D.C. Grid Voltage	—50	—50 volts
Peak R.F. Grid Voltage	80	80 volts
D.C. Plate Current	95	83 ma.
D.C. Screen Current	10	9 ma.
D.C. Grid Current	3	2.5 ma.
Grid Driving Power (Approx.)....	0.22	0.18 watts
Power Output (Approx.)	37	25 watts

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808*

RCA tantalum plate triode. High-frequency oscillator and amplifier. 100% ratings up to 30 Mc. 50% ratings at 130 Mc.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	4 amps.
Amplification Factor	47
Grid-to-Plate Capacitance	2.8 μμfds.
Grid-to-Filament Capacitance	5.3 μμfds.
Plate-to-Filament Capacitance	0.15 μμfd.

Standard UX 4-pin base.
Plate through top, grid through side of envelope.

CLASS-B AUDIO AMPLIFIER (2 TUBES):

D.C. Plate Voltage	1250	1500 volts
D.C. Grid Voltage	—15	—25 volts
Zero Signal D.C. Plate Current	40	30 ma.
Max. Signal D.C. Plate Current	230	190 ma.
Load Resistance (Plate-to-Plate)..	12700	18300 ohms
Grid Driving Power	7.8	4.8 watts
Power Output, Approximate.....	190	185 watts

CLASS-C R.F. AMPLIFIER:

	PLATE-MOD. TELEPHONY	CLASS-C TELEGRAPHY	
D.C. Plate Voltage	1250	1250	1500 volts
D.C. Grid Voltage	—225	—150	—200 volts
D.C. Plate Current	100	135	125 ma.
D.C. Grid Current	32	30	30 ma.
Grid Driving Power	10.5	8	9.5 watts
Grid Bias Loss	7	4.5	6 watts
Power Output (Approx.)	105	120	140 watts

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RCA-809*

General purpose triode. Class-B modulator. Class-C r.f. amplifier. Frequency doubler. Frequency range: 100% ratings up to 60 Mc.; 50% ratings at 100 Mc.

CHARACTERISTICS:

Filament Voltage	6.3 volts (A.C. or D.C.)
Filament Current	2.5 amps.
Amplification Factor	50
Grid-to-Plate Capacitance	6.7 μμfds.
Grid-to-Filament Capacitance	5.7 μμfds.
Plate-to-Filament Capacitance	0.9 μμfd.
Maximum D.C. Plate Dissipation	25 watts
Maximum D.C. Plate Current	100 ma.
Maximum D.C. Plate Voltage	750 volts
Maximum D.C. Grid Current	35 ma.
Maximum Plate Power Input	75 watts
Base	UX 4-pin, plate through top of bulb

CLASS-B AUDIO SERVICE (2 TUBES)

D.C. Plate Voltage	500	750 volts
D.C. Grid Voltage	0	—5 volts
Peak A.F. Grid-to-Grid Voltage	135	140 volts
Zero Signal D.C. Plate Current	40	35 ma.
Max. Sig. D.C. Plate Current	200	200 ma.
Load Resistance (Plate-to-Plate)	5200	8400 ohms
Max. Sig. Driving Power	2.4	2.4 watts
Max. Sig. Power Output	60	100 watts

R.F. AMPLIFIER SERVICE:

	CLASS-B R.F.	CLASS-C PLATE-MODULATED	CLASS-C TELEGRAPHY	
D.C. Plate Voltage	750	600	500	700 volts
D.C. Grid Voltage	—10	—160	—50	—60 volts
D.C. Plate Current	50	83	100	100 ma.
D.C. Grid Current	5	32	20	20 ma.
Grid Driving Power (Approx.)	1.5	7.2	2.5	2.5 watts
Grid Bias Loss	0.05	5.1	1.0	1.2 watts
Power Input	37.5	50	50	70 watts
Power Output	12.5	38	35	55 watts

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810*

RCA power amplifier triode. May be used as a class-C amplifier (telegraphy or telephony) or as a class-C or class-B grid-modulated r.f. amplifier. May be operated at 100% ratings in all classes of service as high as 30 Mc.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	4.5 amps.
Amplification Factor (Approx.)	35
Grid-to-Plate Capacitance	4.8 μμfds.
Grid-to-Filament Capacitance	9.2 μμfds.
Plate-to-Filament Capacitance	12.9 μμfds.
Plate Top Cap	Medium Metal
Grid Side Cap	Medium Metal
Base	Jumbo 4-Large Pin, Bayonet
Socket Connections	Same as RCA-806

R.F. POWER AMPLIFIER—CLASS-C SERVICE:

	TELEPHONY	TELEGRAPHY
D.C. Plate Voltage (Max.)	1600	2000 volts
D.C. Grid Voltage (Max.)	—500	—500 volts
D.C. Plate Current (Max.)	210	250 ma.
D.C. Grid Current (Max.)	70	70 ma.
Plate Input (Max.)	335	500 watts
Plate Dissipation (Max.)	85	125 watts
Power Output	250	375 watts

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811*, 812* (SEE PAGE 258)

813*

RCA beam power tetrode. Requires no neutralization. May be used at maximum ratings up to 30 Mc., at approximately 70 per cent of ratings up to 60 Mc., and at further reduced ratings up to 120 Mc.

R.F. POWER AMPLIFIER AND OSCILLATOR—CLASS-C TELEGRAPHY:

Filament Voltage	10.0 volts
Filament Current	5 amps.
D.C. Plate Voltage (Max.)	2000 volts
D.C. Screen Voltage (Max.)	400 volts
D.C. Grid Voltage (Max.)	—300 volts
D.C. Plate Current (Max.)	180 ma.
D.C. Grid Current (Max.)	25 ma.
Plate Input (Max.)	360 watts
Screen Input (Max.)	22 watts
Plate Dissipation (Max.)	100 watts

TYPICAL OPERATION:

D.C. Plate Voltage	1250	1500	2000 volts
D.C. Screen Voltage	300	300	400 volts
D.C. Grid Voltage	—60	—70	—90 volts
Peak R.F. Grid Voltage	145	150	160 volts
Beam Plate Voltage	0	0	0 volts
D.C. Plate Current	180	180	180 ma.
D.C. Screen Current	23	20	15 ma.
D.C. Grid Current	7	6	3 ma.
Screen Resistor	42,000	60,000	107,000 ohms
Grid Resistor	8500	11,700	30,000 ohms
Driving Power (Approx.)	1	0.8	0.5 watt
Power Output	155	190	260 watts

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RCA-814*

Beam power tetrode with high power gain characteristic. Used as r.f. amplifier, frequency doubler, oscillator and plate-modulated amplifier. 100% ratings up to 30 Mc. 50% ratings at 100 Mc. *Do not confuse* with Taylor T-814.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Grid-to-Plate Capacitance	0.1 μμfd.
Input Capacitance	13.5 μμfds.
Output Capacitance	13.5 μμfds.
Max. D.C. Plate Voltage	1250 volts
Max. D.C. Screen Voltage	300 volts
Maximum Plate Dissipation	50 watts
Maximum Plate Input	180 watts
Maximum Screen Dissipation	10 watts
Max. D.C. Grid Current	10 ma.
Max. D.C. Plate Current	150 ma.
Base	Std. 5-pin ceramic. Plate through top of bulb.

R.F. AMPLIFIER SERVICE:

	CLASS-B	GRID-MOD. GRID-CLASS-C	CLASS-C PLATE MOD. CLASS-C	CLASS-C TELEG.
D.C. Plate Voltage	1250	1250	1000 max.	1250 volts
D.C. Screen Voltage	200	200	300	300 volts
D.C. Grid Voltage	—28	—100	—150	—80 volts
D.C. Plate Current	60	60	120	144 ma.
D.C. Screen Current	1	1.4	17.5	22.5 ma.
D.C. Grid Current	1.8	2.8	10	10 ma.
Screen Resistor	...	...	40,000	42,000 ohms.
Driving Power (Approx.)	0.65	2.3	2	1.5 watts
Power Output	25	29	87	130 watts

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830B

RCA 830-B. Amperex 830-B United 930-B. Class-B modulator for outputs up to 175 watts. May be driven by a push-pull 45 or 2A3 driver stage. Also used for r.f.

R.F. Frequency range: 100% ratings up to 15 Mc. 75% at 30 Mc. 50% at 60 Mc.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	2 amps.
Amplification Factor	25
Maximum Plate Dissipation	60 watts
Grid-to-Plate Capacitance	11 μμfds.
Grid-to-Filament Capacitance	5 μμfds.
Plate Filament Capacitance	1.8 μμfds.
Max. D.C. Plate Voltage	1000 volts
Maximum D.C. Grid Current	60 ma.
Maximum D.C. Plate Current	150 ma.
Base	UX 4-pin

Plate at top of envelope.

CLASS-B MODULATOR OR A.F. AMPLIFIER:

D.C. Plate Voltage	800	1000	volts
D.C. Grid Voltage	—27	—35	volts
Peak Grid-to-Grid A.F. Volts	250	270	volts
Zero Sig. D.C. Plate Current (2 Tubes)	20	20	ma.
Maximum Sig. D.C. Plate Current (2 Tubes)	280	280	ma.
Eff. Load Resistance (Plate-to Plate)	600	7600	ohms.
Grid Driving Power	5	6	watts
Maximum Sig. Power Output	110	150	watts

R.F. SERVICE:

	CLASS-B R.F.	CLASS-C TELE-PHONY	CLASS-C TELEGRAPHY		FREQUENCY DOUBLER	
D.C. Plate Voltage	1000	800	600	1000	1000	volts
D.C. Plate Current	85	95	140	140	75	ma.
D.C. Grid Bias	—35	—150	—95	—110	—435	volts
D.C. Grid Current	6	20	30	30	15	ma.
Grid Driving Power (Ap.)	6*	5	6	7	8.5	watts
Grid Bias Loss	2	3	2.8	3.3	6.5	watts
Power Input	85	76	84	140	75	watts
Power Output (Approx.)	26	50	45	90	45	watts
Mod. D.C. Load Resist.	..	8400	..	..	..	ohms
Approximate A.C. Load Impedance	..	4200	2150	3600	..	ohms

*At Peak.

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831

RCA and Amperex oscillator and r.f. amplifier for high-frequency operation.

Frequency Range: 100% ratings up to 20 Mc. 55% at 75 Mc.

Note: Grid driving requirements vary greatly under different values of load impedance, neutralizing circuits and circuit losses which vary with frequency.

CHARACTERISTICS:

Filament Voltage	11 volts
Filament Current	10 amps.
Amplification Factor	14.5
Grid-to-Plate Capacitance	4.0 μμfds.
Grid-to-Filament Capacitance	3.8 μμfds.
Plate-to-Filament Capacitance	1.4 μμfds.
Maximum Plate Dissipation	400 watts
Maximum D.C. Plate Voltage	3500 volts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	75 ma.

R.F. SERVICE

	CLASS-B TELE-PHONY	CLASS-C PLATE-MOD. TELE-PHONY	CLASS-C TELEGRAPHY		
D.C. Plate Voltage	3500	3000*	2000	3500	volts
D.C. Grid Voltage	—220	—500	—200	—400	volts
D.C. Plate Current	145	200	300	275	ma.
D.C. Grid Current	...	60	45	40	ma.
Grid Driving Power	...	50	25	30	watts
Grid Bias Loss	...	30	9	16	watts
Power Input	510	600	600	965	watts
Power Output	160	375	400	600	watts

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*(Max.)

833*

RCA triode power amplifier. High-frequency r.f. amplifier with all four terminal caps out of special bulb.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	10 amps.
Amplification Factor	35
Grid-to-Plate Capacitance	6.3 μμfds.
Grid-to-Filament Capacitance	12.3 μμfds.
Plate-to-Filament Capacitance	8.5 μμfds.
Max. D.C. Plate Current	500 ma.
Max. D.C. Plate Voltage	3000 volts
Max. Plate Input	1250 watts
Max. Plate Dissipation	300 watts
Max. D.C. Grid Current	75 ma.
Max. D.C. Grid Voltage	—500 volts

R.F. AMPLIFIER SERVICE:

	CLASS-B R.F.	CLASS-C TELE-PHONY	CLASS-C TELEG-RAPHY	
D.C. Plate Voltage	3000	2500	3000	volts
D.C. Plate Current	150	335	415	ma.
D.C. Grid Voltage	—70	—300	—200	volts
D.C. Grid Current	2	75	55	ma.
Grid Driving Power	10	30	20	watts
Power Output	150	635	1000	watts

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834

RCA u.h.f. amplifier and oscillator.

Frequency Range: Up to 350 megacycles.

Rated input at 100 Mc.—100%
Rated input at 350 Mc.— 50%

Note (1): Grid driving power varies with type of circuit used, load impedance, and frequency range (dielectric and circuit losses increase with frequency). Driver should be capable of twice as much output as listed for grid drive.

(2) Regeneration in the frequency doubler will allow lower values of grid bias and grid drive for same output power.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Amplification Factor	10.5
Grid-to-Plate Capacitance	2.6 μμfds.
Grid-to-Filament Capacitance	2.2 μμfds.
Plate-to-Filament Capacitance	0.6 μμfd.
Maximum Plate Dissipation	50 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	100 ma.
Maximum D.C. Grid Current	20 ma.
Base	UX 4-pin

Plate and Grid Through Top of Tube Envelope.

R.F. AMPLIFIER:

	CLASS-C TELEGRAPHY AMPLI-FIER	CLASS-C TELEGRAPHY DOU-BLER	CLASS-C TELE-PHONY	CLASS-B TELE-PHONY	
D.C. Plate Voltage	1250	1000	1000	1000	volts
D.C. Plate Current	95	78	90	50	ma.
D.C. Grid Current	15	10	17.5	0.5	ma.
D.C. Grid Voltage	—193	—684	—310	—90	volts
Grid Driving Power	4.8	8.4	7.5	3	watts
Grid Bias Loss	2.9	6.8	5.5	...	watts
Power Input	119	78	90	50	watts
Approx. Power Output	89	45	60	16	watts
Approx. A.C. Load Imped	6500	6600	5500	...	ohms
Max. D.C. Load Imped.	...	...	11,100	...	ohms

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837

RCA pentode amplifier designed primarily for 12-volt storage battery power supplies (aircraft, marine, etc.)

CHARACTERISTICS:

Heater Voltage	12.6 volts
Heater Current	0.7 amp.
Grid-to-Plate Capacitance	0.2 μμfd.
Input Capacitance	16 μμfds.
Output Capacitance	10 μμfds.
Maximum D.C. Plate Voltage	500 volts

Maximum D.C. Screen Voltage	200 volts
Maximum Plate Dissipation	12 watts
Maximum Plate Input	32 watts
Maximum D.C. Plate Current	80 ma.

Base—Medium 7-pin ceramic. Plate through top of bulb.

R.F. AMPLIFIER SERVICE:

	SUPPRESS. MOD.	PLATE-MOD. PENTODE	CLASS-C TELEG.	
D.C. Plate Voltage	500	400 max.	500	volts
D.C. Screen Voltage	200	140	80	volts
D.C. Grid Voltage	—20	—70	—70	volts
D.C. Plate Current	30	45	60	ma.
D.C. Screen Current	23	30	15	ma.
D.C. Grid Current	3.5	7	8	ma.
D.C. Suppressor Voltage	—65	+40	+40	volts
Screen Resistor	14,000	10,000	28,000	ohms
Driving Power	0.1	0.7	0.7	watts
Power Output	5	11	20	watts

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838

Most used as class-B modulator due to its zero bias characteristic.

R.f. Frequency Range: 100% ratings up to 30 Mc., 65% at 60 Mc., 50% at 90 Mc.

Note (1): Push-pull 2A3 tubes in class-A will serve as a driver for class-B 838 tubes. The class-B input transformer should have a turns ratio of $\frac{\text{Prim.}}{\frac{1}{2}\text{ sec.}}$ = 3.2 if fixed bias is used on the 2A3s. A little greater ratio of stepdown is desirable if the 2A3 drivers are self-biased.

Note (2): For r.f. the driver should have approx. twice as much output as listed in the table in order to compensate for variations of load impedance circuit design and range of frequency of operation.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor varies with amplitude of signal	
Maximum Plate Dissipation	100 watts
Grid-to-Plate Capacitance	8 μμfds.
Grid-to-Filament Capacitance	6.5 μμfds.
Plate-to-Filament Capacitance	5 μμfds.
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	175 ma.
Maximum D.C. Grid Current	70 ma.
Base	4-pin, 50-watt

CLASS-B MODULATOR:

D.C. Plate Voltage	1000	1250	volts
D.C. Grid Voltage	0	0	volts
Approx. Peak A.F. Grid Input Voltage	90	90	volts
Zero Signal D.C. Plate Current (Per Tube)	53	74	ma.
Maximum Signal D.C. Plate Current (Per Tube)	160	160	ma.
Load Resistance (Plate-to-Plate)	7600	11200	ohms
Maximum Power Output (2 Tubes)	200	260	watts
Peak Driving Power (Approx.)	5	5	watts

R.F. SERVICE:

	CLASS-B R.F.	CLASS-C TELEPHONY	CLASS-C TELEGRAPHY	FREQUENCY DOUBLER	
D.C. Plate Voltage	1250	1000	1250	1000	volts
D.C. Plate Current	106	150	155	157	ma.
D.C. Grid Bias	0	—135	—90	—465	volts
D.C. Grid Current	60*	60	30	20	ma.
Grid Driving Power (Approx.)	10*	17.5	6	12.3	watts
Grid Bias Loss	...	8	2.7	9.3	watts
Power Input	133	150	195	157	watts
Approx. Power Output	42.5	100	140	100	watts
Approx. A.C. Load Impedance	...	3300	4070	5360	ohms
Modulator D.C. Load Resistance	...	6666	...	...	ohms

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*(At Peak).

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841

RCA, Amperex, United, High-mu (210) triode. Class-B modulator. Class-C r.f. amplifier or doubler. Oscillator. Resistance-coupled amplifier. Primarily for replacement; superseded by TZ-20, 809, etc.

Frequency Range: 100% ratings up to 6 Mc. New ceramic base types may be operated up to 30 Mc. at full ratings.

• • •

842

RCA audio-frequency amplifier and modulator. Triode. Not as desirable as a type 2A3, which will provide more output at lower plate voltage. Primarily for replacement service in commercial equipment.

• • •

843

RCA triode. Oscillator, a.f. power amplifier and r.f. amplifier of the heater-cathode type for 2.5-volt filament supply. Not in general use.

Frequency Range: 100% ratings up to 6 Mc. 50% at 30 Mc.

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844

RCA screen-grid r.f. amplifier—doubler or buffer. Oscillator. Not in general use.

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845

Triode. Class-A or -AB audio amplifier in public address systems or as modulator in radio transmitters. Seldom used in r.f. amplifiers.

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811*, 812*

The 811 and 812 are companion tubes for Class C r.f. and Class B audio service. The 811, with a mu of 160, is primarily for operation as a class B modulator without bias (up to 1250 v. on the plate). The 812, mu of 29, is primarily for class C r.f. amplifier service. Both types may be used in either class B audio or class C r.f. applications.

R.F. AMPLIFIER, CLASS B MODULATOR CHARACTERISTICS AND RATINGS:

Filament Voltage (A.C. or D.C.)	6.3 volts
Filament Current	4.0 amps.
Amplification Factor (811)	160
Amplification Factor (812)	29
Direct Interelectrode Capacitances:	
Grid-Plate	5.3 μμf.
Grid-Filament	5.3 μμf.
Plate-Filament	0.8 μμf.
Bulb	ST-19
Cap	Medium Metal
Base	Medium 4-pin Micanol, Bayonet

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS: (ICAS)

AS PLATE MODULATED R.F. POWER AMPLIFIER—CLASS C TELEPHONY

Carrier conditions per tube for use with a max. modulation factor of 1.0

D.C. Plate Voltage	1250 max. volts
D.C. Grid Voltage	—200 max. volts
D.C. Plate Current	125 max. ma.
D.C. Grid Current	25 max. ma.
Plate Input	156 max. watts
Plate Dissipation	40 max. watts
Typical Operation:	
D.C. Plate Voltage	1250 volts
D.C. Grid Voltage	
From a fixed supply of	—125 volts
From a grid resistor of	5000 ohms
Peak R.F. Grid Voltage	245 volts
D.C. Plate Current	125 ma.
D.C. Grid Current (approx.)	25 ma.
Driving Power (approx.)	6 watts
Power Output (approx.)	120 watts

AS R.F. POWER AMPLIFIER AND OSCILLATOR—CLASS C TELEGRAPHY

Key-down conditions per tube without modulation

D.C. Plate Voltage	1500 max. volts
D.C. Grid Voltage	—200 max. volts
D.C. Plate Current	150 max. ma.
D.C. Grid Current	35 max. ma.

Plate Input	225 max. watts
Plate Dissipation	55 max. watts
Typical Operation:	
D.C. Plate Voltage	1500 volts
D.C. Grid Voltage	
From a fixed supply of	—175 volts
From a grid resistor of	7000 ohms
From a cathode resistor of	1000 ohms
Peak R.F. Grid Voltage	285 volts
D.C. Plate Current	150 ma.
D.C. Grid Current (approx.)	25 ma.
Driving Power (approx.)	6.5 watts
Power Output (approx.)	170 watts

AS A·F POWER AMPLIFIER AND MODULATOR—CLASS B

D.C. Plate Voltage	1500 max. volts
Max. Sig. D.C. Plate Current	125 max. ma.
Max. Sig. Plate Input	150 max. watts
Plate Dissipation	50 max. watts

Typical Operation:
Unless otherwise specified, values are for 2 tubes.

D.C. Plate Voltage	1500 volts
D.C. Grid Voltage	—9 volts
Peak A.F. Grid to Grid Voltage	145 volts
Zero Sig. D.C. Plate Current	20 ma.
Max. Sig. D.C. Plate Current	200 ma.
Operating D.C. Plate Current	70 ma.
Load Resistance (per tube)	4500 ohms
Effective Load Resistance (plate to plate)	18000 ohms
Recommended Power of Driving Stage (approx.)	10 watts
Max. Sig. Power Output (approx.)	225 watts

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849

RCA-Amperex-United Triode. Especially suited for class-B modulators. May be used in class-C as well as class-B r.f. amplifiers.

Frequency Range: 100% ratings up to 3 Mc. 50% at 15 Mc.

CHARACTERISTICS:

Filament Voltage	11 volts
Filament Current	5.0 amps.
Amplification Factor	19
Grid-to-Plate Capacitance	33.5 μμfds.
Grid-to-Filament Capacitance	17 μμfds.
Plate-to-Filament Capacitance	3 μμfds.
Maximum Plate Dissipation	400 watts
Maximum Plate Dissipation (Telephony)	270 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	125 ma.
Base	250 watts

Plate through top of envelope.

CLASS-B MODULATOR OR A.F. AMPLIFIER:

D.C. Plate Voltage	2000	2500 volts
Grid Bias (Approximate)	—105	—130 volts
Zero Sig. Plate Current (Per Tube)	7	10 ma.
Max. Sig. Plate Current (Per Tube)	325	275 ma.
Load Resistance (Plate-to-Plate)	7040	11,480 ohms
Power Output	870	920 watts

CLASS-B R.F. AMPLIFIER:

D.C. Plate Voltage	1500	2000 volts
D.C. Grid Bias	—70	—95 volts
D.C. Plate Current	340	265 ma.
Carrier Output	155	175 watts

PLATE-MODULATED CLASS-C AMPLIFIER

D.C. Plate Voltage	1500	1800 volts
D.C. Grid Bias	—250	—300 volts
D.C. Plate Current	300	300 ma.
Power Output	300	390 watts

CLASS-C TELEGRAPHY:

D.C. Plate Voltage	1500	2000 volts
D.C. Grid Bias	—175	—200 volts
D.C. Plate Current	300	300 ma.
Power Output	300	450 watts
D.C. Grid Current	75	75 ma.
Grid Driving Power (Approx.)	32	34 watts
Grid Bias Loss	13	15 watts

850

RCA screen-grid r.f. amplifier of the 100-watt type. Primarily for replacement purposes in commercial transmitters. Superseded by more modern types such as 813 tetrode.

Frequency Range: 100% ratings up to 13 Mc. 50% at 30 Mc.

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851

RCA-Amperex-United. High-power air-cooled triode for a.f. or r.f. service.

Frequency Range: 100% ratings up to 3 Mc. 50% at 6 Mc.

CHARACTERISTICS:

Filament Voltage	11 volts
Filament Current	15.5 amps.
Amplification Factor	20
Grid-to-Plate Capacitance	55 μμfds.
Grid-to-Filament Capacitance	30 μμfds.
Plate-to-Filament Capacitance	7 μμfds.
Maximum Plate Dissipation	750 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D.C. Plate Current	1000 ma.
Maximum D.C. Grid Current	200 ma.
Base	Standard 250-watt

Plate through top of envelope.

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852

Triode. RCA, Amperex, United, u.h.f. oscillator. H.f. amplifier or class-B modulator.

Frequency Range: 100% ratings up to 30 Mc., 80% at 60 Mc., 50% at 120 Mc. and 40% at 150 Mc. (2 meters).

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	12
Grid-to-Plate Capacitance	2.6 μμfds.
Grid-to-Filament Capacitance	1.9 μμfds.
Plate-to-Filament Capacitance	1.0 μμfds.
Maximum Plate Dissipation	100 watts
Maximum D.C. Plate Voltage	3500 volts
Maximum D.C. Plate Current	150 ma.
Maximum D.C. Grid Current	40 ma.
Base	UX 4-pin, small

Grid at top, plate through side of envelope.

• • •

860

RCA Screen-grid tetrode. R.f. amplifier for high frequencies. Somewhat superseded by more modern types such as 813 tetrode.

Frequency Range: 100% ratings up to 30 Mc. 80% at 40 Mc.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	200
Grid-to-Plate Capacitance	0.08 μμfd.
Input Capacitance	7.75 μμfds.
Output Capacitance	7.5 μμfds.
Maximum Plate Dissipation	100 watts
Maximum Screen Dissipation	10 watts
Base	UX 4-pin

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861

RCA screen grid r.f. amplifier for normal operation up to 20 megacycles.

Frequency Range: 100% ratings up to 20 Mc. 75% at 30 Mc.

Note (1): Grid driving power requirements vary over wide limits, depending upon load impedance and circuit losses.

Note (2): In modulated operation (plate type) the screen voltage should be modulated simultaneously with the plate voltage. Grid modulation characteristics are approx. similar to class-B r.f. operation, except for grid bias.

CHARACTERISTICS:

Filament Voltage	11 volts
Filament Current	10 amps.
Amplification Factor	300

Grid-to-Plate Capacitance	0.1 μμfd.
Input Capacitance	14.5 μμfds.
Output Capacitance	11 μμfds.
Maximum Plate Voltage	3500 volts
Maximum Plate Dissipation	400 watts
Maximum Screen Dissipation	35 watts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	75 ma.

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865

RCA screen-grid tetrode. Buffer, amplifier, and frequency doublers. As a doubler about 5 to 10 watts may be obtained. Used primarily in commercial and government transmitters and for replacement service; superseded by 802, 807, etc.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	2.0 amps.
Grid-to-Plate Capacitance	0.10 μμfd.
Input Capacitance	8.5 μμfds.
Output Capacitance	8.5 μμfds.
Plate Voltage	500 volts
Screen Voltage	125 volts
Grid Voltage	—80 volts
Amplification Factor	130
Plate Resistance	200,000 ohms
Mutual Conductance	750 micromhos
Plate Current	21 ma.
Maximum Plate Dissipation	15 watts
Base	4-pin. Plate through top of envelope.

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887, 888

RCA u.h.f. water-cooled triodes. Designed for use as oscillators or amplifiers in the ultra-high-frequency spectrum. Either tube may be used at full input as an oscillator up to 240 Mc. or as an amplifier at full input to 300 Mc. Operation at higher frequencies is permissible with reduced input. The characteristics of the 887 are given, those of the 888 are almost identical except that the latter tube has an amplification factor of 30 and has slightly higher interelectrode capacitances.

CHARACTERISTICS:

Filament Voltage	11 volts
Filament Current	24 amps.
Amplification Factor	10
Plate Dissipation (Max.)	600 watts

DIRECT INTERELECTRODE CAPACITANCES:

Grid-to-Plate	6.9 μμfds.
Grid-to-Filament	2.5 μμfds.
Plate-to-Filament	2.7 μμfds.
Type of Cooling	Water and forced air

CLASS-B R.F. AMPLIFIER:

D.C. Plate Voltage (Max.)	3000 volts
D.C. Plate Current (Max.)	200 ma.
Plate Input (Max.)	600 watts

TYPICAL OPERATION:

D.C. Plate Voltage	2500	3000 volts
D.C. Grid Voltage	—250	—300 volts
Peak R.F. Grid Voltage	290	320 volts
D.C. Plate Current	200	200 ma.
D.C. Grid Current	2	1 ma.
Driving Power	45	50 watts
Power Output	165	200 watts

CLASS-C MODULATED AMPLIFIER—MODULATION FACTOR OF 1.0 MAXIMUM CONDITIONS:

D.C. Plate Voltage (Max.)	2000 volts
D.C. Plate Current (Max.)	200 ma.
D.C. Grid Bias (Max.)	—500 volts
D.C. Grid Current (Max.)	75 ma.
Plate Input (Max.)	400 watts
Plate Dissipation	400 watts

CLASS-C AMPLIFIER—C. W. TELEGRAPHY MAXIMUM CONDITIONS:

D.C. Plate Voltage	3000 volts
D.C. Grid Voltage	—500 volts
D.C. Plate Current	400 ma.
D.C. Grid Current	75 ma.
Plate Input	1200 watts
Plate Dissipation	1000 watts

RCA-1602

Amplifier triode. Low microphonic construction. Similar in characteristics to the RCA-10.

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RCA-1603

Triple grid detector-amplifier. Non-microphonic, low-noise design. Used as a pentode or as a triode (grids 2 and 3 connected to plate) with a μ of 20. See 6J7 for characteristics. Similar to 6C6 in size.

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RCA-1608

Coated filament triode, similar to RCA-801, but with a higher amplification factor.

CHARACTERISTICS:

Filament Voltage	2.5 volts
Filament Current	2.5 amps.
Amplification Factor	20
Maximum D.C. Plate Voltage	425 volts
Maximum D.C. Plate Current	95 ma.
Class-C R.F. Output	27 watts
Class-B Linear Output	10 watts
Class-B Audio (Two Tubes)	50 watts

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RCA-1609

Battery-type pentode incorporating low microphonic design for speech amplifier application. 5-prong base.

CHARACTERISTICS:

Filament Voltage	1.1 volts
Filament Current	0.25 amp.
Maximum D.C. Plate Voltage	135 volts
Maximum D.C. Screen Voltage	67.5 volts

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RCA-1610

Pentode crystal oscillator tube having characteristics and tube base identical to that of type 47.

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RCA-1619

Transmitting beam power amplifier having characteristics similar to 6L6 except for 2.5-volt 2-ampere quick-heating filament. See 6L6 for operating characteristics and applications.

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RCA-1624

Fast heating 2.5-volt filament beam-power transmitting tube, somewhat similar to 6L6 except for type of cathode.

CHARACTERISTICS:

Filament Voltage (A.C. or D.C.)	2.5 volts
Filament Current	2 amps.
Transconductance for plate cur. of 50 ma.	4000 approx. micromhos
Direct Interelectrode capacitances:	
Grid-Plate (With external shielding	0.25 max. μμf
Input	11 μμf
Output	7.5 μμf
Bulb	ST-16
Cap	Small Metal
Base	Medium 5-Pin

MAXIMUM RATINGS:

As Push-Pull Class AB_2 Audio Amplifier

D.C. Plate Voltage	600 volts
D.S. Screen Voltage	300 volts
Max.—Signal D.C. Plate Current	90 milliamperes
Max.—Signal Plate Input	54 watts
Screen Input	3.5 watts
Plate Dissipation	25 watts

TAYLOR

T20*

TAYLOR h.f. triode. General purpose, high-μ; suitable for frequencies up to 56 Mc. Suitable for class-B audio service, or as an r.f. frequency-doubler or r.f. amplifier. Isolantite-based tube with plate through top of envelope, 4-pin base. Molybdenum plate. Greater plate dissipation than type 10 or 841 triode.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	1.75 amps.
Amplification Factor	20
Grid-to-Plate Capacitance	4 μμfd.
Maximum Plate Dissipation	20 watts
Maximum D.C. Plate Voltage	750 volts
Maximum D.C. Plate Current	75 ma.
Maximum D.C. Grid Current	25 ma.

CLASS-B MODULATOR OR A.F. AMPLIFIER (2 TUBES):

D.C. Plate Voltage	800	600 volts
D.C. Grid Voltage	—40	—30 volts
Zero. Sig. Plate Current (Per Tube)	10	10 ma.
Maximum Signal Plate Current (Per Tube)	68	70 ma.
Load Resistance (Plate-to-Plate)	12000	8100 ohms
Power Output	70	50 watts

CLASS-C AMPLIFIER:

D.C. Plate Voltage	750 volts
D.C. Grid Voltage	—100 volts
D.C. Plate Current	75 ma.
D.C. Grid Current	20 ma.
Grid Driving Power (Approx.)	3 watts
Grid Bias Loss	2 watts
Power Output (Approx.)	42 watts

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TZ-20

TAYLOR h.f. triode. Primarily designed for zero-bias class-B audio use. Also suitable for all r.f. uses for which the T-20 is suitable. Operating conditions for r.f. use of the TZ-20 will be similar to those of the T-20; the grid bias, however, will be somewhat lower in each case. An improved doubler over the T-20. Isolantite base, metal plate, plate lead through top.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	1.75 amps.
Amplification Factor	62
Average Plate Resistance	26,700 ohms
Mutual Conductance	2320 μmhos

CLASS-B AUDIO AMPLIFIER OR MODULATOR:

D.C. Plate Voltage	800	600 volts
Grid Bias Voltage	0	0 volts
Zero-signal Plate Current	20	14 ma.
Max.-signal Plate Current	69	70 ma.
Load Res., Plate-to-Plate	12,000	8100 ohms
Power Output, Two Tubes	70	50 watts

RADIO-FREQUENCY AMPLIFIER SERVICE:
See operating conditions for T-20.

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T-21*

Six-prong isolantite base 6L6-G beam power amplifier; better insulation than 6L6-G makes it more suited to r.f. or high voltage work.

CHARACTERISTICS:

Heater Voltage	6.3 volts
Heater Current	0.9 amps
Plate Resistance	22500 ohms
Mutual Conductance	6000 mhos
Amplification Factor	138
Plate Dissipation	21 watts
Screen Dissipation	3.5 watts

CLASS-C R.F. AMPLIFIER SERVICE:

Plate Voltage	400 volts
Plate Current, Telegraphy	95 ma.
Plate Current, Telephony	65 ma.
Grid Current	5 ma.
Grid Voltage	—45 volts
Driving Power	0.4 watts
Screen Current	16 ma.
Screen Voltage	300 volts

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T-40*

TAYLOR h.f. triode. General purpose high-mu tube suitable for frequencies up to 60 Mc. Ceramic 4-pin base with plate through top of bulb. Carbon plate.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	2.5 amps.
Amplification Factor	25
Grid-to-Plate Capacitance	4.5 μμfds.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	1000 volts
Maximum D.C. Plate Current	115 ma.
Maximum D.C. Grid Current	40 ma.

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	1000 volts
D.C. Grid Voltage	—80 volts
D.C. Plate Current	110 ma.
D.C. Grid Current	30 ma.
Driving Power (Approx.)	3.5 watts
Power Output	85 watts

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TZ-40*

TAYLOR zero-bias triode designed for class-B modulators and frequency doublers. Ceramic 4-pin base with plate through top of bulb.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	2.5 amps.
Amplification Factor	62
Grid-to-Plate Capacitance	4.5 μμfds.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	1000 volts
Maximum D.C. Plate Current	115 ma.
Maximum D.C. Grid Current	35 ma.

CLASS-B AUDIO AMPLIFIER (2 TUBES):

D.C. Plate Voltage	1000 volts
D.C. Grid Voltage	0 volts
Zero Sig. D.C. Plate Current	44 ma.
Max. Sig. D.C. Plate Current	280 ma.
Load Resistance (Plate-to-Plate)	6800 ohms
Peak A.F. Grid-to-Grid Voltage	220 volts
Power Output	175 watts
Driving Power (Avg.)	3 watts

R.F. SERVICE:
See T-40 data.

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T-55*

TAYLOR class-C r.f. amplifier. U.h.f. oscillator down to 2 meters wavelength.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	2.75 amps.
Amplification Factor	20
Grid-to-Plate Capacitance	3.75 μμfds.
Grid-to-Filament Capacitance	4.0 μμfds.
Plate-to-Filament Capacitance	1.5 μμfds.
Maximum Plate Dissipation	55 watts
Maximum D.C. Plate Voltage	1500 volts
Maximum D.C. Plate Current	150 ma.
Maximum D.C. Grid Current	40 ma.
Base	UX 4-pin

Plate at Top of Envelope.

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	1500 volts
D.C. Grid Voltage	—180 volts
D.C. Plate Current	150 ma.
D.C. Grid Current	30 ma.
Grid Driving Power	10 watts
Grid Bias Loss	5.5 watts
Power Input	225 watts
Power Output	170 watts

CLASS-B AUDIO AMPLIFIER (2 TUBES):

D.C. Plate Voltage	1000 volts	1500 volts
D.C. Grid Voltage (Approx.)	—45 volts	—67.5 volts
Zero Sig. D.C. Plate Current	40 ma.	40 ma.
Load Resistance, Plate-to-Plate	10,000 ohms	12,000 ohms
Audio Output (2 Tubes)	125 watts	175 watts

T-125

TAYLOR carbon-tantalum plate high-frequency triode, suitable as replacement tube for type 203-A.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.85 amps.
Mutual Conductance	4400 µmhos
Amplification Factor	25
Maximum Plate Dissipation	125 watts
Maximum D.C. Plate Voltage	2000 volts
Maximum D.C. Grid Current	60 ma.
Maximum D.C. Plate Current	200 ma.
Grid-to-Plate Capacitance	4.5 µµfds.
Base	Standard 4-pin, 50-watt

Plate through top of envelope; grid through side.

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	2000 volts
D.C. Plate Current	200 ma.
D.C. Grid Bias	—200 volts
D.C. Grid Current	50 ma.
Grid Driving Power (Approx.)	15 watts
Grid Bias Loss	10 watts
Approx. Power Output	300 watts

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TW-150* (SEE PAGE 263)

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T-155

TAYLOR general purpose triode, suitable for u.h.f. service down to 2 meters.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	4 amps.
Amplification Factor	20
Grid-to-Plate Capacitance	3 µµfds.
Grid-to-Filament Capacitance	2.5 µµfds.
Plate-to-Filament Capacitance	1 µµfd.
Maximum Plate Dissipation	155 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	200 ma.
Maximum D.C. Grid Current	60 ma.
Base	Standard 4-Pin 50-watt

Plate through top, grid through side of envelope.

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	2500 volts
D.C. Grid Voltage	250 volts
D.C. Plate Current	200 ma.
D.C. Grid Current	50 ma.

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T-200*

TAYLOR u.h.f. triode, suitable for oscillator or amplifier service. Similar to HF-300.

Note: Grid driving requirements vary widely under different operating conditions.

CHARACTERISTICS:

Filament Voltage	10 to 11 volts
Filament Current	4 amps.
Amplification Factor	16.6
Grid-to-Plate Capacitance	7 µµfds.
Grid-to-Filament Capacitance	5 µµfds.
Plate-to-Filament Capacitance	3 µµfds.
Maximum Plate Dissipation	200 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	80 ma.
Base	Standard 4-pin, 50-watt.

Plate at top, grid at side of envelope.

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	2500 volts
D.C. Grid Voltage	—300 volts
D.C. Plate Current	300 ma.
D.C. Grid Current	50 ma.
Grid Driving Power (Approx.)	24 watts
Grid Bias Loss	15 watts
Power Input	750 watts
Power Output	560 watts

HD-203A

TAYLOR heavy duty 203A tube, intermediate between 204A and 203A. Class-B audio amplifier or modulator. Class-C r.f. amplifier.

Note: Grid driving power requirements vary over wide limits.

A. F. Driver. 2A3's in push pull with fixed grid bias and input transformer ratio of $\frac{\text{primary}}{\frac{1}{2}\text{ sec.}} = 1.6.$

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	4 amps.
Amplification Factor	25
Grid-to-Plate Capacitance	12 µµfds.
Grid-to-Filament Capacitance	7 µµfds.
Plate-to-Filament Capacitance	5 µµfds.
Maximum Plate Dissipation	150 watts
Maximum D.C. Plate Voltage	2000 volts
Maximum D.C. Plate Current	250 ma.
Maximum D.C. Grid Current	60 ma.
Base	Standard 4-pin, 50-watt

Plate out top of envelope

CLASS-B AUDIO AMPLIFIER (2 TUBES):

D.C. Plate Voltage	1500	1750 volts
D.C. Grid Voltage	—45	—67.5 volts
Load Resistance (Plate-to-Plate)	8000	9000 ohms
Static Plate Current (Per Tube)	18	18 ma.
Max. D.C. Plate Current (2 Tubes)	425	425 ma.
Power Output	400	500 watts
Driver Power	18	18 watts

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	1500	1750 volts
D.C. Grid Voltage	—150	—180 volts
D.C. Plate Current	250	250 ma.
D.C. Grid Current	50	50 ma.
Grid Driving Power	15	19 watts
Grid Bias Loss	7.5	9 watts
Power Input	375	433 watts
Power Output	250	300 watts

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203-B

TAYLOR high-mu triode. Redesigned primarily for class-B audio amplifiers. Somewhat superseded by 203-Z.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.85 amps.
Amplification Factor	25
Maximum Plate Dissipation	55 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	150 ma. (in R.F. circuits)
Grid-to-Plate Capacitance	14 µµfds.
Grid-to-Filament Capacitance	6 µµfds.
Plate-to-Filament Capacitance	5 µµfds.
Base	Standard 4-pin, 50-watt

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HD-203C

HD-211C

TAYLOR u.h.f. and h.f oscillator for diathermy machines.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	4 amps.
Amplification Factor	20 and 12
Grid-to-Plate Capacitance	9 µµfds.
Plate-to-Filament Capacitanct	4 µµfds.
Maximum Plate Dissipation	150 watts
Maximum D.C. Plate Voltage	2000 volts
Maximum D.C. Plate Current	250 ma.
Maximum D.C. Grid Current	60 ma.
Base	Standard 4-pin, 50-watt

Plate at top of envelope.

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203-Z*

TAYLOR zero-bias audio amplifier. Designed for class-B audio amplifiers or modulators with zero grid bias. Can be operated as r.f. amplifier below 15 Mc.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.85 amps.
Mutual Conductance	5900 μmhos.
Amplification Factor	85
Maximum D.C. Plate Voltage	1250 volts
Maximum Plate Dissipation	65 watts
Base	Standard 4-pin, 50-watt

Plate through top of envelope.

CLASS-B MODULATOR (2 TUBES):

D.C. Plate Voltage	900	1000	1100	1250	volts
D.C. Grid Bias	zero	zero	zero	zero	volts
Zero Signal D.C. Plate Current (Per Tube)	30	35	40	45	ma.
Max. Signal D.C. Plate Current (2 Tubes)	350	300	350	350	ma.
Load Impedance, Plate-to-Plate	5400	6900	6700	7900	ohms
Audio Power Output	200	200	260	300	watts
Approx. Grid Driving Power	7	7	7	7	watts

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756

TAYLOR triode for doubler and class-C operation. Class-B audio amplifier. Somewhat superseded by T-40.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	2 amps.
Amplification Factor	25
Grid-to-Plate Capacitance	8 μμfds.
Grid-to-Filament Capacitance	3.5 μμfds.
Plate-to-Filament Capacitance	2.7 μμfds.
Maximum D.C. Plate Voltage	850 volts
Maximum D.C. Plate Current	110 ma.
Maximum D.C. Grid Current	20 ma.
Base	UX 4-pin Isolantite

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814

TAYLOR h.f. triode. Class-C r.f. amplifier of high output with relatively low grid driving requirements.

Frequency Range: 2 to 30 Mc.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	4 amps.
Amplification Factor	12
Grid-to-Plate Capacitance	13 μμfds.
Grid-to-Filament Capacitance	7 μμfds.
Plate-to-Filament Capacitance	5.5 μμfds.
Maximum Plate Dissipation	200 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D.C. Plate Current	300 ma.
Maximum D.C. Grid Current	75 ma.
Base	Standard 4-Pin 50-Watt

Plate through top of envelope.

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	2000 volts
D.C. Grid Voltage	—400 volts
D.C. Plate Current	300 ma.
D.C. Grid Current	45 ma.
Grid Driving Power	25 watts
Grid Bias Loss	18 watts
Power Input	600 watts
Power Output	400 watts

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822*

TAYLOR high-mu triode. Class-B audio amplifier or modulator. May be used in class-C r.f. service.

A.F. Driver: Push-pull parallel 2A3 tubes with input transformer ratio of $\frac{\text{Primary}}{\frac{1}{2}\text{ sec.}} = 1.6$.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	4 amps.
Amplification Factor	27
Grid-to-Plate Capacitance	14 μμfds.
Grid-to-Filament Capacitance	8 μμfds.
Plate-to-Filament Capacitance	6 μμfds.
Maximum Plate Dissipation	200 watts
Maximum D. C. Plate Voltage	2000 volts
Maximum D.C. Plate Current	300 ma.
Maximum D.C. Grid Current	60 ma.
Base	Standard 4-Pin 50-Watt

Plate through top of envelope.

CLASS-B AUDIO AMPLIFIER (2 TUBES)

D.C. Plate Voltage	2000 volts
D.C. Grid Voltage (Approx.)	—75 volts
Zero Signal D.C. Plate Current	50 ma.
Maximum Signal D.C. Plate Current	450 ma.
Load Impedance (Plate-to-Plate)	9000 ohms
Power Output	500 watts
Driving Power	30 watts

CLASS-C R.F. AMPLIFIER:

D.C. Plate Voltage	2000 volts
D.C. Grid Voltage	—220 volts
D.C. Plate Current	300 ma.
D.C. Grid Current	50 ma.
Grid Driving Power	20 watts
Grid Bias Loss	11 watts
Power Input	600 watts
Power Output	400 watts

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825

TAYLOR 40-watt triode. Intermediate between 801 and 211 tubes. Class-B audio amplifier operating in the class-AB region. Class-B. r.f. amplifier for telephony or telegraphy in high-frequency transmitters. Superseded by T-40.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	2 amps.
Amplification Factor	8
Grid-to-Plate Capacitance	7 μμfds.
Grid-to-Filament Capacitance	3 μμfds.
Plate-to-Filament Capacitance	2.7 μμfds.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	850 volts
Maximum D.C. Plate Current	110 ma.
Maximum D.C. Grid Current	25 ma.
Base	UX 4-pin

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841A

TAYLOR h.f. triode. Doubler or buffer stage in high-power transmitters. R.F. amplifier down to 7½ meters. Somewhat superseded by T-55.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	2 amps.
Amplification Factor	14.6
Grid-to-Plate Capacitance	9 μμfds.
Grid-to-Filament Capacitance	3.5 μμfds.
Plate-to-Filament Capacitance	2.5 μμfds.
Maximum Plate Dissipation	50 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	150 ma.
Maximum D.C. Grid Current	30 ma.
Base	UX 4-pin

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TW-150*

Taylor low-C general purpose triode. Oscillator, class C r.f. amplifier, class B modulator. Thin wall graphite anode permits high dissipation with small size anode, resulting in lower interelectrode capacity for given plate dissipation.

CHARACTERISTICS:

Eb Max Non-Modulated	3000 volts d.c.
Eb Max. Modulated	3000 volts d.c.
Ib Max. Modulated	200 ma.
Ic Max. Modulated	60 ma.
Plate Dissipation	150 watts
Amp. Factor	35

INTERELECTRODE CAPACITIES:

Grid to Plate	2.3 μμfds.
Grid to Filament	4.4 μμfds.
Plate to Filament	0.5 μμfds.

TYPICAL OPERATION—CLASS C TELEGRAPHY:

D.C. Plate Volts	2000	2500	3000	volts
D.C. Plate Current	200	200	200	ma.
D.C. Grid Current	46.25	45.2	45.3	ma.
D.C. Grid Bias Volts*	—92	—120	—173	volts

Grid Volts (peak a.c.)	322	350	411	
Plate Dissipation	112	127	135	watts
Power Output	288	373	465	watts
Plate Efficiency	72%	74.5%	77.5%	
Plate Angle	165°	160°	150°	
Driving Power	13.35	14.25	16.75	watts

TYPICAL OPERATION—CLASS C TELEPHONY:

D.C. Plate Volts	2000	2500	3000	volts
D.C. Plate Current	200	185	165	ma.
D.C. Grid Current	46.2	43.7	39.6	ma.
D.C. Grid Bias Volts *	—142	—195	—257	volts
Grid Volts (peak a.c.)	379	430	487	
Plate Dissipation	103	101	95	watts
Power Output	297	361	400	watts
Plate Efficiency	74.25%	78%	80.75%	
Plate Angle	150°	140°	130°	
Grid Driving Power	15.75	16.9	17.35	watts

* Bias should be secured from combination of battery, (or power pack), and grid leak.

Battery Bias Volts	60	75	90
Grid Leak Ohms (1)	1775	2740	4225

(1) For two tubes in parallel or push-pull grid leak will be one-half above.

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WESTERN ELECTRIC

WE-212E

WESTERN ELECTRIC general purpose triode for frequencies below 1500 kc. Normally used in audio circuits.

Frequency Range: 100% ratings up to 1.5 Mc.

CHARACTERISTICS:

Filament Voltage	14 volts
Filament Current	6 amps.
Amplification Factor	16
Grid-to-Plate Capacitance	18.8 μμfds.
Grid-to-Filament Capacitance	14.9 μμfds.
Plate-to-Filament Capacitance	8.6 μμfds.
Maximum Plate Dissipation	275 watts
Maximum D.C. Plate Voltage	3000
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	75 ma.

Special W.E. base.

CLASS-B AUDIO AMPLIFIER (2 TUBES):

D.C. Plate Voltage	1500	2000	volts
D.C. Grid Voltage	—75	—105	volts
Maximum Signal D.C. Plate Current	600	600	ma.
Zero Signal D.C. Plate Current	80	100	ma.
Load Resistance (Plate-to-Plate)	5900	8000	ohms
Power Output	500	650	watts
Driver Power	50	50	watts

R.F. SERVICE:

	CLASS-B R.F.	CLASS-C TELEPHONY	CLASS-C TELEGRAPHY	
D.C. Plate Voltage	2000	1500	2000	volts
D.C. Grid Voltage	—120	—200	—250	volts
D.C. Plate Current	200	300	300	ma.
D.C. Grid Current	...	60	60	ma.
Grid Drive (Approx.)	...	21	25	watts
Grid Bias Loss	...	12	15	watts
Power Input	400	450	600	watts
Power Output	135	300	400	watts

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WE-242A

WESTERN ELECTRIC triode. R.f. amplifier or oscillator. Audio amplifier in modulators.

Frequency Range: 100% up to 6 Mc. 50% of plate voltage ratings at 30 Mc.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	12.5
Grid-to-Plate Capacitance	13.0 μμfds.
Grid-to-Filament Capacitance	6.5 μμfds.
Plate-to-Filament Capacitance	4.0 μμfds.
Maximum Plate Dissipation	85 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	150 ma.
Maximum D.C. Grid Current	50 ma.
Base	4-pin, 50-watt

CLASS-B AUDIO AMPLIFIER (2 TUBES):

D.C. Plate Voltage	1000	1250	volts
D.C. Grid Voltage	—55	—80	volts.
Maximum Signal D.C. Plate Current	300	300	ma.
Zero Signal D.C. Plate Current	60	60	ma.
Load Resistance (Plate-to-Plate)	6000	8000	ohms
Power Output	165	200	watts
Driver Power	25	25	watts

R.F. SERVICE:

	CLASS-B R.F.	CLASS-C TELEPHONY	CLASS-C TELEGRAPHY	
D.C. Plate Voltage	1250	1000	1250	volts (max.)
D.C. Grid Voltage	—90	—175	—200	volts
D.C. Plate Current	106	150	150	ma.
D.C. Grid Current	...	30	30	ma.
Grid Driving Power	...	10	11	watts
Grid Bias Loss	...	5	6	watts
Power Input	132.5	150	187.5	watts
Power Output	44	100	125	datts

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WE-251A

WESTERN ELECTRIC h.f. triode broadcast or police transmitter tube for r.f. or a.f. service.

Frequency Range: 100% ratings up to 30 Mc. 66% plate voltage ratings up to 50 Mc.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	16 amps.
Amplification Factor	10.5
Grid-to-Plate Capacitance	8 μμfds.
Grid-to-Filament Capacitance	10 μμfds.
Plate-to-Filament Capacitance	6 μμfds.
Maximum Plate Dissipation	1000 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	600 ma.
Maximum D.C. Grid Current	150 ma.

Air-cooled tube.

R.F. SERVICE:

	CLASS-B R.F.	CLASS-C TELEPHONY	CLASS-C TELEGRAPHY	
D.C. Plate Voltage	3000	2250	3000	volts*
D.C. Grid Voltage	—300	—470	—550	volts
D.C. Plate Current	400	400	600	ma.
Power Input	1200	900	1800	watts
Power Output	400	600	1200	watts

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* Maximum.

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WE-254B

Tetrode r.f. amplifier. *Frequency Range:* 100% up to 15 Mc. 66⅔% at 20 Mc.

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Plate-to-Grid Capacitance	0.85 μμfd.
Input Capacitance	11.2 μμfds.
Output Capacitance	5.4 μμfds.
Amplification Factor	100
Maximum Plate Dissipation	25 watts
Maximum Screen Dissipation	4 watts
Maximum D.C. Plate Voltage	750 volts
Maximum D.C. Plate Current	75 ma.
Maximum D.C. Grid Current	25 ma.
Base	4-pin, plate through top of envelope.

R.F. SERVICE

	CLASS-B R.F.	CLASS-C TELEGRAPHY		
D. C. Plate Voltage	750	500	750	volts
D.C. Screen Voltage	150	150	150	volts

D.C. Grid Voltage	—70	—125	—125	volts
D.C. Plate Current	50	75	75	ma.
Approximate Power Output	12.5	25	37.5	watts

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WE-270A

WESTERN ELECTRIC general purpose triode for broadcast station operation in high-frequency transmitters.

Frequency Range: 100% ratings up to 7.5 Mc. 33% plate voltage ratings at upper limit of 22 Mc.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	9.75 amps.
Amplification Factor	16
Grid-to-Plate Capacitance	21 μμfds.
Grid-to-Filament Capacitance	18 μμfds.
Plate-to-Filament Capacitance	2 μμfds.
Maximum Plate Dissipation	350 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	375 ma.
Maximum D.C. Grid Current	75 ma.

CLASS B AUDIO AMPLIFIER (2 TUBES):

D.C. Plate Voltage	2000	2500	volts
D.C. Grid Voltage	—105	—140	volts
Maximum Sig. D.C. Plate Current	750	750	ma.
Zero Sig. D.C. Plate Current	120	120	ma.
Load Resistance (Plate-to-Plate)	6000	8000	ohms
Power Output	850	1000	watts
Driver Power	75	75	watts

R.F. SERVICE:

	CLASS-B R.F.	CLASS-C TELEPHONY	CLASS-C TELEGRAPHY	
D.C. Plate Voltage	3000	2250	3000	volts (max.)
D.C. Grid Voltage	—180	—300	—375	volts
D.C. Plate Current	175	300	350	ma.
D.C. Grid Current	...	70	70	ma.
Grid Driver (Approx.)	...	32	37	watts
Grid Bias Loss	...	21	11	watts
Power Input	525	657	1040	watts
Power Output	175	450	700	watts

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WE-279A

WESTERN ELECTRIC h.f. triode broadcast or police station operation for A.F. or R.F. service.

Frequency Range: 100% ratings up to 20 Mc. 50% plate voltage ratings at 40 Mc.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	21 amps.
Amplification Factor	10
Grid-to-Plate Capacitance	18 μμfds.
Grid-to-Filament Capacitance	15 μμfds.
Plate-to-Filament Capacitance	7 μμfds.
Maximum Plate Dissipation	1200 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	800 ma.
Maximum D.C. Grid Current	150 ma.

CLASS-B AUDIO AMPLIFIER (2 TUBES):

D.C. Plate Voltage	2000	2500	volts
D.C. Grid Voltage	—150	—200	volts
Maximum Signal D.C. Plate Current	1600	1600	ma.
Zero Signal D.C. Plate Current	220	300	ma.
Load Resistance (Plate-to-Plate)	2240	2800	ohms
Power Output	1760	2200	watts
Driver Power	100	100	watts

R.F. SERVICE:

	CLASS-B R.F.	CLASS-C TELEPHONY	CLASS-C TELEGRAPHY	
D.C. Plate Voltage	3000	2250	3000	volts
D.C. Grid Voltage	—325	—450	—600	volts
D.C. Plate Current	600	600	800	ma.
Power Input	1800	1350	2400	watts
Power Output	600	900	1600	watts

WE-282A

WESTERN ELECTRIC tetrode. Screen-grid r.f. amplifier or frequency doubler.

Frequency Range: 100% ratings up to 30 Mc. 50% ratings at 60 Mc.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3 amps.
Amplification Factor	100
Plate-to-Grid Capacitance	0.2 μμfd.
Input Capacitance	12.2 μμfds.
Output Capacitance	6.8 μμfds.
Maximum Plate Dissipation	70 watts
Maximum D.C. Plate Voltage	1000 volts
Maximum D.C. Plate Current	100 ma.
Maximum D.C. Grid Current	50 ma.
Maximum Screen Grid Dissipation	5 watts
Base	Standard 4-pin 50-watt

R.F. SERVICE:	CLASS-B R.F.	CLASS-C TELEGRAPHY		
D.C. Plate Voltage	1000	750	1000	volts
D.C. Grid Voltage	—90	—150	—150	volts
D.C. Screen Grid Voltage	150	150	150	volts
D.C. Plate Current	100	100	100	ma.
Plate Power Input	100	75	100	watts
Approximate Power Output	33	50	67	watts

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WE-284D

WESTERN ELECTRIC triode for audio-frequency applications.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Maximum Plate Voltage	1250 volts
Mutual Conductance	2500 μmhos.
D.C. Plate Current	175 ma.
Class-A Output, 2 Tubes	50 watts
Class-B Output, 2 Tubes	165 watts

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WE-300A

WESTERN ELECTRIC class-A audio amplifier or modulator, especially suitable for automobile transmitters.

Note: If fixed C bias is used, the plate current should be limited to not over 70 ma.

CHARACTERISTICS:

Filament Voltage	5.0 volts A.C. or D.C.
Filament Current	1.2 amp.
Amplification Factor (Approx.)	3.8
Grid-to-Plate Capacitance	15 μμfds.
Grid-to-Filament Capacitance	9 μμfds.
Plate-to-Filament Capacitance	4.3 μμfds.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	450 volts
Maximum D.C. Plate Current	100 ma.

CLASS A (SINGLE TUBE) MODULATOR:

D.C. Plate Voltage	200	250	350	450	volts
D.C. Grid Voltage	—39	—45	—71	—97	volts.
D.C. Plate Current	40	80	80	80	ma.
Load Resistance	2500	1500	2200	3000	ohms
Power Output	2.6	5.0	9.6	14.6	watts

PUSH-PULL OPERATION (2 TUBES):

D.C. Plate Voltage	450 volts
D.C. Plate Current (Per Tube)	70 ma.
Mutual Conductance	5200 ohms
Class-A Power Output	25 watts

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304B*

WESTERN ELECTRIC u.h.f. oscillator or amplifier up to 300 Mc. Similar to RCA 834.

FREQUENCY	CLASS-C TELEGRAPHY PLATE VOLTS	OSCILLATOR PLATE VOLTS
100 Mc.	1250	1000
200 Mc.	1000	800
300 Mc.	750	600

CHARACTERISTICS:

Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Amplification Factor	11
Grid-to-Plate Capacitance	2.5 μμfds.
Grid-to-Filament Capacitance	2.0 μμfds.
Plate-to-Filament Capacitance	0.7 μμfd.
Maximum Plate Dissipation	50 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	100 ma.
Maximum D.C. Grid Current	25 ma.
Base	UX 4-pin

Plate and Grid at Top of Envelope.

CLASS B AUDIO AMPLIFIER (2 TUBES):

D.C. Plate Voltage	750	1000	1250	volts
D.C. Grid Voltage	—55	—85	—110	volts
Max. Sig. D.C. Plate Cur.	200	200	200	ma.
Zero Sig. D.C. Plate Cur.	40	40	40	ma.
Load Res. (Plate-to-Plate)	7000	10,000	14,000	ohms
Power Output	85	110	140	watts
Driver Power	10	10	10	watts

CLASS-C SERVICE:
See 834.

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WE-305A

WESTERN ELECTRIC r.f. amplifier, oscillator or harmonic generator at ultra-high frequencies.

Frequency Range: 100% ratings up to 50 Mc. 50% plate voltage rating at 100 Mc.

Note: Plate, screen, and filament center-tap leads come out through rods at top of tube to enable short leads at very high frequencies. Cooling lugs of copper are needed for operation at frequencies above 50 Mc.

CHARACTERISTICS:

Filament Voltage	10 volts
Filament Current	3.1 amps.
Plane-to-Grid Capacitance	0.14 μμfd.
Input Capacitance	10.5 μμfds.
Output Capacitance	5.4 μμfds.
Maximum Plate Dissipation	60 watts
Maximum Screen Dissipation	6 watts
Maximum D.C. Plate Voltage	1000 volts
Maximum D.C. Screen Voltage	200 volts
Maximum D.C. Plate Current	125 ma.
Maximum D.C. Grid Current	40 ma.

R.F. SERVICE

	CLASS-B R.F.		CLASS-C R.F.		
D.C. Plate Voltage	1000	1000	750	500	volts
D.C. Grid Voltage	—135	—250	—175	—200	volts
D.C. Screen Voltage	200	200	200	200	volts
D.C. Plate Current	90	125	125	125	ma.
Approx. Power Output	30	85	65	42	watts

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WE-307A

WESTERN ELECTRIC pentode. Oscillator, high-frequency amplifier and doubler, suppressor-modulated amplifier. Designed for portable h.f. and u.h.f. transmitters.

Frequency Range: 100% ratings up to approx 60 Mc.

Unusual Feature: Quick-heating filament instead of heater for intermittent use in automobile transmitters.

CHARACTERISTICS:

Filament Voltage	5.5 volts
Filament Current	1.0 amps.
Grid-to-Plate Cap.	0.55 μμfds.
Input Cap	15 μμfds.
Output Cap.	12 μμfds.
Max. Plate Dissipation	15 watts

R.F. SERVICE:

	SUPPRESS. MOD.	CLASS-C TELEG.	
D.C. Plate Voltage	500	500	volts
D.C. Screen Voltage	200	200	volts
D.C. Suppressor Voltage	—50	00	volts
D.C. Grid Voltage	—35	—35	volts
Peak R.F. Grid Voltage	50	50	volts
Peak A.F. Grid Voltage	50	00	volts
D.C. Plate Current	40	52	ma.
D.C. Screen Current	21	18	ma.
Power Output (Approx.)	6	17	watts
Screen Resistor	14,000	14,000	ohms

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WE-308B

WESTERN ELECTRIC triode, designed for modulators in radio-telephone transmitters.

CHARACTERISTICS:

Filament Voltage	14 volts
Filament Current	6 amps.
D.C. Plate Current	300 ma.
Maximum Plate Voltage	2250 volts
Mutual Conductance	7500 μmhos
Class-A Output (2 Tubes)	100 watts
Class-B Output (2 Tubes)	500 watts

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WE-316A

U.h.f. oscillator or amplifier especially designed for operation at frequencies above 100 megacycles. The upper limit of oscillation as a regenerative negative grid oscillator is 750 Mc.

Note: Outputs of approximately 8 watts can be obtained at ¾ meter, and 4 watts at ½ meter (600 Mc.).

CHARACTERISTICS:

Filament Voltage	2 volts
Filament Current	3.65 amps.
Thermionic Emission	0.4 amp.
Amplification Factor	6.5
Grid-to-Plate Capacitance	1.6 μμfds.
Grid-to-Filament Capacitance	1.2 μμfds.
Plate-to-Filament Capacitance	0.8 μμfds.
Maximum Plate Dissipation	30 watts
Maximum D.C. Plate Voltage	450 volts
Maximum D.C. Plate Current	80 ma.
Maximum D.C. Grid Current	10 ma.

All leads extend directly out from tube elements.

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WE-356A

General-purpose u.h.f. triode. Oscillator, r.f. amplifier and modulator. Full input to 100 Mc.

CHARACTERISTICS:

Filament voltage	5.0 volts, a.c. or d.c.
Nominal filament current	5.0 amperes
Amplification factor	50
Grid to plate transconductance	3800 micromhos
Plate resistance	13,000 ohms

AVERAGE DIRECT INTERELECTRODE CAPACITANCES:

Plate to grid	2.75 mmf
Plate to filament	1.0 mmf
Grid to filament	2.25 mmf

MAXIMUM RATINGS:

Max. direct plate voltage	1500 volts
Max. direct plate current	120 ma.
Max. plate dissipation	50 watts
Max. r-f grid current	6 amps.
Max. direct grid current	35 ma.
Max. frequency for above ratings	100 megacycles
Max. plate voltage for upper frequency limit of 250 mc.	1000 volts

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WE-357A

High power, general purpose u.h.f. triode. Oscillator, r.f. amplifier and class-B modulator.

CHARACTERISTICS:

Filament voltage	10.0 volts
Nominal filament current	10.0 amperes
Amplification factor	30
Grid-plate transconductance	9000 micromhos
Plate resistance	3300 ohms

AVERAGE VALUES OF THE DIRECT CAPACITIES BETWEEN THE ELECTRODES:

Grid to Plate	4.25 μμfds.
Grid to filament	9.5 μμfds.
Plate to filament	2.5 μμfds.

MAXIMUM RATINGS:

Maximum direct plate voltage	4000 volts
Maximum direct plate current	0.5 ampere
Maximum continuous plate dissipation	350 watts
Maximum direct grid current	0.100 ampere

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RECTIFIERS

RK-19, RK-21, RK-22

RAYTHEON rectifiers. Intermediate between 83 and 866 rectifiers, but of high vacuum type construction. Designed for 1000-volt d.c. supplies.

CHARACTERISTICS:

	FULL-WAVE RK-19	HALF-WAVE-RK-21	FULL-WAVE RK-22
Heater Voltage	7.5	2.5	2.5 volts
Heater Current	2.5	4.0	8.0 amps.

Maximum RMS Voltage Per Plate	1250 volts
Maximum Peak Inverse Voltage	3500 volts
Maximum Peak Current	600 ma.
Maximum D.C. Load Current (with Cond. Input)	200 ma.

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RX-21*

EIMAC mercury-vapor rectifier tube similar to the KY-21 except that the RX-21 has no control grid.

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KY-21*

EIMAC grid-controlled mercury-vapor type rectifier. Half-wave rectifier tube which has a control grid to permit power circuit keying. Rated to supply a d.c. load of 1.5 amperes at as high as 3500 volts with choke coil input to the filter circuit. (Full-wave operation with two tubes). Filament 2.5 volts at 10 amperes.

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249B

TAYLOR half-wave mercury vapor rectifier, somewhat similar to Taylor 866-B except for filament.

CHARACTERISTICS:

Filament Voltage	2.5 volts
Filament Current	7.5 amps.
Peak Inverse Voltage	10,000 volts
Peak Current	2.5 amps.
Voltage Drop per Tube	15 volts

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836

RCA half-wave high-vacuum rectifier.

CHARACTERISTICS:

Heater Voltage	2.5 volts
Heater Current	5 amps.
Peak Inverse Voltage	5000 volts
Peak Plate Current	1.0 amp.
Average Plate Current	0.25 amp.
Base	Standard 4-pin

Plate through top of bulb.

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866 Jr.*

TAYLOR Mercury-vapor half-wave rectifier for operation in full-wave or bridge rectifier systems. Intermediate in load capability between the type 866 and 83 rectifiers.

CHARACTERISTICS:

Filament Voltage	2.5 volts
Filament Current	2.5 amps.
Maximum RMS A.C. Voltage	1250 volts
Maximum D.C. Load Current (Choke Input)	250 ma.
Base	UX 4-pin, Isolantite

866B*

TAYLOR mercury-vapor half-wave rectifier for operation in full-wave or bridge rectifier systems. Intermediate in load capacity between 866 and 872A rectifiers.

CHARACTERISTICS:

Filament Voltage	5 volts
Filament Current	5 amps.
Peak Inverse Voltage	8500 volts
Peak Current	2 amp.

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866* -866A*
872* -872A *

Note: The 866-A and 872-A rectifiers are limited to 5,000 peak inverse voltage if the temperature near the base of the tube is below 15° C., or above 50° C.

Uses: Half-wave rectifiers, of the mercury-vapor type, for high-voltage plate supplies in radio transmitters. Two or four tubes may be connected in full-wave rectifier circuits. (See chapter 17.)

Max. peak inverse voltage is the highest peak voltage that the rectifier tube can safely stand in the opposite direction to which it is supposed to pass current. In a single-phase, full-wave choke input circuit, the peak inverse voltage is approx. 1.4 times the r.m.s. voltage applied to the tube. In a single phase, half-wave circuit with condenser input, the peak inverse voltage may be 2.8 times the r.m.s. value.

Max. peak plate current is the highest value of peak current that the rectifier tube can safely pass. With large choke inductance input to the filter, the peak current is not much higher than the load current. With condenser input, peak current may be 4 times as high as load current.

CHARACTERISTICS:	866	866A	872	872A
Filament Voltage	2.5	2.5	5.0	5.0 volts
Filament Current	5.0	5.0	10	6.75 amps.
Peak Inverse Voltage	7500	10000	7500	10000 volts*
Peak Current	1.0	1.0	5.0	5.0 amps*
Tube Voltage Drop (Approx.)	15	10	15	10 volts
Base	4-pin	4-pin	50-watt	50-watt

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* Maximum.

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CCS and ICAS RATINGS

As we go to press the RCA Manufacturing Co., Inc., announces a new system of rating their air-cooled transmitting tubes.

The CCS (Continuous Commercial Service) ratings are essentially the same as the maximum ratings shown for RCA types in the preceding tables.

The ICAS (Intermittent Commercial & Amateur Service) ratings, however, permit a considerable increase in the power input to a particular tube, and consequently the power output rating is also increased.

Complete data for the operation of a particular type under the new CCS and ICAS ratings may be obtained on request from RCA.

TEN

Transmitter Design

THE amateur who is technically inclined will realize much pleasure not only in the actual construction of his transmitter but also in planning it. Receivers are designed pretty much as an integral unit, but there is an infinite combination of tubes, excited circuits, amplifier circuits, and power supply arrangements which one may incorporate in a "200-watt" transmitter. For this reason few complete transmitter circuit diagrams are shown in this book.

If a tube requires 25 watts r.f. driving power for a certain application, it is obvious that it makes little difference just what exciter circuit is used so long as it puts out 25 watts on the desired bands. Because of its characteristics one exciter may be preferred by one amateur, another exciter by another amateur.

It is fortunate that there is this flexibility with regard to transmitter design, because it makes it easy for an amateur to start out with a low power transmitter and then add to it from time to time, perhaps later going on phone. It also permits one a certain degree of "custom tailoring" of his transmitter to suit his particular requirements.

In several following chapters of this book are described inexpensive yet versatile and efficient exciters, power amplifiers, speech amplifiers, modulators, and power supplies. It is the purpose of this chapter to give the reader sufficient general design information to be able to work out various combinations of these independent yet complementary units and to evolve one which is well suited to his particular needs and pocketbook. However, before proceeding further one should be thoroughly familiar with the chapter on fundamental transmitter theory, chapter 7.

Exciters and Transmitters

A five-watt crystal oscillator may be accurately referred to as a transmitter *when it is used to feed an antenna.* On the other hand a multi-tube r.f. unit winding up in a 150-watt power amplifier may be properly termed an exciter *when it is used to drive a higher power amplifier.* Thus we see that any r.f. unit, even a simple oscillator, may be either an exciter or a transmitter depending upon how it is used.

The requirements for a low power (15 to 75 watt) transmitter are practically the same as for an exciter of the same output: The overall efficiency should be good, the unit should cover all the desired bands with a minimum of coil changing and retuning, and both initial cost and upkeep should be low in proportion to the power output.

Virtually all medium and high power amplifiers (200-800 watts output) are very much the same except for the particular make and power rating of components used. Perhaps half the amateurs making use of high power use cross-neutralized push-pull final amplifiers which differ only in the method of obtaining bias and method of antenna coupling.

For this reason, several low power r.f. units and several medium and high power amplifiers are described, and the reader is permitted to use his own ingenuity in working out the combination which appears to fit his requirements. If one is designing a complete transmitter, to which no additions are to be made, it is probably best to decide first upon the final amplifier and then work backwards from there, the driving requirements of the particular tubes used determining the exciter. On the other hand many amateurs do not have the wherewithal to start right off with high power, and therefore very likely to decide upon the highest powered r.f. unit they can afford and let it go at that. In the latter event the unit may have slightly more output than required to drive an amplifier whose addition is contemplated at a later date. However, a reserve of excitation power is not a liability and does not represent poor economy unless carried to extremes. Hence, one who cannot afford to start off with high power can pick out the highest powered exciter he can afford and use it as a transmitter, without worrying too much about its adaptability for use with a particular power amplifier later on. A 75-watt r.f. unit is slightly larger than necessary for driving a pair of 35T's, HK54's, 808's, T40's, etc., but there is no reason why one should not use such a combination. *Not enough* excitation is a much more serious condition than an overabundance of excitation, there being no objection to the latter except from an economic standpoint.

Choosing the Tubes

Low power exciters invariably use receiving tubes or "modified" receiving tubes for the sake of economy. Large scale production brings the cost of 42's, 6L6's, etc. down to a price that would be impossible were they designed for and purchased only by amateurs. Some tubes, like the T21 and 807, resemble standard receiving tubes in one or more respects and while costing more than a standard receiving tube equivalent (6L6G in this case) are still obtainable at a price below that which would be necessary were they not outgrowths of standard receiving tubes.

The tubes in the high power amplifier and in the class B modulator (if used) should be chosen with care. While in general there is little to choose between tubes by reliable manufacturers, some are better adapted than others for certain applications. Also, the more recently released tubes of a particular manufacturer are usually better and less expensive than older tubes of the same general type. The tubes that are recommended as being preferable to similar tubes by the same manufacturer are marked with an asterisk in the Tube Tables listing, chapter 9. Interpretation of these asterisks and also the question of driving power are covered in the introductory portion of that chapter. The latter is an important item, as it determines the required power output of the exciter unit or preceding stage.

Driving Power

It is always advisable to have a slight reserve of driving power in order to be on the safe side. Therefore the potential output of an exciter on the band upon which its output is least (usually the highest frequency band) should be slightly greater than the excitation requirements of the following stage as determined from the tube tables. The requirements for most all applications are given for the more popular tubes.

Plate modulated class C amplifiers require the most excitation, the tube requiring full maximum rated grid current and preferably at least 2½ times cutoff bias if full plate input is to be applied.

C.w. and buffer amplifiers should preferably be run at full rated grid current (though they *may* be run with as much as 50% less) and at 1½ times cutoff or greater bias. Thus an unmodulated final amplifier or buffer can be used with considerably less excitation than a plate modulated stage of the same power.

Cathode modulated amplifiers require about the same amount of excitation power as c.w. amplifier, the bias being greater but the grid current much less. Cathode modulated stages are commonly run at from 2½ to 4 times cutoff bias at approximately an eighth the grid current recommended for plate modulation.

High efficiency grid modulation requires still less excitation. The bias is from 2 to 4 times cutoff but the grid current is very low, seldom greater than a few ma. even for high power stages. The power dissipated in the grid swamping resistor, a necessary adjunct to a correctly operated grid modulated stage, keeps the excitation requirements from being less than they are.

The excitation required for a typical 200-watt output amplifier will run about as follows: Plate modulated, 35 watts; c.w. or buffer, 20 watts; cathode modulated, 15 watts; grid modulated, 10 watts. The whole problem of excitation requirements depends so much upon operating conditions that one had best refer to the manufacturers data sheets or to chapter 9 of this Handbook.

The question of calculating excitation requirements for a doubler stage was not covered in the foregoing discussion, because the excitation power required depends to such a great degree upon the doubler efficiency desired. For high efficiency doublers, the bias should be at least 5 times cutoff and the grid current about half the maximum rated value for the tube. Thus it is seen that for good doubler efficiency a tube requires even more excitation power than for a plate modulated stage of the same power output rating.

Also to be taken into consideration when tentatively planning a transmitter are such things as the limiting factor in tube design. For instance in a grid modulated transmitter the output is always limited by the plate dissipation, while for plate modulated phone work either the plate voltage or plate current rating is exceeded first. Thus we see that for grid modulation a tube with high plate dissipation is of prime importance, while for plate modulated operation the matter of filament emission and insulation are of greatest importance.

Another thing to be taken into consideration, especially when designing a phone transmitter, is the item of filament voltage. Obviously a saving can be effected if both r.f. amplifier tubes and modulator tubes can be run from the same filament winding.

Planning

It is suggested that the low power r.f. units of chapter 11 be constructed exactly as shown, the diagram and values being followed implicitly. However, in the final amplifier some leeway with regard to choice of tubes, bias supply, and such can be tolerated, and for that reason one need not adhere to the particular tubes used in the models illustrated in chapter 12. Also, as pointed out before, it is not necessary to use any particular exciter with a certain type of final amplifier.

Thus the problem of designing a transmitter from the data given in this handbook is somewhat as follows, an example of the things to be considered when laying out, say, a 200-watt phone transmitter.

1. What type of modulation: grid, plate, cathode, etc.? (Tubes and excitation and speech requirements will be determined by this; so it should be decided first.) Suppose we decide upon plate modulation. Then a pair of T40's will deliver about 200 watts, and for plate modulation will require about 12 watts excitation for good modulation.

2. What for an exciter? To be on the safe side we figure on about 20 watts driving power. Any exciter using a 6L6, T21, or 807 in the last stage, running at 500 volts, will deliver this amount of power. Suppose we are not interested in 160-meter operation but are interested in quick band changes, and decide upon a "4-25" exciter (described in chapter 11).

3. What for a modulator? By proper design of the power supply, to assure good regulation, the same supply can be used for plate voltage for both modulated and modulator stages. Hence the modulator tubes should be capable of running at 1100 volts (the plate voltage we have chosen for the T40 class C stage) and deliver at least 125 watts of audio power. A pair of TZ40's will deliver

this power at 1100 volts with very little drive and with but a small kick in plate current (especially on voice sounds). So we decide on TZ40's for the modulator, and we can run them off the same filament transformer as the T40's. A 125-watt variable-ratio modulation transformer is a common size and will serve to couple the modulator to the class C stage.

4. What for a speech amplifier? The front end of the speech amplifier will depend upon the gain of the particular microphone used. The TZ40 modulators need not be driven hard for only 125 watts output; hence a pair of push-pull 45's will serve nicely. Suppose we have a crystal microphone of the diaphragm type; a suitable speech system would be a 6SJ7 pentode R-C coupled into a 6J5 triode, transformer coupled through a 1:3 ratio step up push-pull input transformer to the 45's, the amplifier having integral 350-volt power supply. The gain will be sufficient for close-talking purposes.

5. How about power supplies? We have decided upon a single 1100-volt supply for both final amplifier and modulators. Because of the varying demand upon the supply by the modulators, excellent regulation is absolutely necessary. This calls for a pair of 866 rectifiers with a transformer delivering about 1300 volts r.m.s. each side of center tap, rated at 400 watts; a swinging input choke of 350 ma. rating, at least 5 hy. inductance at full current; a 4 μfd. 1500-volt filter condenser; a smoothing choke of 250 ma. rating; and a 2 μfd. 1500-volt condenser. The class B modulators, being in push-pull, need but little filter. Hence we take off plate voltage for them at the first filter condenser. The second section of filter then serves only for the class C stage, giving a very low percentage of ripple. This also decouples the modulator and class C stage, improving the quality of modulation, and results in less plate voltage drop during modulation than would be the case if the Class B plate current had to flow through the resistance of both filter chokes instead of just one.

For the exciter a 475-volt, 175-ma. supply should suffice, when only 20 watts output is required. This can consist of an 83 rectifier in conjunction with a choke-input filter with proper components. A separate filament transformer should be used so that the primary of the plate transformer may be opened without killing the filaments of the exciter tubes or the 83 rectifier.

6. Metering provision. Shall we use meter jacks, plugging one or two meters into jacks wired into the various stages, thus using a minimum number of meters to measure all circuits? Or shall we use a meter switching system whereby one meter is switched into several circuits by a selector switch for the purpose of measuring current. Or shall we use separate meters? We decide upon the latter, using the minimum number that will serve the purpose. We can borrow a filament voltmeter to check the various filament voltages under load when the transmitter is first fired up; so we decide to forego filament voltmeters: a desirable item but one which is not absolutely necessary except for an initial check. That leaves a 0-300 ma. for the plate of the class C stage, a similar one for the modulators, a 0-100 for the grid current to the final stage, and a similar one (or 0-150) for the plate of the 807 in the exciter. If we had decided upon meter switching or meter jacks a single 0-100 could be switched from exciter plate to final grid current and a single 0-300 ma. used for both modulator and class C plate current. But it is handy to be able to read all circuits simultaneously; hence we decide to go whole hog on these meters and economize somewhere else.

7. What provision for antenna coupling? This depends entirely upon the type antennas to be used, and can be decided after study of the antenna chapter. It should be considered in the design of the transmitter, however, as the method of coupling will have a bearing upon the mechanical layout of the final amplifier tank circuit.

8. What type of construction? Shall the transmitter be built in a relay rack as a single unit? Or shall it be built

up in units on individual chassis with plug-in interconnecting cables and supported by shelves in a "bookcase" type cabinet? Shall the speech amplifier be placed on the operating desk where the operator can reach the gain control, or shall it be placed with the transmitter proper? Every amateur will have to decide these problems for himself, as the answer will depend upon both pocketbook and individual preferences.

9. What safety precautions should be taken to protect the operator? These will depend somewhat upon the type of construction used. The question of safety precautions is covered later in this chapter, and every amateur should read it over very carefully and fix them firmly in mind.

10. What about a.c. mains supply? Will the house wiring or the outlet which will supply the transmitter do so without being overloaded; will the voltage drop be excessive? A 200-watt phone transmitter will draw approximately 750 watts total from the line (about 7 amps.). Plug a kilowatt heater element in the outlet and see what happens to the line voltage at that point. If nothing blows, the wire does not overheat, and the line voltage does not drop more than about 5 volts, then the entire transmitter and its 750-watt load may be run from the outlet without need for heavier wiring.

DESIGN CONSIDERATIONS

The foregoing discussion gives an idea of the principal considerations in the general planning of a transmitter. In the actual construction of the transmitter there are many others of more specific nature that are just as important. Some of these should be obvious to anyone well versed in transmitter theory, but others are empirical practices that experience has shown to be advisable or preferable to other methods.

Transmitter Wiring

At the higher frequencies, solid enamelled copper wire is most efficient for r.f. leads. Tinned or stranded wire will show greater losses at these frequencies. Tank coil and tank condenser leads should be of heavier wire than other r.f. leads, though there is little point in using heavier wire than is used for the tank coil itself.

All grounds and by-passes in an r.f. stage should be made to a common point, and the grounding points for several

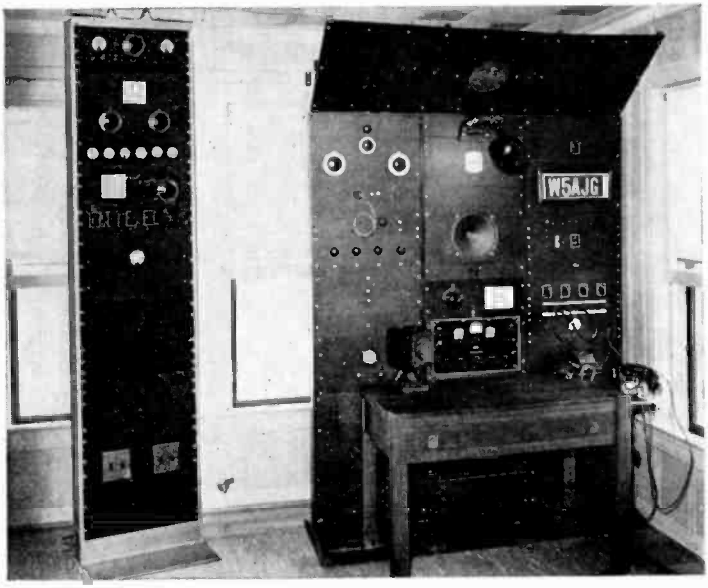


Figure 1.

ILLUSTRATING RACK-AND-PANEL TYPE CONSTRUCTION OF ENTIRE STATION.

By constructing all units on standard-width chassis and panels, everything can be rack-mounted as illustrated here to make a very neat and efficient station, at the same time providing maximum safety to the operator. The panels on the racks to the right are of tempered Masonite (Presdwood), which is inexpensive, easy to drill, and attractive when painted with black or gray crackle paint.

stages bonded together with heavy wire.

Best type flexible leads to terminals coming out envelope of tubes is thin copper strip, cut from thin sheet copper. Heavy, rigid leads to these terminals may crack the envelope glass when a tube heats or cools.

Wires carrying only a.f. or d.c. should be chosen with the voltage and current in mind. Some of the low-voltage-filament type transmitting tubes draw heavy current, and heavy wire must be used to avoid voltage drop. The voltage is low, and hence not much insulation is required. Filament and heater leads are usually twisted together. An initial check should be made on the filament voltage of all tubes of 25 watts or more plate dissipation rating. This voltage should be measured right at the tube sockets. If it is low, the filament transformer voltage should be raised. If this is impossible, heavier or paralleled wires should be used for filament leads, cutting down their length if possible.

Spark plug type high tension ignition cable makes the best wire for high voltage leads. This cable will safely withstand the highest voltages encountered in an amateur transmitter. If this cable is used, the high voltage leads may be cabled right in with filament and other low voltage leads. For high voltage leads in low power exciters where the plate voltage is not over 450 volts, ordinary radio hookup wire of the higher quality type will serve the purpose. Twisted lamp cord, in good condition with insulation intact, can be used for power supply leads between low power exciter units and power supplies where the voltage does not exceed 400 volts.

No r.f. leads should be cabled; in fact it is better to use enamelled or bare copper wire for r.f. leads and rely upon spacing for insulation. All r.f. joints should be soldered, and the joint should be a good mechanical junction before soldering is applied. Soldering technique is covered in chapter 19.

Coil Placement

While metal shield baffles are effective in suppressing stray capacity coupling between circuits, they are not always effective in suppressing inductive coupling. To eliminate all inductive coupling between two coils in inductive relation to each other, each coil should be completely enclosed in an individual shield can. This is not always convenient; so more often the inductive coupling is minimized by orienting the coils for maximum suppression of coupling, and shield baffles used only to prevent stray capacity coupling between stages.

For best Q a coil should be in the form of a solenoid approximately as long as its diameter. For minimum interstage coupling coils should be made as small physically as is practicable. The coils should then be placed so that adjoining coils are oriented for minimum mutual coupling. To determine if this condition exists, apply the following test: The axis of one of the two coils must lie in the plane formed by the center turn of the other coil. If this condition is not met there is bound to be appreciable coupling unless the unshielded coils are very small in diameter or are spaced considerable distance from each other.

Variable Condensers

The question of optimum C/L ratio and condenser plate spacing is covered in the chapter on transmitter theory. For all-band operation of a high power stage it is recommended that a condenser just large enough for 40-meter c.w. operation be chosen (this will have sufficient capacity for phone operation on all higher frequency bands). Then use fixed padding condensers for operation on 80 and 160 meters. Such padding condensers are available in air, gas-filled, and vacuum types.

Insulation

On frequencies above 7 Mc., ceramic, polystyrene, or mycalex insulation is to be recommended, though hard rubber will do almost as well. Cold flow must be considered when using polystyrene (victron, Amphenol 912, etc.) or hard rubber. Bakelite has low losses on the lower frequencies but should never be used in the field of high-frequency tank circuits.

Lucite, which is available in rods, sheets, or tubing, is excellent for use at all radio frequencies where the r.f. voltages are not especially high. It is very easy to work with ordinary tools and is not expensive.

The most important things to keep in mind regarding insulation is that the best insulation is none at all. If it is necessary to reenforce air-wound coils to keep turns from vibrating or touching, use strips of lucite cemented in place with Amphenol 912 coil dope. This will result in lower losses than the commonly used celluloid ribs and duco cement.

Metering

The ideal transmitter would have an individual meter in every circuit requiring measurement. However, for the sake of economy many of us are forced to measure filament and plate voltages by means of a test set or universal meter during the initial tryout of the transmitter and then assume that these voltages will be maintained. Further economies can be effected by doubling up on meters when measuring current in various circuits in which the current is variable and is an index of transmitter tuning. By a system of plugs and jacks, or a selector switch, one or two milliammeters can be used to make all the measurements necessary to tune up a transmitter properly. However, it often is of considerable advantage to be able to observe the current of several circuits or stages simultaneously. Thus the problem boils down to: buy as many meters as you can afford or as many as the total transmitter investment justifies, purchasing the most necessary meters first. Obviously one would not be justified in buying $100 worth of meters for a transmitter containing other parts totaling $75. On the other hand the purchase of a filament voltmeter to keep careful tab on the filament voltage of a pair of 250 watt tubes is a good investment.

Probably the most popular arrangement calls for meter switching or meter jacks in the low power stages and individual meters in the last stage. Ordinarily, r.f. meters are not used except in certain antenna coupling circuits. Where line voltage does not fluctuate appreciably, one can get by very nicely with just d.c. milliammeters, plate current meters in the low power stages and a grid and a plate meter in the final stage.

Meter Switching

This method can be used to advantage where the voltages on the leads which carry the current to be measured is not greater than about 500 volts to ground. 50-ohm resistors are inserted in the leads, and because the resistance of the meter is so low compared to the 50 ohm resistors, the meter can be considered as being inserted in series with the circuit when it is tapped across the resistor. Thus with a double pole selector switch having sufficient positions one can use a single meter to measure the current in several circuits. The resistor should be made 25 ohms where the current to be measured runs over 200 ma., and the resistor increased to 200 ohms when the current to be measured is less than 15 ma. It is necessary to cut down the resistance where heavy current is present in order to avoid excessive voltage drop when the meter is not shunting the resistor, and it is necessary to increase the value of resistance where the current is so low that a low range meter must be used to measure the current. Low range milliammeters begin to show appreciable resistance themselves, and their calibration will be thrown off when shunted by too low a value of resistor.

Meter switching is not practicable in high voltage circuits. For measuring plate current in high power stages, the resistor should be placed either in the B minus lead or in the filament return (center tap). Placing the meter resistor in the B minus is not practical except when a power supply is used to feed but a single stage or heater-type tubes or separate filament transformers are used, as otherwise the meter would indicate total current to all the stages. Placing the meter in the filament return gives a reading of the total *space current,* which includes both grid current and plate current (and in the case of tetrodes and pentodes, screen current). This point is covered later under "Meter Jacks."

It is possible, by means of various systems of shunts, to use a single low-range meter for measuring widely different values of current in different circuits, much in the manner of the single-meter test set so popular with servicemen. For instance a 0-25 ma. meter could be used for measuring grid current in several stages and then used as a 0-250 ma. instrument when switched into the plate circuit of the final stage by the incorporation of a shunt in the latter circuit to extend the range to 250 ma. Ordinarily, however, a meter is used as a single-scale instrument with this type of switching, a 0-25 ma. meter being used only to read current in circuits carrying up to 25 ma.

Meter Jacks

A popular method of using one meter to measure the current in several circuits is to incorporate jacks in the various circuits to be measured. Instead of using low values of resistors across the jacks to provide a current path when the meter is not plugged in a circuit, shorting type jacks are used so that when a meter is removed from a jack the circuit is automatically closed.

As with meter switching, meter shunts may be placed across certain of the jacks to extend the range of a milliammeter; however, it is more common practice to have a low range meter and a high range meter and plug the appropriate meter in each circuit.

Meter jacks should not be used except where one side of the circuit can be grounded. This permits one to measure grid current, and, indirectly, plate current. The plate current is ascertained by measuring the current flowing in the filament return and subtracting the grid current (including screen current if the tube has a screen).

In connecting up meter jacks it is important that they be wired so that the meters read in the correct direction. This can be determined by figuring just which way the current is flowing in each circuit. If this were not done, the leads to the meter would have to be reversed when reading grid current after reading cathode current. It necessitates insulating the frame of either the grid current jack or the cathode current jack from a grounded metal panel if the latter is used. It is common practice to ground the frame of the cathode circuit jack and insulate the frame of the grid current jack, as this affords maximum protection to the operator.

A piece of heavily-insulated rubber covered two-wire cable can be used to connect the meter to the meter plug. If the meter is permanently mounted on the panel, the meter cord should be long enough to reach all meter jacks into which it is to be plugged. To protect low range meters, cathode current jacks in stages drawing heavy current are usually placed in such a position that it is impossible to reach the jack with the cord attached to the low-range meter.

Meter jacks should never be placed in high-voltage leads, and it is inadvisable to use them in any circuit where one side of the jack is not at ground potential. When used for measuring cathode current, the *frame* of the jack should always be grounded, as a defective contact in the jack or a blown meter might otherwise endanger the operator by putting high potential on the meter cord and plug.

A 50-ohm carbon resistor across the terminals of all cathode current meter jacks will not affect the calibration of the meter yet will protect the operator from possible shock in the event that the meter should blow or the cord open up or come loose on the ground side. In this case the resistor is more of a protective device than a substitute path for the current when the meter is being used in some other circuit, and little current will flow through the resistor unless the jack, cord, or meter becomes defective.

The Audio System

In constructing audio equipment, the low level stages should always be mounted on a metal chassis and the bottom of the chassis shielded. For amateur work "high fidelity" is neither necessary nor desirable, as the sideband width is increased without an increase in intelligibility. This means that high-output microphones of the "p.a." type designed particularly for speech transmission (such as the high output, diaphragm crystal) can be used, and the speech amplifier need have but moderate gain. This greatly simplifies the problem of construction, as the difficulties and chances for trouble go up rapidly as the maximum overall gain of an amplifier is increased much beyond this point. Elaborate precautions against r.f. and a.f. feedback and hum pickup must be taken when low-level high-fidelity microphones of the broadcast type are used, but with the type recommended only a few simple precautions need be taken.

If a microphone which requires an input transformer is used, such as the dynamic type, care must be taken in the orientation of the input transformer in order to avoid hum pickup, especially if it is within a couple of feet of power transformers. Heavily-shielded input transformers of the "hum bucking" type are recommended for input transformers.

It is a good idea to design the amplifier for about 150 or 200 cycle cutoff, as this not only increases the intelligibility and effective modulation power (as explained in chapter 13) but also minimizes hum troubles. This means that one can use inexpensive audio components and also that one need not isolate the d.c. from the primary of a.f. transformers, because we don't want extreme bass response anyhow. *Low harmonic distortion* is of more importance in getting a good sounding amateur signal than is wide-range frequency response; in fact the latter will actually *reduce* the intelligibility when a high order of harmonic distortion is present.

The foregoing is more appropriately and extensively covered in the chapter on radiotelephony theory, but is mentioned here because it is so much tied in with transmitter design: how we lay out or plan the speech system of a transmitter depends upon just what features are to be incorporated and what requirements must be met. Before planning a speech amplifier or modulator one should read both the chapter on radiotelephony theory and the chapter on workshop practice.

Safety Precautions

The best way for an operator to avoid serious accidents from the high voltage supplies of a transmitter is for him to use his head, act only with deliberation, and not take unnecessary chances. However, none is infallible, and chances of an accident are greatly lessened if certain factors are taken into consideration in the design of a transmitter in order to protect the operator in the event of a lapse of caution. If there are too many things one must "watch out for" or keep in mind there is a good chance that sooner or later there will be a mishap; and it only takes *one.* When designing or constructing a transmitter, the following safety considerations should be given attention.

Grounds

Everything of metal on the front panel of a transmitter capable of being touched by the operator should be at ground potential. This includes dial set screws, meter "zero adjuster" screws, meter cases if of metal, meter jacks, *everything* of metal protruding through the front panel or capable of being touched or *nearly* touched by the operator. This applies whether or not the panel itself is of metal. Do not rely upon the insulation of meter cases or tuning knobs for protection.

The B negative or chassis of all plate power supplies should be connected together and to an external ground such as a waterpipe. In the case of a bias supply the B positive should be connected to the common ground.

Exposed Wires and Components

It is not necessary to resort to rack and panel construction in order to provide complete enclosure of all components and wiring of the transmitter. Even with breadboard construction it is possible to so arrange things and incorporate a protective housing which will not interfere with ventilation yet will prevent contact with all wires and components carrying high voltage d.c. or a.c.

If everything on the front panel is at ground potential (with respect to external ground) and all units are effectively housed with protective covers, then there is no danger except when the operator must reach into the interior or part of the transmitter, as when changing coils, neutralizing, adjusting coupling, or shooting trouble. The latter procedure can be made safe by making it possible for the operator to be *absolutely certain* that all voltages have been turned off and that they cannot be turned on either by short circuit or accident. This can be done by incorporation of the following system of main primary switch and safety signal light.

Combined Safety "Go" Signal and Main Switch

The common method of using red pilot lights to show when a circuit is "on" is useless except from an ornamental standpoint. When the red pilot is not lit it *usually* means that the circuit is turned off, but it *can* mean that the circuit is on but the lamp is burned out or not making contact.

To enable you to grab the tank coils in your transmitter with absolute assurance that it is impossible for you to obtain a shock except from possible undischarged filter condensers (see following topic for elimination of this hazard) it is only necessary to incorporate a device similar to that of figure 2. It is placed near the point where the main 110-volt leads enter the room (preferably near the door) and in such a position as to be inaccessible to small children. Notice that this switch breaks *both* leads; switches that open just one lead do not afford complete protection as it is sometimes possible to complete a primary circuit through a short or accidental ground. Breaking just one side of the 110 may be all right for turning the transmitter on and off, but when you are going to stick an arm inside the transmitter, *both* 110 volt leads should be broken.

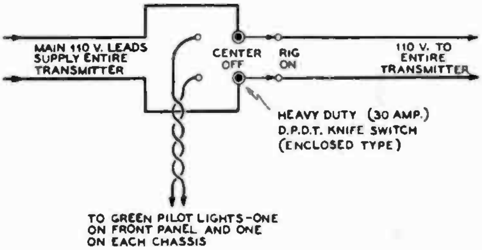


Figure 2.

COMBINED MAIN SWITCH AND SAFETY SIGNAL.

After shutting down the transmitter for the day, throw the main switch to neutral. If you are going to work on the transmitter, throw the switch all the way to "pilot," thus turning on the green pilot lights and making it impossible for there to be primary voltage on any transformer in the transmitter even by virtue of a short or accidental ground. To live to a ripe old age, simply obey the rule of "never work on the transmitter unless green lights are on."

When you are all through working your transmitter for the time being, simply throw the main switch to neutral. Then you can leave the transmitter and even go on a vacation with absolute peace of mind.

When you find it necessary to work on the transmitter or change coils, throw the switch so that the green pilots light up. These can be ordinary 15-watt green bulbs. One should be placed on the front panel of the transmitter; others should be placed so as to be easily visible when changing coils or making adjustments requiring the operator to reach inside the transmitter. These lamps are inexpensive and as several will draw less than 100 watts from the line, a half dozen may be scattered around the transmitter.

For 100 per cent protection, just obey the following rule: *never work on the transmitter or reach inside any protective cover except when the green pilots are glowing.* To avoid confusion, no other green pilots should be used on the transmitter; if you want an indicator jewel to show when the filaments are lit, use amber instead of green.

If the main switch is out of reach of small children, a conspicuous sign such as "DO NOT TOUCH UNDER ANY CIRCUMSTANCES" placed on the switch cover will guard against the off chance that someone else would throw the switch unexpectedly. An alternative is to place the switch on the under side of the operating table out of sight. The latter is not so desirable when small children have access to the room.

Safety Bleeders

High capacity filter condensers of good quality hold their charge for some time, and when the voltage is more than 1000 volts it is just about as dangerous to get across an undischarged 4-μfd. filter condenser as it is to get across a high voltage supply that is turned on. Most power supplies incorporate bleeders to improve regulation, but as these are generally wire wound resistors and as wire wound resistors occasionally open up without apparent cause, it is desirable to incorporate an auxiliary safety bleeder across each heavy duty bleeder. Carbon resistors will not stand much dissipation and sometimes change in value slightly with age. However, the chance of their opening up when run well within their dissipation rating is almost unheard of.

To make *sure* that all condensers are bled it is best to short each one with an insulated screwdriver. However, this is sometimes awkward and always inconvenient. One can be virtually sure by connecting auxiliary carbon bleeders across all wire wound bleeders used on supplies of 1000 volts or more. For every 500 volts, connect in series a 500,000-ohm 1-watt carbon resistor. The drain will be negligible (1 ma.) and each resistor will have to dissipate only 0.5 watt. Under these conditions the resistors will last indefinitely with no chance of opening up. For a 1500-volt supply, connect three 500,000-ohm resistors in series. If the voltage exceeds an integral number of 500 volt divisions, assume it is the next higher integral value; for instance, assume 1800 volts as 2000 volts and use four resistors.

Do *not* attempt to use fewer resistors by using a higher value for the resistors; not over 500 volts should appear across any single 1-watt resistor.

In the event that the regular bleeder blows, it will take several seconds for the auxiliary bleeder to drain the condensers down to a safe voltage, because of the very high resistance. Hence, it is best to allow 10 or 15 seconds after turning off the plate supply before attempting to work on the transmitter.

"Hot" Adjustments

Some amateurs contend that it is almost impossible to make certain adjustments such as coupling and neutralizing unless the transmitter is running. The best thing to do is to make all neutralizing and coupling devices adjustable from the front panel by means of flexible control shafts which are broken with insulated couplings to permit grounding of the panel bearing.

If your particular transmitter layout is such that this is impracticable and you refuse to throw the main switch to make an adjustment—throw the main switch—take a reading—throw the main switch—make an adjustment—and so on, then protect yourself by making use of long adjusting rods made from half inch dowel sticks which have been wiped with oil when perfectly free from moisture.

If you are addicted to the use of pick-up loop and flashlight bulb as a resonance and neutralizing indicator, then fasten it to the end of a long dowel stick and use it in that manner.

Exciters and Low Powered Transmitters

SIMPLE 15 WATT TWO BAND EXCITER OR TRANSMITTER

Illustrated in figures 1 and 2 is the simplest practical exciter or transmitter for fixed-station use. It uses only one tube and one crystal, and with four easily wound coils provides about 15 watts output on 80 meters and approximately 12 watts on 40. With few exceptions, the parts are all inexpensive standard receiver items. With the particular antenna-coupling circuit illustrated, the unit may be used with a wide variety of antennas, although the simple antenna to be described is strongly recommended. It gives excellent performance on both bands.

The unit operates as a regenerative crystal oscillator of the harmonic type on 40 meters and as a straight tetrode crystal oscillator on 80 meters. The change from one form of oscillator to the other is taken care of automatically when the coils are changed, as a result of the jumper in the 80-meter coil.

If the unit is used as an exciter, the antenna coupling tank L_2 and C_6 may be omitted, the output of the oscillator being link coupled to the following stage instead. The antenna tank circuit illustrated was included in the model shown because it can be used in conjunction with an end-fed wire for two-band operation. If the unit is first used as a transmitter and then later used as an exciter when another stage is added, the antenna tank circuit can be removed from the oscillator unit and used as the grid tank of the amplifier.

Construction

The whole transmitter is built on a 9½ by 6½ by 1 inch thick wooden baseboard to which is mounted a 10½ by 6½ inch "presdwood" front panel.

Baseboard-mounting type bakelite sockets are used for both the tube and the coils. Five-prong sockets are used for the coils and a six-prong one for the tube. Another five-prong socket of the same type is placed directly behind the tube and used to mount the crystal.

The panel supports the two midget "tank" condensers, C_1 and C_6, and the 0-100 ma. meter. A small through-type insulator directly above the antenna-tuning condenser is used for an antenna terminal.

The two Fahnesock clips at the right rear of the baseboard are used for key connections. A small four-terminal strip at the left rear of the baseboard provides a convenient method of making heater and plate voltage connections to the power supply. The only other components mounted on either the panel or base are two two-terminal tie points. These are screwed to the baseboard, one between each coil and condenser. They are used to support the coupling links, which will be described later.

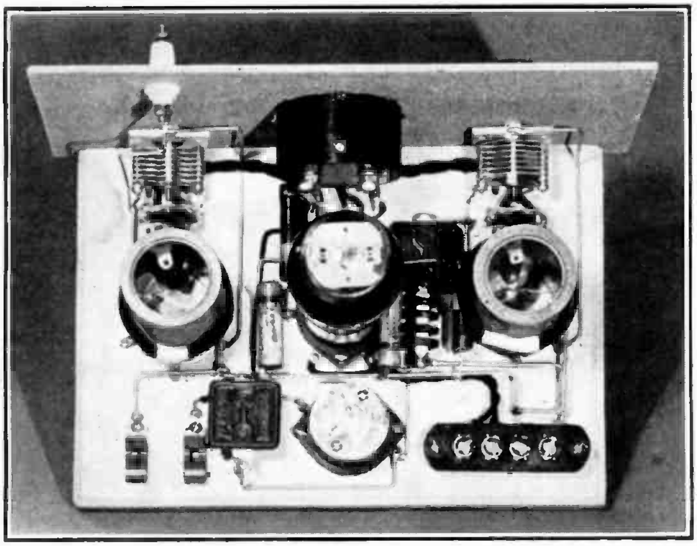


Figure 1.

SIMPLEST PRACTICAL EXCITER OR TRANSMITTER.

This unit delivers 12 to 15 watts on 40 or 80 meters with an 80-meter crystal. The antenna coupling tank (to the left) can be omitted if the unit is to be used only as an exciter.

Wiring

With the exception of the coupling link, the heater leads, and one of the meter leads, all wiring is done with no. 14 bus-bar. This heavy wire allows the various fixed condensers and resistors to be supported directly from the wiring.

A single piece of bus-bar runs along the back of the baseboard between the tube and the crystal and connected to one of the power supply terminals at one end and to one of the key terminals at the other is used for a *common ground* lead. All of the ground connections shown on the diagram are made to this lead, which in turn should be connected to a water-pipe or other good external ground.

As may be seen from the diagram, there is a link around each coil. These links couple the plate coil to the simple antenna-matching circuit. The link around the plate coil is three turns of push-back wire, while the one around the antenna coil is four turns of the same type of wire. The links are each 1¾ inches in diameter and are permanently connected in the transmitter. They are supported by the tie-points previously mentioned. Two small pieces of tape wrapped around each link coil serve to hold the turns together. The link around the plate coil should be placed at such a height above the socket that when the plate coil is plugged in, the link is around the bottom portion of the coil. The bottom of the plate coil should be the end which is connected through C_3 to ground on 40 meters and, by means of the jumper, directly to ground on 80 meters.

The link coil around the antenna coil should be positioned so that it falls at the *center* of the *antenna coil*. About six inches of twisted push-back wire is used as a coupling line between the two coils. The twisted line is connected to tie-points at each end of the line.

Coils

The jumper on the 80-meter coil allows the transmitter to work as a con-

COIL TABLE

Band	Plate Coil	Antenna Coil
80	41 turns, close-wound	50 turns, center-tapped, close-wound
40	21 turns, spaced to a length of two inches	26 turns, center-tapped, spaced to a length of two inches

All coils wound with no. 20 double-cotton-covered wire on 1½" dia. forms.

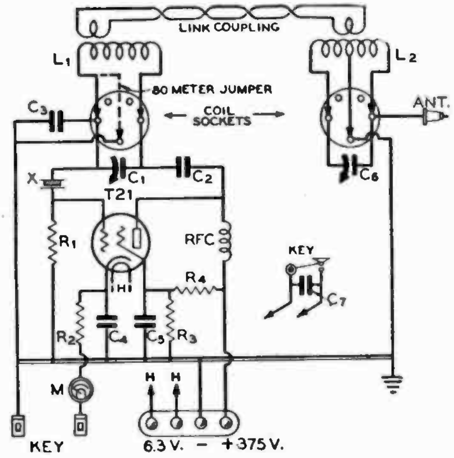


Figure 2.

THE R.F. PORTION OF THE TRANSMITTER

C_1—50-μμfd. midget variable
C_2—.01-μfd. mica
C_3—.0005-μfd. mica
C_4, C_5—.01-μfd. 600-volt tubular
C_6—50-μμfd. midget variable
C_7—.02-μfd. 600-volt tubular
R_1—100,000 ohms, 1 watt
R_2—400 ohms, 10 watts
R_3—20,000 ohms, 10 watts
R_4—5000 ohms, 10 watts
RFC—2.5-mh., 125-ma. choke
X—80-meter X or AT crystal
L_1, L_2—See coil table M-O-100 milliamperes

ventional tetrode oscillator on 80 meters and as a regenerative oscillator on 40 meters.

The antenna coil connections are the same for both bands. If the socket connections are made as shown in the diagram, the two ends of the coils are connected to the cathode and plate prongs and the center tap to the grid prong.

The leads to the key may be any reasonable length (up to 10 feet, if necessary). A 0.02-μfd. condenser, C_7, is connected directly *across the key.* This condenser is used to minimize key clicks and is most effective when placed right at the key rather than in the transmitter. Be sure the *frame* of the key connects to the grounded key terminal and not the terminal that goes to the meter.

Power Supply

The power supply recommended is a standard brute-force filtered affair using receiver components throughout. The parts are mounted on a small baseboard in the most convenient manner and the heater and plate voltage connections brought out to a four-post terminal strip similar to that on the transmitter. The power transformer should not deliver more than 350 v. r.m.s. each side of the c.t. or else the peak voltage on the filter condensers will be too high when the key is up.

Antenna

The best type of antenna for use with this transmitter is the end-fed half-wave 80-meter type. Such an antenna, if erected reasonably in the clear, will give good results on both 80 and 40 meters. On both bands the antenna is not particularly directional, although a slight increase in signal strength will be noticed in certain directions. On 40 meters the antenna produces low-angle radiation, an advantage in working dx.

The antenna should measure 135 feet from the far end *to the antenna terminal on the transmitter* and be erected in the clear and as high and as much in a straight line as possible.

Tuning Up

If all the wiring has been done properly, no difficulty should be experienced in placing the transmitter into operation. Leads to the power supply and key should be connected (ordinary lamp cord of good quality will do) and a 6.3-v. 150-ma. dial light placed in series with the an-

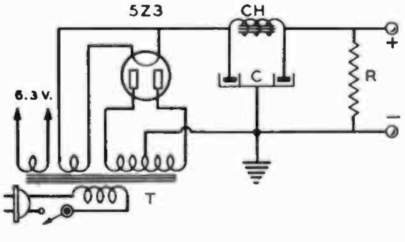


Figure 3.

RECOMMENDED POWER SUPPLY.

T—700 v.c.t., 90 ma.; 5 v., 3 a.; 6.3 v., 3 a.
CH—30 hy., 110 Ma.
C—Dual 8μfd. electrolytic, 450 v.
R—40,000 ohms 20 watts

tenna at the transmitter. A crystal with a frequency between 3502 and 3648 kc. should be placed in the crystal socket. A crystal in this range will allow operation on both the 80- and 40-meter bands.

When the transmitter is properly adjusted for 80-meter operation it should be possible to tune the antenna coupling circuit through resonance without pulling the oscillator out of oscillation. The dial light should increase in brilliance as the antenna circuit is tuned up to resonance and then decrease as it is detuned on the other side.

When this condition is obtained, remove the dial lamp from the antenna and make the antenna connection directly to the antenna post. Then, without touching the antenna-tuning condenser, turn the plate condenser toward maximum capacity until the point of maximum capacity at which the circuit will still oscillate is found. The final adjustment of the plate condenser should be made while listening to the signal from the transmitter in a monitor or receiver. The condenser should be set at the furthest point toward maximum capacity at which the keying is clean and distinct without chirps or lag.

The farther down the plate coil the coupling link is placed, the looser the coupling to the antenna circuit. If the coupling is too tight, the oscillator won't oscillate or the note will be chirpy. If the coupling is too loose, the full power will not be delivered to the antenna.

The coupling should be adjusted by varying the position of the *plate coil coupling link,* never by detuning the antenna condenser. The latter should always be tuned to resonance. If it cannot be tuned to resonance without the transmitter's going out of oscillation or developing keying chirps, the coupling is too tight.

If the dial lamp in the antenna lead does not give sufficient indication to be observed handily, a 2-volt 60-ma. bulb may be substituted. Do not use a 60-ma. lamp unless you are unable to get a satisfactory indication on a 150-ma. bulb. The maximum antenna current will be low at this point (a current "node") and will vary somewhere in different antenna installations.

On 40 meters the tuning is somewhat simpler, because the transmitter acts as a regenerative harmonic oscillator and will oscillate and key cleanly regardless of how heavily the plate circuit is loaded. Therefore it is necessary only to tune for greatest output, without regard to keying chirps or non-oscillation.

When the unit is used as an exciter the tuning is the same except that instead of tuning for greatest brilliancy of the lamp in the antenna lead, adjustments should be made for maximum grid current to the following stage. Coupling is adjusted as described for operation with an antenna; the position of the link around L_1 is varied until the desired coupling is obtained. *Be sure to turn off the power supply* before making coupling adjustments.

6L6G-809 MULTIBAND EXCITER OR TRANSMITTER

A most practical exciter where 30 to 40 watts output is required is the 6L6G-809 combination illustrated in figures 4 and 5 and diagrammed schematically in

COIL DATA FOR 6L6G-809 EXCITER

BAND	6L6G	809
160	60 turns #24 d.c.c. closewound 1½" diam.	68 turns #20 d.c.c. closewound 2¼" diam. c.t.
80	30 turns #20 d.c.c. closewound 1½" diam.	44 turns #20 d.c.c. 1½" diam. 2" long c.t.
40	16 turns #20 d.c.c. 1½" diam. 1½" long	20 turns #20 1¾" diam. 1½" long c.t.
20	8 turns #20 d.c.c. 1½" diam. 1½" long	12 turns #20 1¾" diam. 1½" long c.t.
10	Use 20-meter coil	6 turns #16 enam. 1½" diam. 1½" long

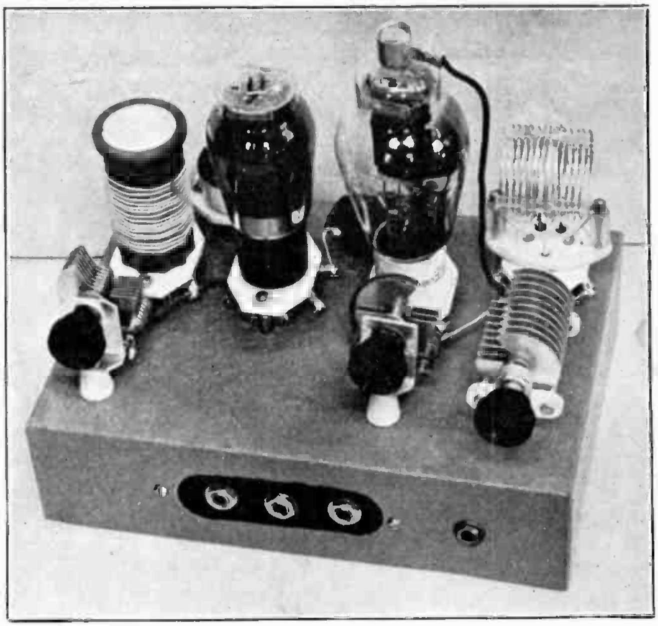


Figure 4.

6L6G - 809 MULTIBAND EXCITER.

Delivering from 30 to 40 watts on all bands from 10 to 160 meters on one, two or four times crystal frequency, this exciter can also be used as a low-power transmitter to feed directly into an antenna.

figure 6. The exciter can also be used to feed an antenna directly, making an excellent low-power transmitter.

A 6L6G crystal oscillator of the regenerative type delivers output on either the fundamental or second harmonic of the crystal when crystals of the usual type are employed. High-frequency crystals of the harmonic cut type (this includes all 10-meter crystals and certain 20-meter crystals) will work only on the frequency marked on the crystal holder. As there is no reason for doubling in the oscillator except with low-frequency crystals, this is no handicap.

The amount of regeneration in the oscillator is determined by the capacity of C_1. Too much regeneration (too little capacity) will result in excessive crystal current and possibly self-oscillation not controlled by the crystal. Too little regeneration (too much capacity) will result in low second harmonic output, especially with 40-meter crystals. The optimum value will depend somewhat upon the physical layout of the parts, and will be between .00025 and .0005 μfd. A value of .0004 μfd. will ordinarily be found satisfactory. There is no need to change the value of this condenser once the correct size for the particular layout and driven tube is determined, and for that reason a mica condenser is employed. When determining the best value experimentally, it is advisable to do it with a 40-meter crystal in the circuit.

The 809 stage is neutralized and therefore can be used either as a straight amplifier or as a doubler. The output when doubling is practically as great as when working straight through, but the plate current runs a little higher. The

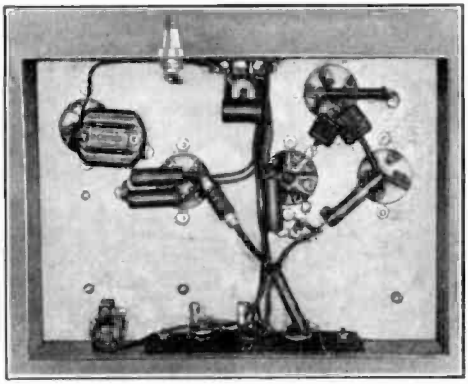


Figure 5.

UNDER-CHASSIS VIEW OF 6L6G-809 EXCITER.

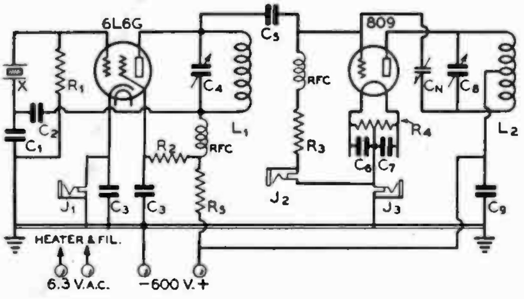


Figure 6.
SCHEMATIC DIAGRAM OF THE 6L6G-809 EXCITER OR TRANSMITTER.

C_1—.0004-µfd. mica (critical)
C_2—.002-µfd. mica
C_3—.01-µfd. tubular
C_4 — 100-µµfd. midget variable
C_5—.001-µfd. mica
C_6, C_7—.01-µfd. tubular
C_8—50-µµfd. double-spaced midget
C_9—.004-µfd. mica, 1000 v.
C_n—10-µµfd. double spaced midget
R_1—100,000 ohms, 2 watts
R_2—10,000 ohms, 10 watts
R_3—5000 ohms, 10 watts
R_4 — 100-ohm 10-watt c.t. resistor
R_5—3000 ohms, 30 watts
RFC — 2.5-mh. midget r.f. choke
L_1, L_2—See coil table

coils should be accurately center-tapped if the neutralization adjustment is to hold when changing coils. If this is done carefully, the neutralization will hold sufficiently on all lower frequency bands after the stage is neutralized with the 20-meter coil in the circuit. It is advisable to use the 809 as a doubler to 10 meters, though it can be used as a straight amplifier on that frequency if sufficient care is taken.

The plate current to the 6L6G under operating conditions should run about 50 ma., the 809 grid current between 20 and 30 ma. under load, and the 809 plate current can be anything up to 100 ma. so long as the tube shows no color.

Because of the connection of the grid current jack, the jack J_3 measures plate current only; the grid current does not flow through the meter when it is placed in J_3. The jack J_2 must be insulated from the panel because neither side is grounded except indirectly through J_3. For the sake of appearance, all three jacks are mounted on a bakelite strip as seen in figure 4 and the frames J_1 and J_3 are wired directly to the metal chassis.

Keying may be accomplished by inserting the key either in J_1 or J_2. The key will arc badly if inserted in J_3, because of the method of connecting the grid return.

Because both rotor and stator of each of the three variable condensers are "hot" with r.f., they are all mounted on ceramic standoff insulators. For best results it is recommended that the general physical layout of figure 4 be followed.

"4-25" BANDSWITCHING 25-WATT EXCITER

An improved version of the now popular 4-25 exciter is illustrated in figures 7 and 8. Inspection of the wiring diagram, figure 10, shows the exciter to consist of an 807 driven either by a 42 oscillator or a 42 quadrupler. It can be used on 10, 20, 40 and 80 meters and requires but one crystal for operation on all four bands. The output when run at the specified plate voltage is a good 25 watts on 10 meters and approximately 30 watts on the lower frequencies.

A conventional 42 pentode oscillator

Figure 7.

FRONT PANEL VIEW OF THE "4-25".

The throw knob of the husky 110-volt toggle switch may be seen to the right above the meter. The two terminals in the upper right-hand corner carry only low voltage r.f. from the coupling link. The unit delivers 25 watts on 10, 20, 40, and 80 meters from one crystal and may be plate modulated for phone operation if desired.

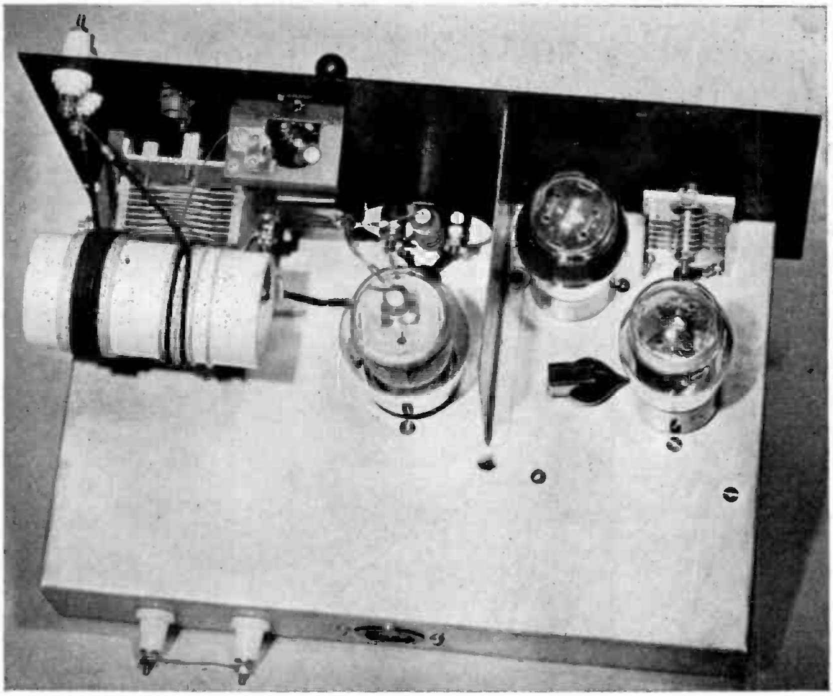


Figure 8.
SHOWING LAYOUT OF COMPONENTS ABOVE THE CHASSIS.
The method of mounting the final tank coil and coupling link is clearly illustrated in this view. The shielding baffle results in more stable operation when working "straight through" with the 807. Note the short leads to the bandswitch above the 807 tuning condenser.

circuit with low screen voltage and light loading is used. The former results in very low crystal current, and the latter permits clean keying of the oscillator even when sluggish crystals are used.

A second 42 is used as a triode quadrupler to 20 meters. By means of the selector switch S_1 it is possible to excite the 807 on 20 meters from the quadrupler, or, by throwing the switch to disconnect the quadrupler from the oscillator and feed the oscillator directly into the 807, thus exciting it on 80 meters. Twenty-meter or 80-meter excitation is available to the 807 at the flip of a switch.

It is possible by doubling in the 807 stage to obtain not only 20- and 80-meter output from the 807, but 40- and 10-meter output as well. The tuning condenser for the 807 is made large enough to hit two bands. This results in a rather high-C tank circuit when the condenser is tuned to the lower frequency band, but as the high capacity setting is used only when the 807 is used as a straight amplifier, this merely tends to make the output more uniform both when doubling and working straight through.

The plate coil for the 807 is wound so that with all of the turns in the circuit it hits 80 meters with the condenser plates nearly all the way in, and 40 meters with the plates nearly out. A tap on the coil makes it possible to short out a portion of the coil, permitting coverage of both 10 and 20 meters with the tuning condenser.

In order to go from 80 to 40 meters it is only necessary to retune the tank condenser. By throwing the excitation switch to the doubler and closing the switch S_2 it is possible to cover 20 and

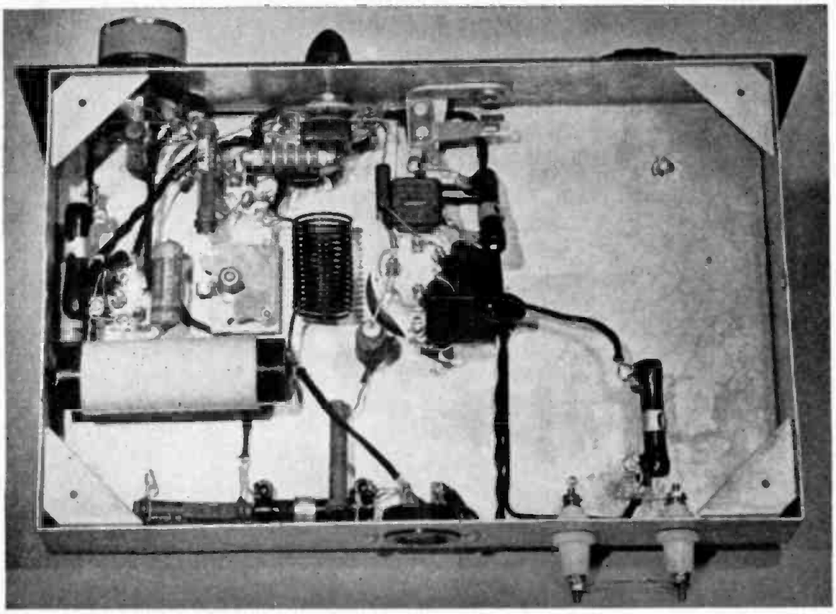


Figure 9.
BOTTOM VIEW OF THE EXCITER, SHOWING LAYOUT OF PARTS BELOW THE CHASSIS.
The insulator terminals to the rear of the unit are for connection to a modulator if one is used.

10 meters in the same manner. The oscillator and doubler tank condensers need not be touched when changing bands. This permits very rapid band change with a minimum of effort.

No metering facilities are provided for either of the 42 stages. The reason for this is that regardless of tuning, neither of these tubes will draw sufficient current or run sufficiently hot to damage them. Both oscillator and quadrupler are tuned for maximum output without regard to plate current. These stages each draw in the neighborhood of 40 ma. when tuned for maximum output.

Construction

The entire exciter, exclusive of power supply, is built upon a 7″ x 11″ x 2″ chassis and 7″ x 12″ front panel. The illustrations show the correct arrangement of the various components. The crystal tank condenser C_1 is mounted upon the front panel as it will require slight readjustment when going from one extreme edge of the 80-meter band to the other.

The quadrupler tank condenser C_2 is mounted behind the panel because when once set it is left alone. The quadrupler tunes rather broadly and when peaked at 14,250 kc. will work satisfactorily between 14,000 and 14,500. This permits output from the 807 anywhere between these frequencies or between 28,000 and 29,000 kc. without requiring readjustment of C_2. A shielding partition 4 inches wide by 4¾ inches high effectively shields the plate circuit of the 807 from the oscillator and quadrupler. The 807 is underslung by mounting the socket below the chassis on 1-inch bushings or collars. Lowering the socket an inch below the chassis helps shield the input from the output leads of the 807, making a shield "collar" around the lower part of the 807 unnecessary. The underslung socket arrangement also permits a shorter plate lead and keeps the 807

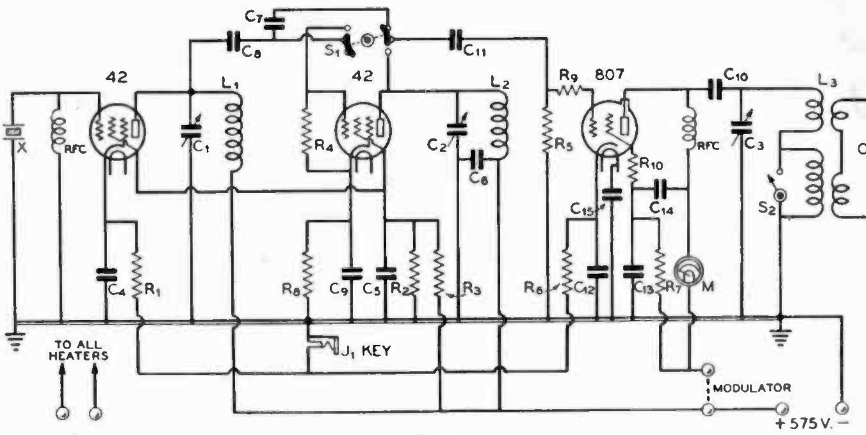


Figure 10.

WIRING DIAGRAM OF THE IMPROVED "4-25" UNIT.

C_1 — 50-μμfd. midget, .03" spacing
C_2 — 25-μμfd. midget, .03" spacing
C_3—150-μμfd. variable, low minimum, .03" spacing
C_4, C_5, C_6—.01-μfd. tubular, 600 w.v.
C_7—50-μμfd. midget mica, 1000 v. test
C_8, C_9 — 100-μμfd. midget mica, 1000 v. test
C_{10}—.002-μfd. standard mica, 1000 v. test. For plate modulation use 2500 v. test
C_{11}, C_{12}, C_{13}, C_{14}, C_{15} — .003 μfd. midget mica, 1000 v. test
R_1—2500 ohms, 10 watts
R_2—25,000 ohms, 2 watts
R_3—25,000 ohms, 10 watts
R_4—150,000 ohms, 2 watts
R_5—100,000 ohms, 2 watts
R_6—500 ohms, 10 watts
R_7—25,000 ohms, 10 watts
R_8—2500 ohms, 10 watts
R_9, R_{10}—50 ohms, 1 watt carbon
RFC—2.5 mh. 125 ma. midget r.f. chokes
J_1 — Keying jack, closed circuit type
S_1—D.p.d.t. selector switch (rotary "tone control" type)
S_2—S.p.s.t. 110 volt a.c. switch with good insulation (see text)
M—0-150 ma. d.c.
Coils—See text

from sticking up above the level of the top edge of the front panel.

Grounding the rotor of C_3 makes it possible to mount the condenser directly on the front panel without insulation. The two aluminum mounting brackets supplied with the condenser are fastened to the back of the condenser frame at a slight angle, as may be seen in the end view of the exciter. When the brackets are fastened this way the holes almost line up with the mounting holes in the ceramic coil form. By drilling out the holes with a slightly larger drill the coil form holes can be made to line up well enough for the form to be fastened to the brackets by means of bolts. Fiber insulating washers must be used to prevent cracking of the ceramic form when the bolts are tightened.

In the model illustrated the switch S_1 is of the inexpensive "tone control" type costing less than fifty cents. It is a rotary type, double-pole, double-throw switch and has sufficient insulation for use in this position. Because of the rotary mechanism, the manner of making the correct connections may be confusing, but if a rotary switch is used it is only necessary to wire it exactly as shown in the wiring diagram.

Switch S_2 is a standard 110-volt a.c. switch available at many radio parts dealers and most electrical supply houses. This switch was designed to break 15 amperes at 125 volts and has excellent insulation and a very positive action. The power factor of the insulation used is not particularly good on 10 and 20 meters, but on these bands the switch is closed and there is no voltage on it. Because of the low resistance and heavy current-carrying capacity of the switch, it makes an excellent shorting switch for the tank circuit. The properties of the insulation are such that on 40 and 80 meters the losses are very low even though there is considerable r.f. voltage on one of the switch contacts on these bands. The mounting plate is cut down as shown in the illustration. This gets rid of the "OFF-ON" engraving.

An r.f. relay can be substituted for S_2 if desired. The relay should have low resistance contacts and preferably work on 6.3 volts a.c. The switch S_1 should in this case have another set of contacts, in order to control the relay. With this arrangement it is necessary to throw but one switch.

The Coils

Oscillator coil L_1 consists of 58 turns of no. 20 d.c.c. closewound on a 1-inch diameter form, the form being 3½ inches long. It is mounted under the chassis as shown in the illustration. The quadrupler coil consists of 17 turns of no. 14 enameled wire. This coil is wound on a ¾-inch diameter hardwood dowel or other form, then removed from the form and spaced to 1¾ inches. When removed from the form the diameter of the coil will be somewhat greater than ¾ inch because of the spring in the wire.

The "cold" ends of both oscillator and quadrupler coils connect to the same tie point, as may be seen in the illustration. The "hot" end of the quadrupler coil is soldered directly to a stator lug on C_2.

Coil L_3 is wound with no. 18 d.c.c. on a standard ceramic form 1¾ inches in diameter and 3½ inches long. The large portion of the coil consists of 15 turns "loosely closewound" (closewound, but not squeezed together tightly). The small part of the coil (10- and 20-meter portion) consists of 4 turns spacewound as shown in the illustration of the end view of the exciter.

Setting on the chassis is a finished coil all ready for bolting to the condenser brackets. The coil is constructed as follows:

Insert one end of the no. 18 d.c.c. through the second wire hole from one end of the form (ignoring the mounting hole). Wind 15 turns and then cut the wire off leaving about 5 or 6 inches free. Poke the wire through the ninth wire hole and skin the insulation from all the wire projecting from the inside of the form. Then pull the wire up through the thirteenth wire hole. This wire lead will fasten directly to the switch.

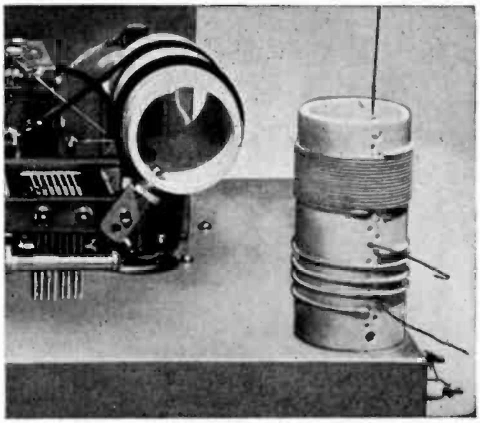


Figure 11.
FINAL TANK COIL DETAIL.
The ceramic coil form is fastened to the tank condenser by means of tilted brackets. To the right is a coil all ready to be fastened to its mounting brackets.

Insert one end of some more no. 18 d.c.c. in the fourteenth, or next, wire hole and solder it to the other wire inside the coil form. Now spacewind 4 turns in the same direction as the closewound portion of the coil, poking the wire through the third wire hole *counting from the other end of the form,* ignoring the mounting hole as before. Now come back one wire hole, or to the fourth wire hole from that end, to bring this lead through. Space the 4 turns evenly and apply a coat of good coil dope to the whole coil. A dope of the "liquid victron" type is to be preferred for lowest losses on 10 meters.

The wire extending from the closewound end of the coil goes to ground and simply is wrapped around under the bolt which fastens the coil form to one of the mounting brackets. The lead on the other end of the coil goes directly to the stator of the condenser. The tap is fastened to the top connection of the switch S_2.

This arrangement permits very short leads on 10 and 20 meters, an important consideration on these two bands when using a bandswitch. With the bandswitch closed this coil will resonate on 10 meters with the plates nearly out and on 20 meters with the plates about two-thirds of the way in. With the switch open the condenser will tune to 40 meters with the plates almost all the way out and to 80 meters with the plates almost entirely meshed.

The output link consists of a series link arrangement permitting uniform coupling on all four bands. For link coupling to another tuned circuit, one coupling turn placed just up from the ground end of the high-frequency section of the coil should be connected in series with two or three turns wound around the center of the low-frequency portion of the coil. Be careful to wind the link turns in the *same direction*. Adding or subtracting a turn from either section has little effect upon the other section. This makes it possible to adjust the coupling independently so that approximately the same degree of coupling is obtained on 10 and 20 meters as on 40 and 80 meters.

When coupling to a high-impedance load such as a 400- or 500-ohm line, it will be necessary to use more link turns. The pickup links shown in the illustration give just the proper loading for working into 450 ohms on all bands. Five turns around the center of the low-frequency portion of the coil were connected in series with two turns around the cold end of the high-frequency portion of the coil. For most purposes the load impedance will be lower than 450 ohms and fewer link coupling turns will be used.

Should one turn around the high-frequency coil give too much coupling on 10 meters, a larger diameter turn may be used to decrease the amount of coupling. The pickup turns may be wound with no. 18 solid push-back hookup wire having good insulation. It is desirable to keep the capacity coupling between the tank coil and pickup turns as low as possible. For this reason, self-supported pickup turns of no. 12 or 14 enameled wire about 2¼ inches in diameter would be somewhat preferable to the arrangement shown.

Wiring

All wiring is done with no. 18 solid pushback wire. Condensers C_{12}, C_{13}, C_{14} and C_{15} should be placed right at the 807 socket. A common ground connection is made to a lug under the nuts that fasten the socket. A lug is also placed under the head of the bolt, above the chassis. A wire is soldered from this lug to the rotor frame of C_3. The front panel should not be relied upon for a ground return, because of the long path resulting and due to the fact that the panel is bolted at only a few points. Likewise, a wire is run from the rotor of C_1 to the point on the chassis where most ground returns are made in the crystal oscillator.

Leads to all by-pass condensers are made as short as possible. The resistors, excepting R and R_1, have no r.f. on them and need not be placed with respect to lead length. Instead they are placed wherever room permits and leads are run over to them.

The circuit used permits the mounting of all three variable condensers directly to the panel or chassis. C_1 and C_2 have the plate voltage impressed across them and therefore should have at least .03-inch gap. The condenser C_3 has no plate voltage impressed across it but will be subjected to higher r.f. peaks, especially if the 807 is plate modulated. For this reason this condenser also should have at least .03-inch gap.

If a modulator capable of delivering considerably more power than is needed for 100 per cent modulation is utilized, the by-pass condenser C_{10} should be of 1200-volt rating to prevent its being blown by high audio peak voltages.

Power Supply

The power supply should be capable of delivering between 550 and 600 volts under load and should have very good regulation. The one illustrated in the

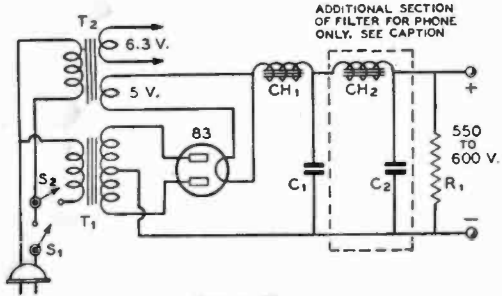


Figure 12.

RECOMMENDED POWER SUPPLY FOR THE "4-25."

T_1—700 to 750 v. each side c.t., 200 ma.
T_2—5 v. at 3 amp. and 6.3 v. at 3 amp.
C_1, C_2—4-µfd. 600 w.v. oil filled condensers
CH_1—5-25-hy. 200-ma. swinging choke
CH_2—20-hy. 200-ma. smoothing choke
R_1—50,000 ohms, 20 watts
Note: CH_2 and C_2 are required only if 807 is modulated for phone or if the exciter is used to drive a grid-modulated stage.

wiring diagram is especially well suited for use with the exciter. The second section of filter comprising CH_2 and C_2 will not be required except when plate modulating the 807 or when using the exciter to drive a grid-modulated amplifier. When the exciter is used for c.w. work or to drive a plate-modulated amplifier, a single section of filter will be sufficient.

The exciter makes an excellent phone transmitter. A modulator capable of delivering approximately 25 watts of audio will be required for full modulation. It is very important that the keying jack J_1 not be opened when modulation is applied; *damage to the 807 screen and blown by-pass condensers may result.*

Tuning Up

The initial tuning should be done preferably with a crystal that quadruples close to 14,250 kc. With the switches S_1 and S_2 in their "high-frequency" positions (10 and 20 meters) C_1 and C_2 are tuned for maximum drive to the 807, which should be tuned to 10 meters while initial adjustments are being made to C_2. The ten-meter setting of C_3 will be with the plates almost entirely out. The setting of C_1 should be backed off slightly from the "edge" of oscillation (maximum capacity setting at which the crystal will oscillate). This gives better keying and makes it unnecessary to retune the condenser when changing bands.

To change bands merely throw switches SW_1 and SW_2 and retune the condenser C_3. When going from 10 to 20 or from 40 to 80 it is not even necessary to throw the switches. Just return C_3 to the high capacity resonance setting.

Condenser C_2 need never be touched after the initial adjustment is made, but C_1 may require touching up if a crystal on the high-frequency end of the 80-meter band is used (such as for 75-meter phone). For this reason C_1 was put on the front panel instead of on the chassis like C_2.

As the exciter stands it can be used only with 80-meter crystals. By tapping L_1 at a suitable point and incorporating a shorting switch, 40-meter crystals also can be accommodated. This might be desirable where the constructor already possesses several 40-meter crystals and wants to make use of them for additional frequencies on the three high-frequency bands. Tuning of the exciter will be the same except that there will be no 80-meter output. The second 42 will operate as a doubler instead of a quadrupler when a 40-meter crystal is used.

The exciter can be used to cover 160, 80, 40 and 20 meters instead of 80, 40, 20 and 10 meters by incorporating a 250-µµfd. condenser at C_3 and using larger coils.

The 807 should not be loaded to more than 90 ma. For phone the 807 should not be loaded so heavily that it will not modulate upwards. This may happen in trying to load the tube to draw 90 ma. when less than 500 volts is applied to the plate, especially when the tube is operated as a doubler.

E. C. Operation

The "4-25" may be driven from an electron-coupled exciter having output on 80 meters simply by coupling to the grid of the 4-25 oscillator by means of an untuned pickup coil of a few turns around the cold end of the e.c. output tank. If too many turns are used the 4-25 oscillator may tend to run self-controlled. The e.c. oscillator should have an output of at least 5 watts; if the output is much less than this too many pickup turns will be required and the 42 will tend to oscillate as a result of imperfect screening and lack of neutralization.

10-WATT ELECTRON-COUPLED EXCITER

The use of stabilized, variable-frequency oscillators for transmitter frequency control is becoming more and more popular among amateurs. The problem of getting a sufficiently stable oscillator is more difficult than in the case of a superheterodyne because of r.f. feedback from the transmitter, especially when high power is used.

If an oscillator is protected from feedback from the following stages, is either protected from or made immune to temperature changes, and is fed from a stabilized source of voltage, than it is possible to approach the stability of crystal control—even surpassing it if certain compensating circuits are incorporated.

In the common electron-coupled oscillator in which a tapped coil is used in the cathode circuit, it is difficult to avoid r.f. pickup by the cathode from the heater circuit. One way of avoiding this type of r.f. pickup is to tie one of the heater terminals to the cathode and feed the other heater terminal by means of an interwound cathode coil, the turns being wound between the turns of that portion of the oscillator coil between cathode and ground.

Another way of avoiding this type of r.f. pickup by the oscillator is to use a grounded cathode type oscillator, such as a Hartley. This is done in the exciter to be described, a 6K8 type mixer tube serving as combined oscillator and buffer amplifier. This type of oscillator secures electron coupling between the oscillatory circuit and the output plate by virtue of the direct connection between the oscillator grid and the hexode injection grid. As the injection grid is shielded from the output plate, all of the coupling is through the electron stream.

This exciter utilizes an oscillator operating in the 160-meter band followed by a class-A isolating stage and an output stage which doubles to 80 meters. The output frequency range is 3500 to 3650 kc. Gang tuning between the oscillator and the doubler provides uniform output over this band. The 3500 to 3650 kc. range allows full coverage on 20 and 40 meters and, as there is some leeway on the high-frequency end of the dial, coverage of the low-frequency half of the 10-meter band. The rest of the 10-meter band may be covered by simply resetting the two "bandset" condensers in the exciter.

The exciter may be modified easily for 75- and 160-meter phone operation as explained subsequently.

Additional stability in the oscillator is obtained by tapping the grid down on the coil. Tapping the grid one-third of the way down the coil is equivalent to using slightly greater than twice as much C with the grid connected to the end of the coil.

Tapping the grid down the coil causes small separate tuned circuits to be formed; these circuits may lead to parasitic oscillations if the tapping is carried too far. With the tap one-third of the way down, however, there is no tendency toward parasitics.

A 500-$\mu\mu$fd. zero temperature-coefficient condenser is used across the whole grid coil to provide an effectively high-C 160-meter oscillator section. Also across the grid coil is a 100-$\mu\mu$fd. midget variable air condenser for bandsetting.

It will be noted from the diagram that the hexode section of the 6K8 besides functioning as an electron-coupling section between the oscillator section and the next stage is also used as a Pierce oscillator for crystal-controlled operation on the band edges. Either 80- or 160-meter crystals may be used for this purpose.

To eliminate the effect of a varying load on the oscillator, the screen of the

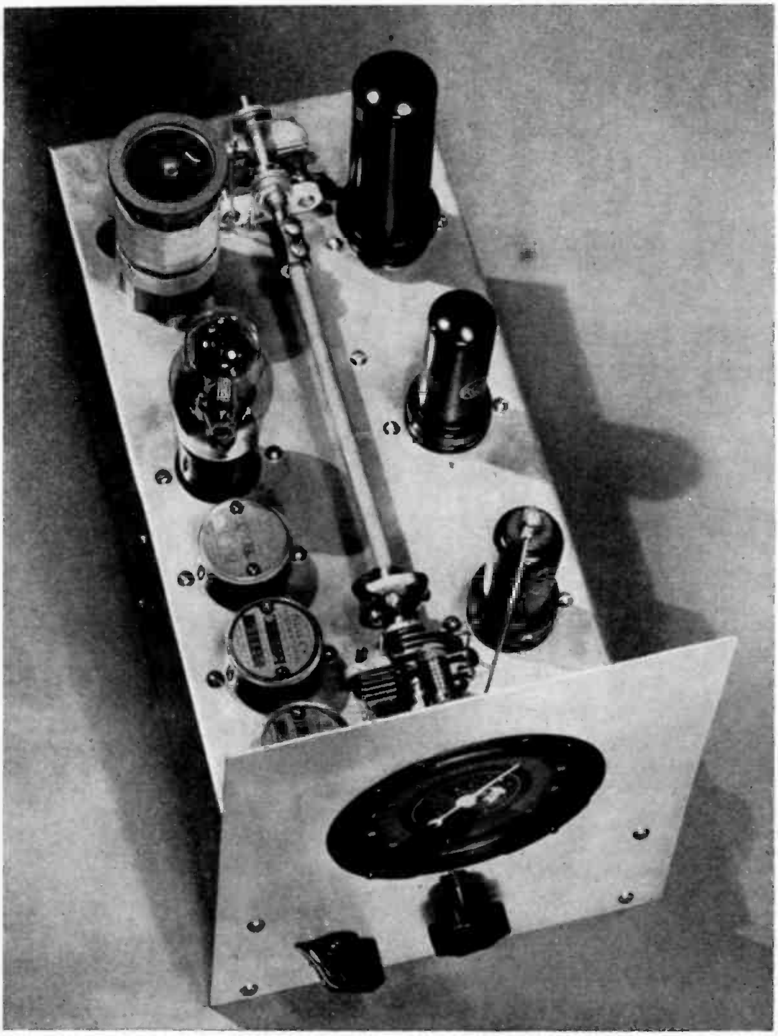


Figure 13.

10 WATTS OUTPUT EITHER CRYSTAL OR SELF-CONTROLLED.

The doubler output tank is ganged with the oscillator tuning condenser in order to provide uniform output over the band of 3500 to 3650 kc.

6F6 is supplied 150 volts of regulated voltage from the VR-150 voltage regulator. The regulated 150 volts is also applied to the 6K8 output plate and, through a resistor which drops it to 80 volts, to the plate of the triode oscillator section.

Plate voltage of 250 volts for the 6F6 comes from a voltage divider in the power supply. The tap on the voltage divider is separately filtered by an 8-μfd. electrolytic condenser. As it is this voltage which is dropped to 150 volts and regulated for the oscillator, the oscillator receives well filtered voltage. Due to its regulating action, the VR-150 also acts like a good sized section of additional filter on the stages receiving regulated voltage.

Following the class-A 6F6 is the 6L6 output stage. Shunt plate feed is used to allow the tank and "bandspread" condensers to be grounded. Screen voltage for the 6L6 is taken from the same 250-volt tap on the voltage divider that supplies the 6F6 plate. The full 500 volts from the power supply is used on the 6L6 plate. This stage operates as a doubler when the crystal selector switch is on the e.c.o. position or on the crystal positions with 160-meter crystals. With 80-meter crystals the stage operates as a straight amplifier, giving slightly more output than the e.c.o. setting.

A 20-$\mu\mu$fd. condenser across the output tank ganged with the oscillator tuning condenser allows the output to be kept at peak across the whole tuning range.

Switch Action

A single four-section five-position selector switch takes care of all the switching operations when changing from crystal to e.c.o. and between the three crystals available. Two sections of the switch are in the control grid and plate circuits of the 6K8 hexode section. The center three contacts on these select any one of the three crystals available. The two end contacts on the grid section are connected together, and when the switch is thrown to the end, or e.c.o., position, positive voltage is fed through R_4 and to the control grid. This small voltage on the hexode control grid raises the e.c. output considerably.

The third and fourth sections of the switch each have their end contacts connected together, while the rest of the contacts are left blank. In the e.c.o. positions one of the sections applies plate voltage to the triode section of the 6K8 and the other connects the dial lamps across the filament supply.

Chassis Layout

The two photographs show how the parts are arranged on the chassis. The chassis measures 12 x 6 x 3 inches. The three tubes are spaced evenly along the right side. The left side mounts the three crystals, the VR-150 regulator and the output coil, from front to back, in the order named. At the center of the chassis near the front and rear edges are mounted the two "bandspread" condensers, C_1 and C_2. These are ganged together by couplings and a length of quarter-inch shafting.

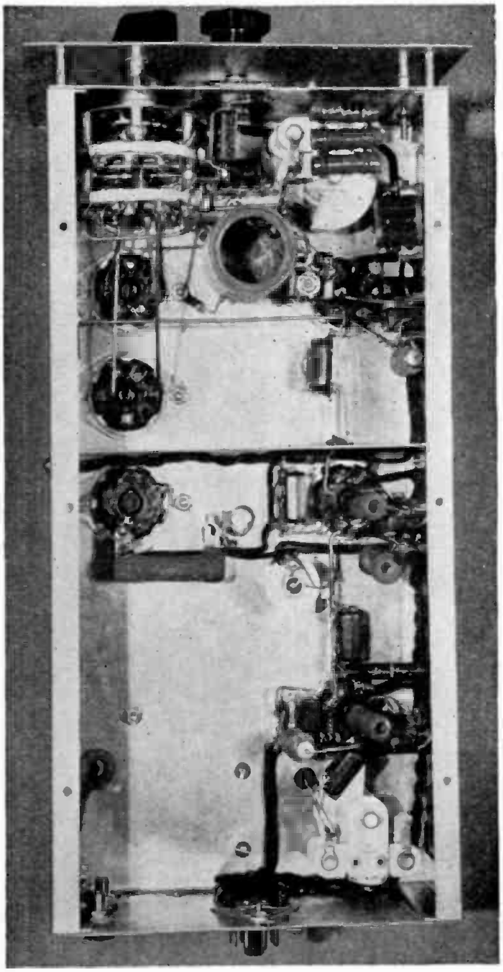


Figure 14.

UNDER-CHASSIS VIEW OF THE VARIABLE FREQUENCY EXCITER.

The baffle separating front from the rear section not only shields the oscillator from the output circuits electrically but also tends to reduce heating of the oscillator by the resistors which carry appreciable current. The latter are all placed to the rear and ventilation holes in the rear compartment prevent heat from reaching the oscillator.

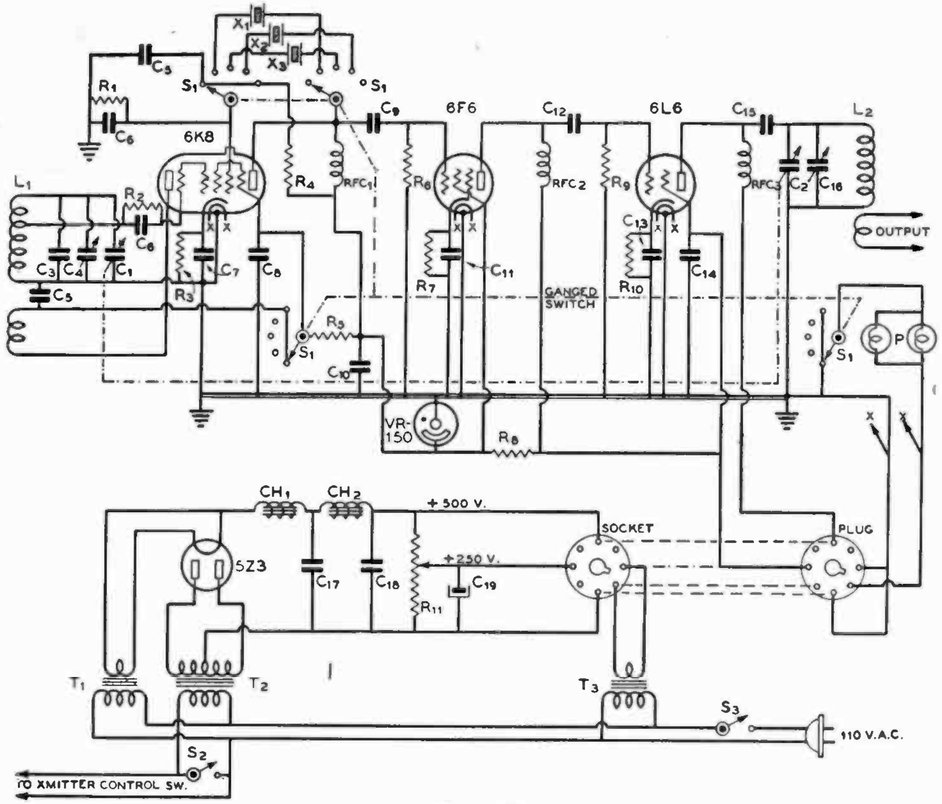


Figure 15.

WIRING DIAGRAM OF THE ELECTRON-COUPLED EXCITER.

C_1—75-μμfd. midget with one stator plate removed

C_2—20-μμfd. midget

C_3—500-μμfd. zero-coefficient ceramic

C_4—100-μμfd. midget

C_5—.005-μfd. mica

C_6—.0001-μfd. mica

C_7, C_8—.005-μfd mica

C_9—.0001-μfd. mica

C_{10}, C_{11}—.005-μfd. mica

C_{12}—.0001-μfd. mica

C_{13}, C_{14}, C_{15}—.005-μfd. mica

C_{16}—100-μμfd. midget

R_1—50,000 ohms, ½ watt

R_2—100,000 ohms, ½ watt

R_3—500 ohms, 1 watt

R_4—300,000 ohms, ½ watt

R_5—10,000 ohms, 10 watts

R_6—100,000 ohms, ½ watt

R_7—500 ohms, 10 watts

R_8—2500 ohms, 10 watts

R_9—100,000 ohms, 1 watt

R_{10}—500 ohms, 10 watts

S_1—Four-pole, five-position, two-section isolantite tap switch

S_2, S_3—S.p.s.t. toggle switches

X_1, X_2, X_3—Band-edge crystals—near 3500, 3600 and 3650 kc.

L_1—Grid winding—22 turns tapped at 7 turns from "hot" end; feedback winding—16 turns, both windings of no. 22 d.c.c. close wound on 1¼-inch form. ⅛-inch space between windings.

L_2—25 turns no. 22 d.c.c. close wound on 1½-inch form. Link winding — 8 turns no. 22 d.c.c. close wound, spaced ¼-inch from plate winding.

RFC_1—2.5 mhy.

RFC_2—8 mhy.

RFC_3—2.5 mhy.

Power Supply

C_{17} C_{18}—4-μfd. 600-volt oil filled

C_{19}—8-μfd., 450-volt electrolytic

R_{11}—25,000 ohms, 80 watts

T_1—5 v., 3 a.

T_2—1400 v.c.t., 150 ma.

T_3—6.3 v., 4 a.

CH_1, CH_2—25 hy., 140 ma.

The under-chassis layout is shown in the bottom-view photograph. The 100-μμfd. oscillator bandsetting condenser, C_4, is between the 6K8 socket and the front of the chassis. It is mounted through the chassis so that the rotor shaft is available from above. The oscillator coil, which is wound on a 1¼-inch diameter form with the prongs cut off, is secured to the underside of the chassis at the center of the oscillator compartment. All of the wiring is short and direct, where possible. Heavy wire is used for all leads falling within the field of the oscillator coil and these are firmly tied down at each end.

The 500-μμfd. zero-coefficient fixed oscillator padding capacity is mounted by its leads across the terminals of the 100-μμfd. air bandset condenser. A brass sleeve over a long screw holding the 6K8 socket in place is used to hold the tie-point which supports the coil end of the oscillator grid leak and condenser combination.

The shield across the underside of the chassis separates the entire oscillator circuit from the rest of the unit. Besides providing electrical separation, this shield also acts as a baffle to keep the heat generated by the various dropping and cathode resistors from reaching the oscillator section, as has been discussed before. A row of quarter-inch vent holes in the bottom plate and across the rear drop of the chassis allows free circulation of air through the *rear* section of the chassis.

The wiring and arrangement of the class-A and output stages are conventional and need no detailed discussion. The placement of the various parts is clearly visible in the illustrations.

The front panel, which measures 7 x 8 inches, is separated from the chassis by four ⅝-inch sleeves. Placing the panel away from the chassis in this manner allows the "works" of the dial to be kept out of the oscillator compartment, removing a source of vibration from the field of the coil.

Not shown in the photographs is the bottom plate which covers the complete unit. Four sponge-rubber feet of the type used to shock-proof tuning assemblies in b.c. receivers are placed on the bottom plate to separate the entire unit from the effects of operating-table and room vibration.

Operation

No difficulty should be experienced in placing the unit into operation. With the coil and condenser sizes specified, approximately 80 degrees of bandspread will be obtained for the 3500 to 3650 kc. range, and the oscillator and output stage tanks will track perfectly over this range.

With 80-meter crystals, the e.c.o. and crystal outputs are 10 and 12 watts, respectively. With 160-meter crystals, the output measures 10 watts on both the crystal and e.c. positions. These outputs are sufficient to excite either a 40-meter "straight" crystal stage or an 80 to 40 tri-tet or harmonic oscillator in the transmitter. The exciter also could be used to replace the present crystal stage where a straight 80-meter crystal oscillator has been used.

75- and 160-Meter Phone

By removing one or two turns from both grid winding and plate winding of L_1, it is possible to make the oscillator cover the range of 1800 to 2000 kc. simply by omitting C_4 and substituting a 200-μμfd. condenser for C_1. It will no longer be practical to gang the output tank condenser, and therefore C_2 should be omitted and C_{16} provided with an extension shaft so that it may be adjusted from the front panel.

Because L_1 is so effectively isolated from L_2 both capacitively and inductively, no neutralization of the 6L6 is required for operation on 160 meters. Hence either 160 or 75 meter output may be had from the 6L6 by plugging in a suitable coil at L_2.

While ordinarily it is desirable to operate a self-controlled oscillator on a subharmonic of the transmitter output from the standpoint of maximum stability, it is relatively unimportant on 160 meters because the stability of any oscillator is inherently better on low frequencies when figured on an absolute basis rather than on a percentage basis.

THE "421" EXCITER

The "421" exciter or low powered transmitter is an outgrowth of the well-known "Bi-Push" exciter which has enjoyed widespread popularity for the last three years. While the components for a "421" cost no more, the exciter possesses many important advantages over its predecessor. It permits all band operation, allows quicker band change, shows lower crystal current, puts a more constant load on the power supply, puts less maximum drain on the power supply, allows crystal keying, and provides considerably greater output.

Essentially the exciter consists of a 42 oscillator and two pentode-connected 42 doublers, with provision for exciting the grids of a push-pull T21 amplifier from any of the three 42 stages by virtue of untuned pickup coils and a band switch. The exciter is constructed on a 5½ x 18 x 3 inch chassis, the construction layout being illustrated in figures 16 and 17.

The T21's deliver from 60 to 65 watts output on all bands down to 10 meters, and operation may be had on 1, 2, or 4 times crystal frequency. Fair operation may be obtained on 8 times crystal frequency by quadrupling in the first doubler stage, though the excitation to the T21's will be a little less than when using the stage as a doubler and working the T21's on four times crystal frequency.

Inspection of the wiring diagram will show that both crystal oscillator and the T21 stage are keyed simultaneously in the cathode circuit. The two 42 frequency doubler stages are always drawing current whether being used or not, and whether the key is up or down, thus stabilizing the plate voltage and also the screen voltage on the oscillator during keying.

All three 42 stages are run with high cathode bias and moderately low screen voltage; hence the plate current is low even when the doublers are detuned or the oscillator is not oscillating. For this reason no provision is made for measuring the plate current to these stages. No matter how these stages are tuned the plate current cannot be made to go high enough to damage the tubes, and therefore one need simply tune for greatest excitation to the T21's without regard to plate current to the 42's.

In spite of the comparatively high bias on the oscillator, the crystal current is not excessive because the screen voltage from screen to cathode measures less than 100 volts, due partly to the large voltage drop in the 2500-ohm cathode resistor.

Very few by-pass condensers are used for the three 42 stages, most of these condensers doing double duty. The condensers C_8, C_9, and C_{10} should be placed at the socket of the last 42, as this stage is the only 42 stage that must work at 10 meters. This makes the by-pass leads to the oscillator several inches long, but as the oscillator is never used on fre-

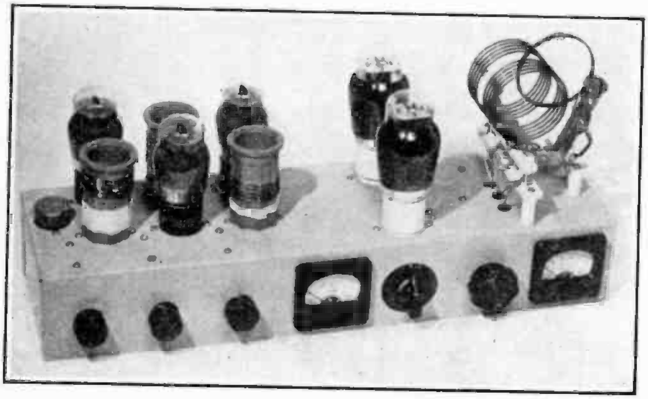


Figure 16.
THE "421" SEMI-BAND-SWITCHING EXCITER OR TRANSMITTER.

This unit delivers 65 watts on all bands from 10 to 160 meters and may be plate modulated for phone. Any three adjacent bands may be covered by changing only one coil. For c.w. work oscillator keying is provided. No regenerative or critical "trick" circuits are incorporated.

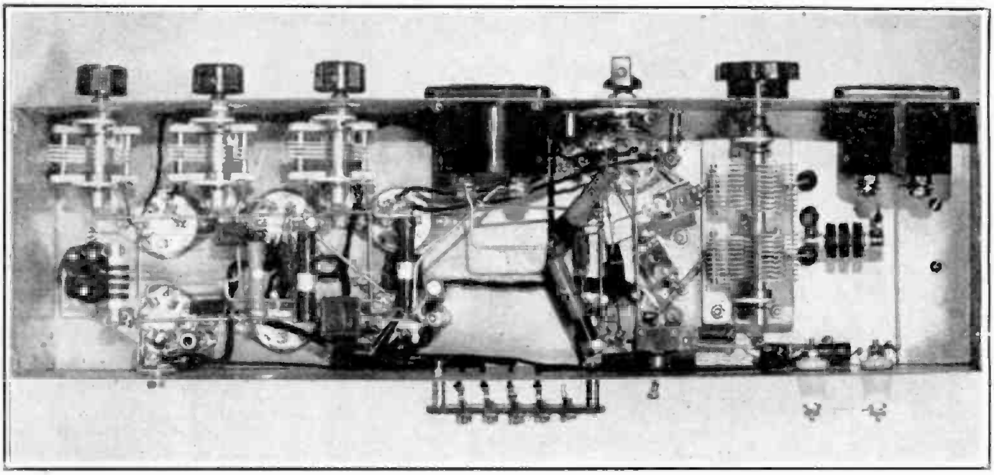


Figure 17.

UNDER-CHASSIS VIEW OF THE "421" EXCITER-TRANSMITTER.

The three midget condensers to the left are mounted on ceramic pillars; the split stator final tank condenser is mounted by means of holes provided in the ceramic base. As the rotor of none of these condensers is grounded, knobs having well-protected set screws should be used.

quencies above 7 Mc., the by-passing is quite satisfactory.

To prevent arcing of the final tank condenser (which is not double spaced) when the final stage is either modulated or unloaded, the rotor is not grounded. The output capacity of the two T21's is sufficiently high to provide a good "split stator" capacity balance to ground. The shielding baffle between the two stators of the condenser is removed and the resulting hole in the ceramic base is used as a mounting hole to fasten the condenser to the chassis.

While the number of grid turns for the various coils is not especially critical, it may be necessary on the 10- and 20-meter coils to alter the number of turns slightly if the exact physical layout shown in the illustrations is not followed. The reason for this is that the leads to the selector switch S_1 make up an appreciable part of the inductance of the T21 grid circuit on the higher frequency bands.

The T21 tuning condenser, C_4, does not have sufficient capacity for 160-meter operation. In order to attain operation on that band the 160-meter coil is padded with two 2500-volt test 150-$\mu\mu$fd. mica condensers in series, making an effective 75-$\mu\mu$fd. padding capacity across this coil. The condensers are supported by their leads outside the coil in such a manner that they do not interfere with the movement of the swinging link.

421 COIL TABLE

All coils are wound on 1½ in. dia. forms with grid coil at ground end of plate coil, at bottom of form.

160 Meters

Plate winding: 62 turns no. 24 enam. close wound. Grid winding: 58 turns no. 24 enam. close wound. Start plate coil at top of form. Wrap layer of insulating paper over lower half of coil, and starting at bottom of coil form wind grid coil. Upper portion of grid coil is wound over lower portion of plate coil.

80 Meters

Plate winding: 28½ turns no. 24 enam. close wound. Grid winding: 45 turns no. 24 enam. close wound, separated ⅜ in. from plate winding.

40 Meters

Plate winding: 15½ turns no. 18 enam. close wound. Grid winding: 22 turns no. 22 d.c.c. close wound, separated ½ inch.

20 Meters

Plate winding: 8½ turns no. 18 enam. spaced to 1 inch. Grid winding: 10 turns no. 22 d.c.c. close wound, separated ½ in. from plate winding.

10 Meters

Plate winding: 4½ turns no. 18 enam. spaced to ½ inch. Grid winding: 7 turns no. 22 d.c.c. close wound, separated ¼ inch from plate winding.

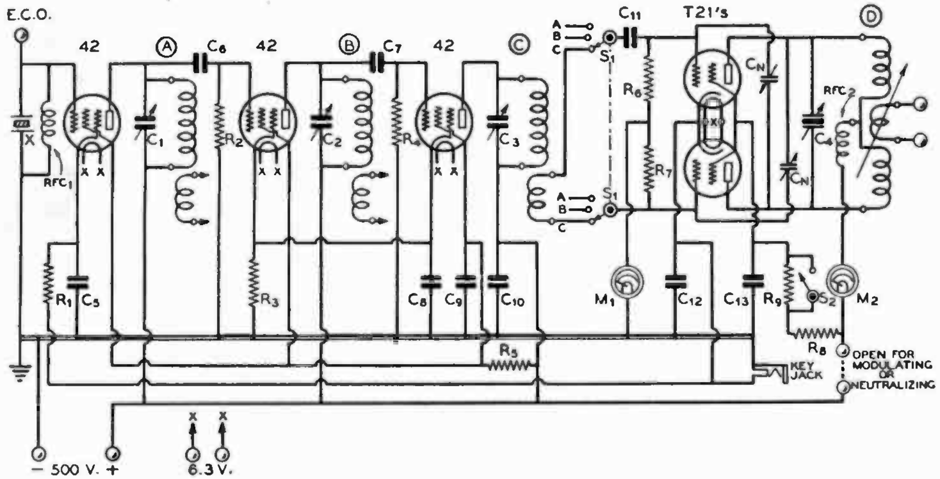


Figure 18.

WIRING DIAGRAM OF THE "421" EXCITER.

C_1, C_2, C_3—50-μμfd. midgets, insulated from chassis
C_4 — 140-μμfd. per section dual midget, rotor insulated from chassis
C_5 — .003-μfd. midget mica, 900 v. test
C_6, C_7 — 50-μμfd. midget mica, 900 v. test
C_8, C_9, C_{10}, C_{11}, C_{12}, C_{13} — .003-μfd midget mica, 900 v. test
C_N—3-30 μμfd. ceramic trimmers with adjusting screw removed
R_1—2500 ohms, 10 watts
R_2—100,000 ohms, 2 watts (carbon)
R_3—750 ohms, 10 watts
R_4—100,000 ohms, 2 watts (carbon)
R_5—25,000 ohms, 10 watts
R_6, R_7—20,000 ohms, 2 watts (carbon)
R_8—15,000 ohms, 10 watts
R_9—250,000 ohms, 1 watt
Coils A, B, C — wound on 1½ inch forms (see coil table)
Coil D—Commercial 100-watt coils with swinging link. 160-meter coil padded with 75 μμfd. (see text)
S_1 — 2-pole 3-throw band switch
S_2 — Well insulated toggle switch (open for tuning)
M_1—0-15 ma. d.c.
M_2—0-300 ma. d.c.

Neutralization

The T21's are neutralized on 20 meters, with the 20-meter plate coil in place and the T21's excited on 20 meters. First, open the neutralizing jumper so as to remove plate and screen voltage from the T21's while permitting voltage to be applied to the rest of the exciter. Then completely remove the adjusting screws from the small 3-30 μμfd. ceramic base mica trimmers. With S_1 thrown to the proper position and the correct coils and crystal in place, tune for maximum 20-meter excitation to the T21's as indicated by the grid current on meter M_1.

Now, as C_4 is slowly tuned, a "kick" in grid current will probably be noticed at resonance. The two movable plates should be bent in or out together a bit at a time until absolutely no flicker is noticed when the condenser C_4 is tuned through resonance from a few degrees either side. Merely removing the screws gives almost the correct adjustment for exact neutralization with some makes of trimmer, and in some instances further adjustment of the trimmers will not be necessary.

If the suggested physical layout is followed and leads are made symmetrical, the amplifier will neutralize "stone cold" and the adjustment will hold very accurately for all bands.

Tuning

After first opening the screen switch S_2, the 42 stages are tuned for greatest grid current to the T21's on the desired band of operation. With S_2 open the plate current to the T21's will not go over about 75 ma. when excitation fails, thus protecting the T21's from excessive dissipation and plate current while tuning up. After tuning the 42's for maximum T21 grid current as read on M_1 (it should be from 6 to 10 ma. with no plate voltage on the T21's), the T21 tuning condenser C_4 is tuned to the "dip." With S_2 open the T21 off-resonance plate current will be quite low, about 25 ma., but it is enough to permit one to find the resonance point. Switch S_2 is then closed and final adjustments made on all tuning condensers.

Before closing switch S_2, it is a good idea to make sure that the crystal oscillator is not adjusted too close to the "edge" of oscillation, as the T21's will be damaged if allowed to run more than a moment without excitation when S_2 is closed. Make sure the crystal "takes off" readily by throwing the plate voltage on and off a few times.

One should also keep in mind that T21's, like 6L6's and 807's, can be permanently damaged by permitting full screen voltage to be applied when there is no plate voltage. So make sure there is always a coil in the final stage before applying voltage.

The T21's can be loaded to around 190 ma. When full load is applied the grid current should not fall below 5 ma. If it does, some juggling of the number of grid turns or spacing between windings of the 42 coils is in order. Any value of grid current between 5 and 8 ma. is satisfactory for full load operation of the T21's, little difference in operation being noted. However, the efficiency begins to suffer if the grid current falls below 5 ma. when the T21's are fully loaded. When changing bands, condensers C_1, C_2, and C_3 should *all three* be retuned for maximum grid current to the T21's. This is necessary because throwing the switch S_1 detunes the 42 stages slightly. For maximum drive to the T21's from the *second* 42, the *third* 42 plate tank should be retuned also, as its adjustment affects the grid impedance of the third 42 and thus the load on the previous stage.

E. C. O. OPERATION

If it is desired to use the "421" in conjunction with an electron coupled exciter it may be done with excellent results provided the output of the e.c.o. unit is greater than 7 or 8 watts and is on 40, 80, or 160 meters. The e.c.o. unit should be placed as close to the "421" as possible. The two chassis are tied together with a short lead to provide a common ground, and the "e.c.o." tap on the "421" is connected to a link around the output coil of the e.c.o., the other end of the link being grounded. If too many turns are used the first 42 in the "421" will self-oscillate. If too few turns are used, it will not receive sufficient excitation. The optimum number of link turns will be around 4 on 40 meters, 10 on 80 meters, and 20 on 160 meters. The output tank of the first 42 is tuned to the excitation frequency; it is not operated as a doubler.

Power Supply

The power supply should deliver approximately 500 volts at a load of 300

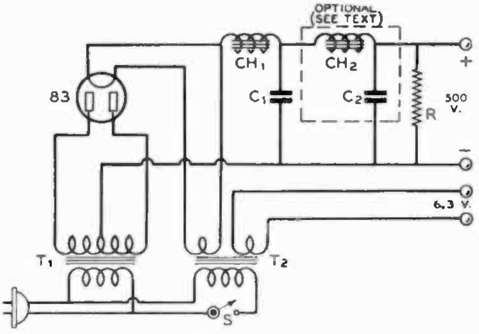


Figure 19.

RECOMMENDED POWER SUPPLY FOR THE "421" EXCITER.

T_1—625 to 650 v. each side c.t., 150 watts
T_2—5 v. 3 amp. and 6.3 v. 4 amp.
CH_1—5-20 hy. low resistance swinging choke 300 ma.
CH_2—10 hy. low resistance choke, 300 ma.
C_1 C_2—4-μfd. 600 v. condensers
R—50,000 ohms, 20 watts

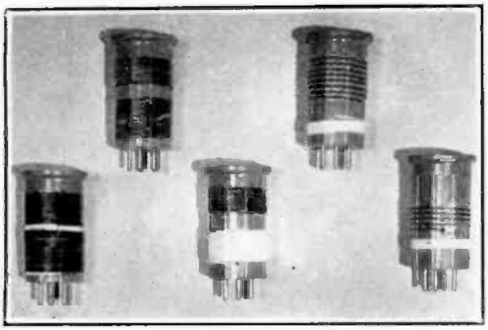


Figure 20.
OSCILLATOR AND DOUBLER COILS.
From left to right are the 160-, 80-, 40-, 20-, and 10-meter coils. Winding data may be found in the coil table.

ma. with good regulation. This calls for an 83 rectifier and a choke input filter with low d.c. resistance chokes. For c.w. operation or when used as an *exciter* to *drive* a c.w. or *plate* modulated amplifier, a single section filter will suffice. When the "421" itself is modulated, or when it is used as an exciter to drive a *grid* modulated amplifier, a two-section filter is desirable. A suitable power supply is shown in figure 19.

Antenna Coupling

The swinging link coil provided with the jack mounting base will sometimes provide insufficient coupling when working into certain kinds of untuned lines on 160 and 80 meters. If it is impossible to obtain sufficient coupling even with the link coil all the way "in" it will be necessary to add a couple of turns to the link.

100 WATT BANDSWITCHING EXCITER OR TRANSMITTER

In the accompanying illustrations is shown a unit delivering approximately 100 watts output on all bands from 10 to 160 meters without need for changing coils. Coil switching is incorporated in all three stages of the unit. Using an 814 beam tetrode in the last stage, the output approaches 100 watts on 10 meters and is well in excess of 100 watts on all lower frequency bands.

The oscillator is a conventional 6L6 tetrode type with a tank coil circuit that hits both 80 and 160 meters simply by rotating the condenser plates. To accommodate 40-meter crystals a shorting switch is connected to a tap on the coil to permit shorting out of sufficient turns to hit 40 meters. The oscillator is run at moderate plate voltage and very low screen voltage to keep the r.f. crystal current low, as not much output is required to drive the 807 stage.

The 807 buffer utilizes a manufactured type midget coil turret to permit output on all bands simply by throwing the coil switch. However, the 10-meter section is not used, inasmuch as the output of the 807 is not sufficient when quadrupling from 40 meters to drive the 814; the latter requires somewhat more excitation on 10 meters than on the other bands due to relatively high input capacity and resulting tank circuit losses with capacity coupling.

The 814 stage thus may be driven either on 1 or 2 times crystal frequency, and the 814 stage may be run either straight through or as a doubler, the efficiency being nearly as good when doubling as when working straight through as a result of high bias and adequate excitation. Thus output from the 814 is available on 1, 2, or 4 times crystal frequency.

As the oscillator tank is mounted below the chassis and the buffer and 814 amplifier tanks are separated by a shield

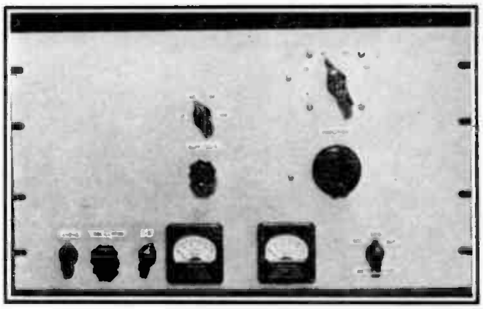


Figure 21.
100-WATT 10-160 METER BAND-SWITCHING EXCITER.
This exciter delivers about 90 watts on 10 meters and well over 100 watts on lower frequency bands.

Figure 22.

REAR VIEW OF EXCITER SHOWING OSCILLATOR AND BUFFER.

The 814 plate tank and bandswitch may be seen behind the shield baffle separating the oscillator and buffer from the final stage.

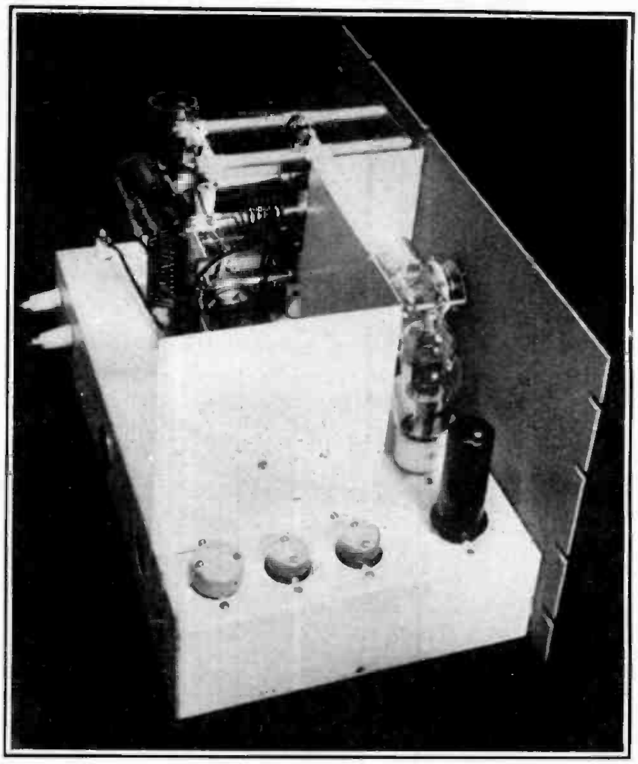
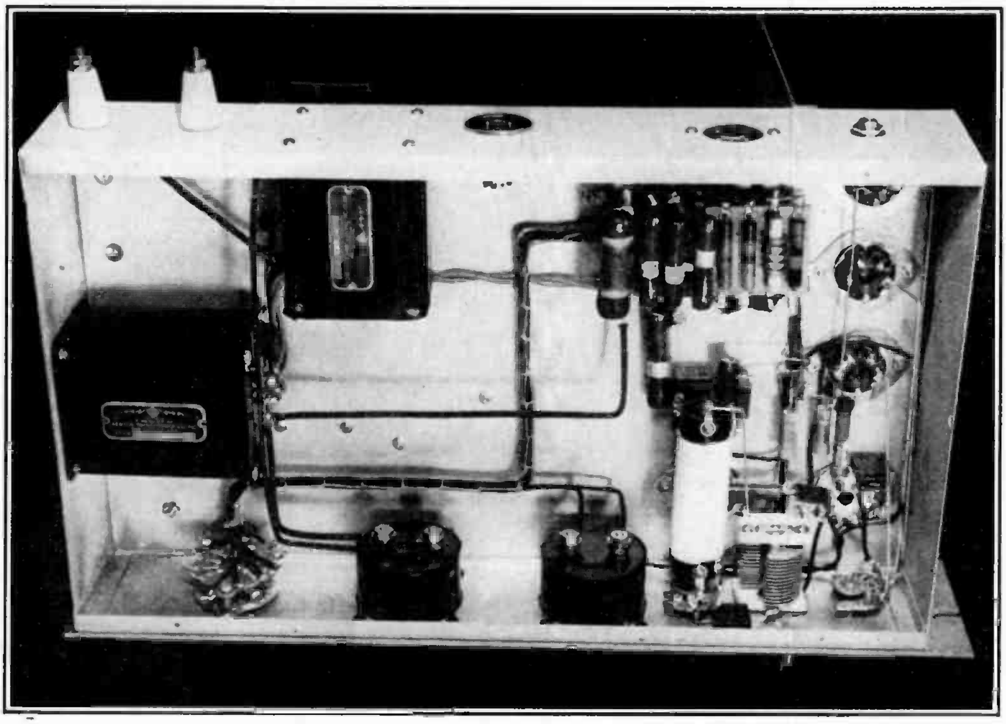


Figure 23. (Below)

UNDER-CHASSIS OF THE 100-WATT 814 BAND-SWITCHING EXCITER.

The tapped oscillator coil may be seen to the lower right. Most of the resistors are mounted on a terminal strip for the sake of neatness. The meter switch may be seen to the left of the two meters.



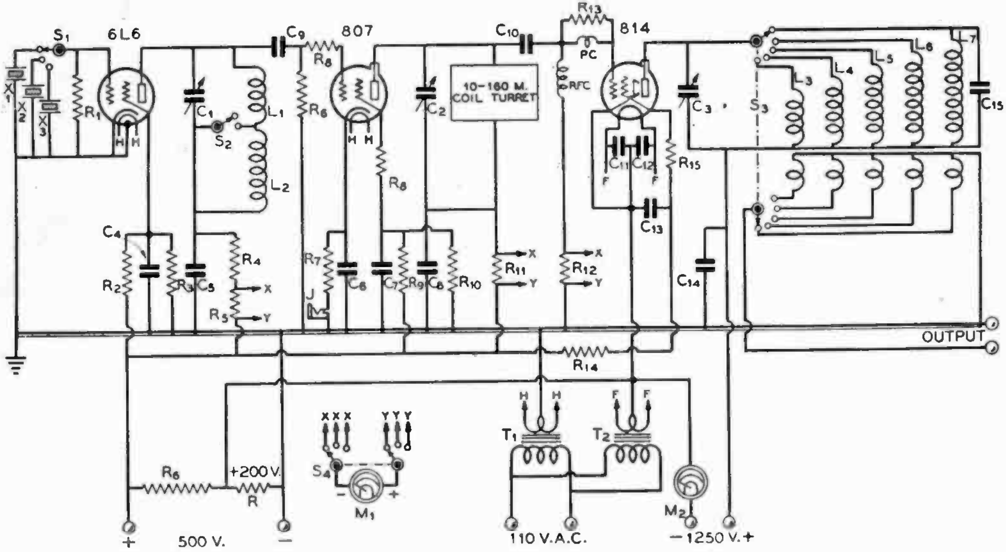


Figure 24.
WIRING DIAGRAM OF BANDSWITCHING 814 EXCITER.

R—4000 ohms, 25 watts
R_1—50,000 ohms, 1 watt
R_2—50,000 ohms, 1 watt
R_3—60,000 ohms, 2 watts
R_4—2500 ohms, 10 watts
R_5—50 ohms, 1 watt
R_6—100,000 ohms, 2 watts
R_7—750 ohms, 10 watts
R_8—50 ohms, 1 watt
R_9—100,000 ohms, 1 watt
R_{10}—50,000 ohms, 2 watts
R_{11}, R_{12}—50 ohms, 1 watt
R_{13}, PC—Parasitic suppressor
R_{14}—5000 ohms, 10 watts
R_{15}—50 ohms, 1 watt
C_1—140-μμfd. midget variable
C_2—100-μμfd. midget variable
C_3—100-μμfd. variable, 3000 v. spacing
C_4, C_5, C_6, C_7, C_8—.003-μfd. midget mica, 1000 v. test
C_9—25-μμfd. midget mica, 1000 v. test
C_{10}—100-μμfd. mica, 1000 v. test
C_{11}, C_{12}, C_{13}—.003-μfd. midget mica, 1000 v. test
C_{14}—.002-μfd., 5000 v. test
C_{15}—50-μμfd. air padder, 4000 v. spacing
M_1—0-100 ma. d.c.
M_2—0-250 ma. d.c.
T_1—6.3 v. 2 amp.
T_2—10 v. 4 amp.
S_1—Single-pole 3-throw "tone control" switch
S_2—Single-pole 2-throw "tone control" switch
S_3—High power two-gang five position bandswitch
S_4—Double-pole rotary meter switch

baffle above the chassis, all three stages are effectively shielded from each other. This results in stable operation when working "straight through."

Three crystal sockets and a crystal switch permit selection of three crystals from the front panel. The leads from the crystal sockets to the 6L6 grid via the crystal switch should be made as short and direct as possible. In fact, when a 40-meter crystal is used it is advisable to place it in the front crystal socket.

The particular method of connecting the low voltage power supply permits both screen voltage and fixed bias to be obtained for the 814, at the same time providing a desirable compensating action which keeps the 814 grid current from rising to dangerously high values when the load is removed. This compensating effect is obtained with grid leak bias and screen voltage from a series dropping resistor but is not obtained with ordinary fixed bias and fixed screen voltage. With the system shown it is important that the B— 500 and B—1250 volt leads are *not* connected together as is common practice.

The 814 plate tank consists of a husky, two-gang band switch and five coils; data for winding the latter are given in the coil table. To provide a low minimum tuning capacity for good 10-meter efficiency yet sufficient capacity to give a good "Q" on 160 meters, a 100-μμfd. variable condenser is used for tuning and

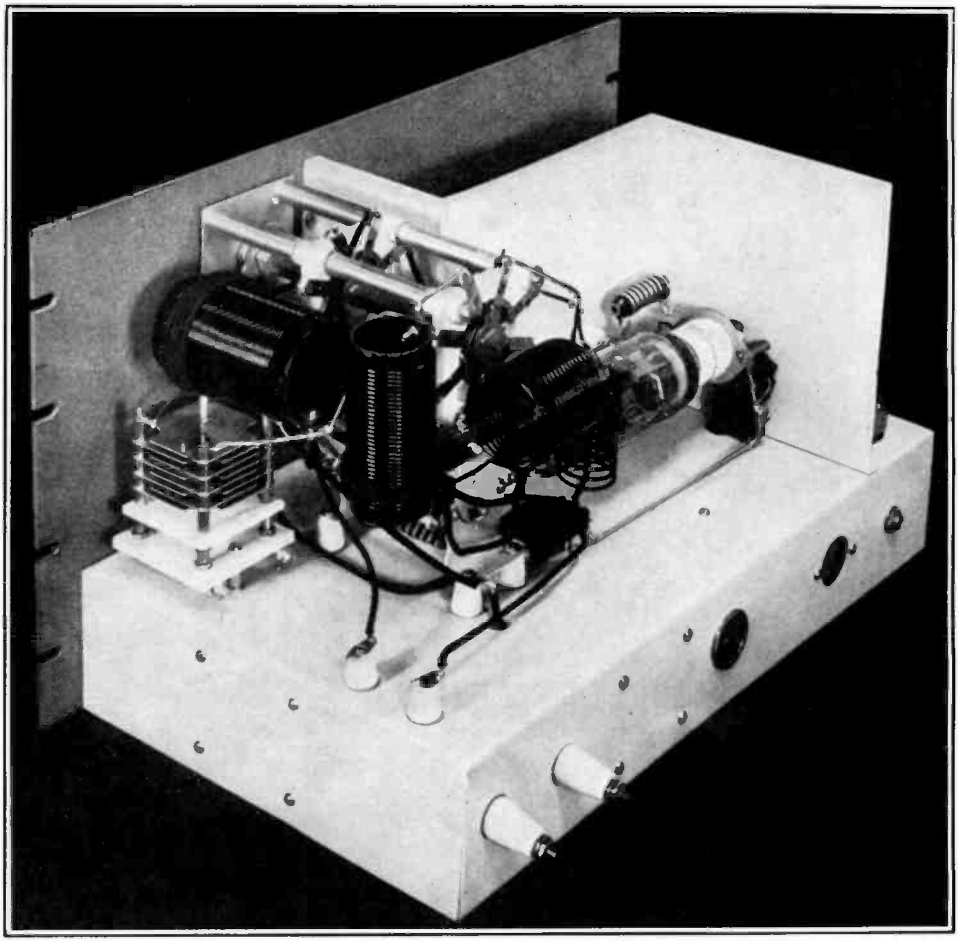


Figure 25.

814 OUTPUT AMPLIFIER OF 100-WATT BANDSWITCHING EXCITER.

Four of the five coils are visible in this photo. The 10-meter coil is hidden by the bandswitch and tank condenser. The fixed air padding condenser, permanently connected across the 160-meter coil, may be seen in the left foreground.

the 160-meter coil is permanently shunted by a 50-$\mu\mu$fd. air padder.

Both to permit shortest possible leads and as a safety precaution, the 814 tuning condenser is set back from the front panel and driven by means of an extension shaft and insulated coupling. The rotor of this condenser is 1250 volts above ground and the insulated coupling makes it unnecessary to rely upon the insulation of the tuning knob, a bad practice when the voltage is as high as this. The rotor of C_1 and the rotor of C_2 are also above ground, but as the voltage is not particularly high it is only necessary to use knobs with well protected set screws. These two condensers are insulated from the chassis by means of fiber washers.

A 250-ma. meter is permanently connected in the B negative of the 814. Because screen voltage is derived from the low voltage power supply, the meter reads plate current only; it is not necessary to allow for the screen current when reading this meter. A 100-ma. meter is used to measure current in the various oscillator and buffer circuits by means of a meter switch.

U.h.f. parasitic suppressors are used both in the 807 and 814 stages. These consist of 50-ohm resistors in the 807 control grid and screen grid leads, and a 50-ohm resistor in the 814 screen and regular parasitic suppressor in the 814 control grid. These suppressors also eliminate all tendency towards instability when working "straight through" on crystal frequency.

The 10- and 20-meter coils must be mounted with very short leads to the 814 coil switch. The leads to the other three coils are not so important. There is bound to be some coupling (both capacitive through the switch and inductive as a result of the unshielded coils) between the high-frequency coils when being used and the low-frequency coils which are left "floating." This is because the 40-meter coil hits fairly close to 10 meters with nothing in shunt and the 80-meter coil self-resonates near 20 meters. The coils were so designed and placed that the effect is not particularly serious, but small sparks can be drawn from the unused tanks. Fortunately this results in but little loss in efficiency when the 814 stage is loaded, but it does keep the unloaded minimum plate current from being as low as would be the case were plug-in coils used.

COIL DATA
For 100-Watt Bandswitching Exciter

OSCILLATOR COIL

74 turns of no. 22 d.c.c. close wound on 3½ in. length of 1 in. dia. bakelite tubing, tapped at 24th turn. L_1 is 40-meter section (24 turns).

BUFFER COIL

Manufactured 10-160 meter midget coil turret. 10-meter tap not used.

814 PLATE COILS

10 Meters

6 turns no. 12 enamelled 1⅛ in. dia. spaced to 1⅛ in. (Wound on 1 in. form and form removed.) Link 1 turn at cold end.

20 Meters

11 turns no. 12 enamelled 1⅛ in. dia. spaced to 2 in. (Wound on 1 in. form and form removed.) Link 1 turn at cold end.

40 Meters

18 turns no. 12 enamelled 1¾ in. dia. spaced to 2¼ in. and turns held in place with two celluloid strips cemented to coil with duco cement. Link 2 turns at cold end.

80 Meters

32 turns no. 12 enamelled close wound on 3½ in. length of 1½ in dia. bakelite tubing. Link 3 turns at cold end.

160 Meters

44 turns no. 14 enamelled close wound on 3¾ in. length of 2 in. dia. bakelite tubing. Link 4 turns at cold end.

All links wound with solid no. 16 having high voltage insulation.

On 10 meters the plate current should not be allowed to run over 100 ma. or the plate dissipation will be exceeded. On other bands the plate current should be kept below 110 ma. when doubling and below 130 ma. when working "straight through." The grid current should be adjusted to about 10 ma. when working straight through and about 15 or 20 ma. when doubling. Under no conditions should the grid current be allowed to run over 20 ma. when the 814 is loaded.

The grid current to the 814 can be adjusted by detuning the 807, as the 807 is run at such low screen voltage that it will not draw excessive plate current or overheat when detuned.

The particular bandswitch used for the 814 plate tank has six positions, which leaves one extra. Instead of being left blank this position is jumpered to the 160 meter switch point. This makes it impossible to remove plate voltage from the 814 by throwing the switch to the unused position. Tubes such as the 814 can be permanently damaged by running them with full screen voltage and no plate voltage.

When mounting the 814 socket, be sure to orient it so that the position of the 814 will correspond to that recommended for horizontal mounting in the manufacturer's application notes. In wiring the 814 socket be sure to connect the beam forming plates to the *filament return* instead of to ground as is the more common practice. Connecting the beam forming plates to ground in this case will put 200 volts negative bias on them, greatly reducing the output of the stage.

TWELVE

Medium and High Power R. F. Amplifiers

THE amplifiers shown on the following pages are typical of those that have through popular use become the standard type of r.f. amplifier for power outputs of from 200 to 800 watts. Most of those illustrated are of the push-pull type, because of the advantages possessed by a balanced circuit. However, a representative single ended amplifier is shown in figure 9. It will be noticed that this amplifier is essentially the same as a push-pull amplifier except that one tube and one neutralizing condenser are removed.

Standard Push-Pull Amplifier

A standard push-pull amplifier circuit is shown in figure 1. While some variations in the method of obtaining the bias are possible, and certain methods are better adapted than others to certain applications, the basic r.f. circuit remains the same. All of the push-pull amplifiers illustrated in this chapter use this basic circuit.

The recommended method of obtaining bias for c.w. or plate modulated telephony is to use just sufficient fixed bias to protect the tubes in the event of excitation failure and obtain the rest from a grid leak. However, the grid leak may be returned directly to the filament supply if an overload relay is incorporated in the plate circuit, the relay being adjusted to trip immediately when excitation is removed. For grid modulation it is necessary that all the bias be obtained from a fixed source; this makes a grid leak impracticable for this class of service.

It will be noticed that J_2 is placed in the filament return rather than in positive high-voltage lead. This is a safety precaution. When connected as shown in the diagram, J_2 will read plate current only, as J_1 is returned to the "hot" side of J_2 instead of to ground. This will require an extra external lead if fixed bias is used, as the positive of the bias supply cannot be connected to ground under these conditions without resulting in a short across the meter jack J_2.

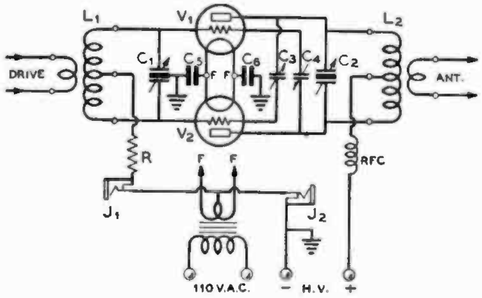
When measuring current in the filament return of filament type tubes, it is necessary that the stage have *either* an individual power supply or else a filament supply which is not used to supply any other filament type tubes (heater tubes will be o.k.). If the requirement is not met, a meter jack will read the current being drawn by more than one stage at the same time. If desired individual meters may be substituted for the two-meter jacks.

On the low frequency bands a plate r.f. choke will not always be required with this type of amplifier. However, one is usually desirable on the higher frequency bands, and as the choke does no harm in any case its incorporation is recommended.

The grid leak R_1 serves effectively as an r.f. choke in the grid circuit because

FIGURE 1. STANDARD PUSH-PULL R.F. AMPLIFIER CIRCUIT.

The mechanical design must be symmetrical and the output coupling must be evenly balanced. Individual meters may be substituted for the two meter jacks. If a grid r.f. choke is substituted for R_1 for fixed bias operation, a 200 ohm wire wound resistor should be placed in series if a low-frequency parasitic oscillation occurs.



C_1—Approx. 1 μμfd. per section per meter of wavelength. 1000 volt spacing for HK54 35T, T55, HF100, 808, etc. 2000-volt spacing for 100TH, HK254, HF200, T200, etc.

C_2—Refer to tank condenser data and Q charts in chapter 7 for capacity and spacing.

C_3, C_4—Suitable neutralizing condensers, 50% greater air gap than C_2.

C_5, C_6—.002 μfd. or larger.

R_1—Of such value that normal grid current for tubes will produce enough voltage drop to make a total of twice cut-off bias including any fixed bias. Higher resistance can be used with slight increase in efficiency if reserve of excitation is available. Wattage rating equal to I^2R.

RFC—2.5-mh. r.f. choke designed for all-band operation, of suitable d.c. rating. Not always found necessary.

T_1—Filament transformer of suitable voltage and current rating. Tapped primary desirable, especially if transformer is located some distance from the amplifier.

the r.f. voltage impressed upon it is very low, and no grid r.f. choke is required when a grid leak is used. However, if no grid leak is incorporated, as would be the case for fixed bias for grid modulation, an r.f. choke should be substituted for R_1. It should not resonate with the plate choke or there may be a low frequency parasitic oscillation. A 200-ohm 10-watt wirewound resistor in series with the grid r.f. choke will suppress this type of parasitic oscillation.

It will be noted that the rotor of the plate tank condenser is left "floating" (ungrounded). This permits a tank condenser of less spacing to be used, as there is no d.c. impressed across it. When the rotor is left "floating" it is imperative that the amplifier be symmetrical from a physical standpoint and that the coupling to the external load be symmetrical. Because the rotor will be at high d.c. potential if the condenser *should* arc over, it is advisable to use an insulated coupling between the rotor shaft and the tuning dial or knob.

Because of the high minimum capacity of tuning condensers having sufficient capacity for proper 160-meter operation, it is good practice to use a split stator plate tuning condenser just sufficiently large for 40-meter c.w. operation (about 75μμfd. per section for commonly used ratios of plate voltage to plate current) and then use external plug-in fixed padding condensers for 75- and 160-meter operation. The cost is about the same as for a split stator condenser having sufficient capacity for 160-meter phone operation, and the efficiency on 10 and 20 meters is higher because of the lesser bulk and minimum capacity of the tuning condenser. In the low and medium power range, fixed air padders are the least expensive; for high power operation, fixed vacuum condensers are about as economical as the regular air types. Recommended values of tank circuit capacity for different bands and applications are given in chapter seven.

As the power in the grid circuit is so much lower, it is customary to use a split stator condenser with sufficient capacity for operation on the lowest frequency band and also to ground the rotor. A physically small condenser has a greater ratio of maximum to minimum capacity and it is possible to get a grid

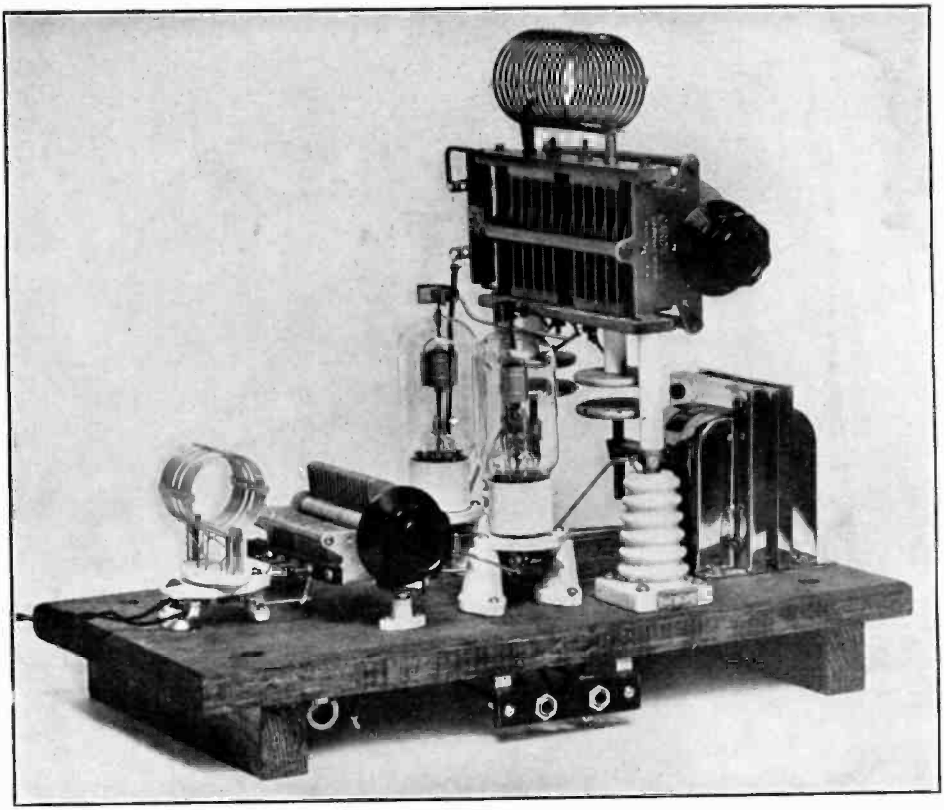


Figure 2.
NOVEL BREADBOARD AMPLIFIER.
A design such as this permits extremely short leads. In this model no r.f. lead is over 2 inches long. The neutralizing condensers are removed from their bases and mounted as shown. Each top plate is connected to the tank condenser section directly above it and the grid connections are cross-connected. The grid leak and the filament and plate supply leads are below the baseboard. The tubes shown are 35T's.

condenser that will be satisfactory on all bands from 10 to 160 meters without need for external auxiliary capacitors. As both r.f. and d.c. voltages are relatively low in the grid circuit the rotor of the condenser can be grounded without increasing the cost appreciably, as very little more spacing will be required and the condenser is relatively small anyway (in comparison to the plate tank condenser). Grounding of the rotor simplifies mounting of the condenser and also provides circuit balance and insures electrical symmetry. It also has a retarding effect upon u.h.f. parasitics by bypassing them to ground in the grid circuit.

For high power operation on 10 and 20 meters sometimes a fixed capacitance is used in conjunction with a variable inductance to replace the more common type of plate tank consisting of a fixed inductance and variable capacitance. This is permissible in the circuit of figure 1 so long as the fixed tank condenser is symmetrical. It is not advisable to substitute a single-section variable condenser of twice the spacing and half the per-section capacity for C_2 because it would upset the symmetry of the circuit; the rotor (frame) consists of so much more metal than the stator that there would be considerable unbalance with this type of condenser.

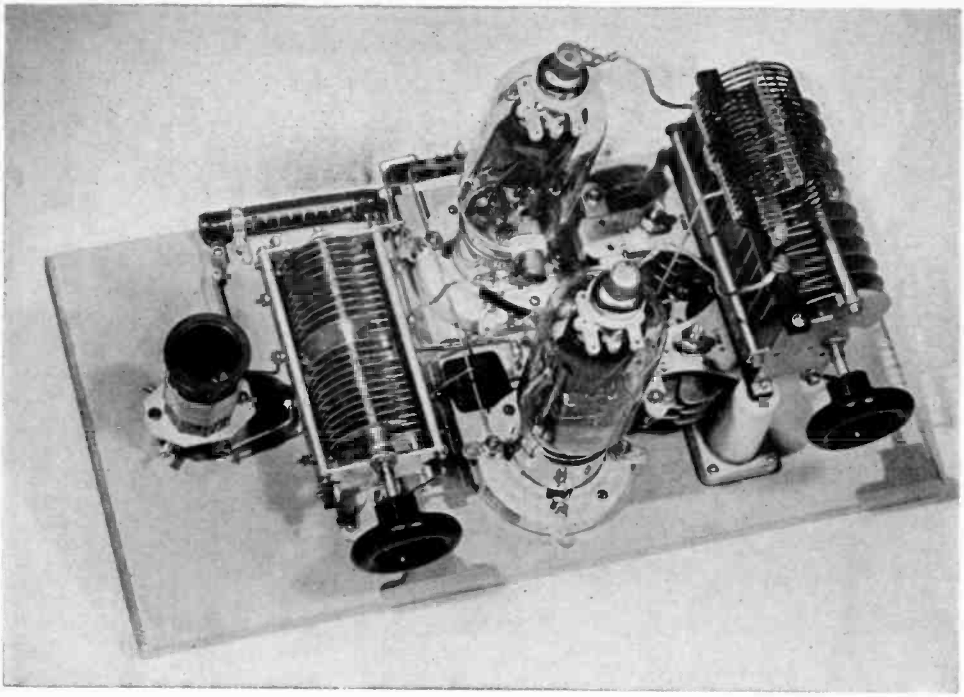


Figure 3.
HIGH-POWER AMPLIFIER FOR HIGH EFFICIENCY AT MODERATE PLATE VOLTAGE.
High transconductance tubes such as the 810 will deliver high output at high efficiency at moderate plate voltage. This amplifier can be run at 1 kilowatt input on c.w. or 850 watts on phone (plate modulated) if supplied 2000 volts. The bakelite control knobs illustrated provide excellent insulation but for maximum safety to the operator the incorporation of a Masonite front panel and insulated shaft couplings or insulated extension shafts is advisable.

The push-pull amplifiers illustrated are designed for link coupling from the exciter or driver. This provides the most efficient energy transfer on the higher-frequency bands.

The maximum allowable plate voltage, plate current and grid current for the various tubes is given in chapter 9.

The pictorial illustrations are merly for the purpose of furnishing ideas for possible mechanical layouts. All of the arrangements shown permit very short r.f. leads, but it is not necessary to use the particular tubes specified in each case for the particular physical layout illustrated. For instance, 35T's, HK54's, 808's, or T55's could be used in the amplifier pictured in figure 2 by providing the proper grid leak and filament transformer. The latter should preferably be placed right at the amplifier, though it can be placed at the power supply if allowance is made for the voltage drop due to the filament current. The voltage should be correct *at the tube sockets.*

Two examples of *breadboard* construction are shown in figures 2 and 3. This type of construction usually allows shorter leads than the panel-and-chassis type of layout. Breadboard construction does not present such a finished and "commercial" appearance as does a panel arrangement, and precautions must be taken to see that the stage is well protected so that it is not possible to touch

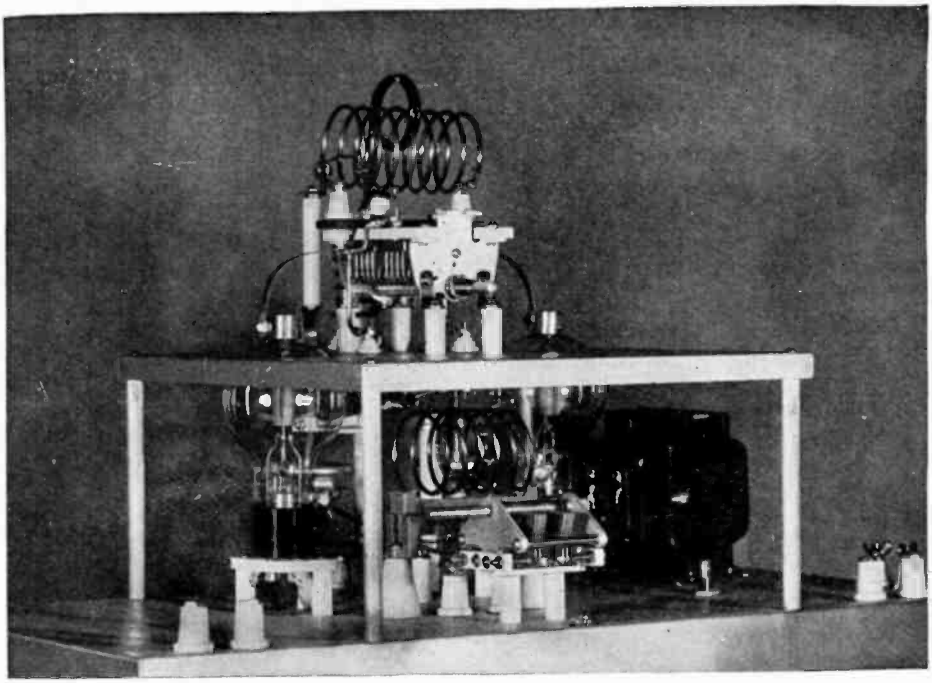


Figure 4.
"TWO DECK" AMPLIFIER CONSTRUCTION.
This type of construction provides excellent shielding between plate and grid circuits. The amplifier is normally mounted behind a panel and flexible shafting used to operate the condensers; the panel has been removed for the purpose of taking this photograph, however. Holes are cut in the top deck to accommodate the tops of the 808's and allow adequate cooling.

it while in operation and thus receive a dangerous shock or burn.

Circuits which use variable inductances and fixed air or vacuum condensers for 10- and 20-meter operation are becoming quite popular. An example of this type of amplifier is shown in figures 6 and 7. In the under-chassis view the mechanism for moving the standoff insulators at each of the coils toward and away from each other may be seen. The bottoms of the particular insulators shown are threaded and a short stud screwed into the bottom of each of the outer ones runs through a ¼- by 2-inch slot in the chassis and into a cylindrical brass block below the chassis. The center insulator is firmly fastened to the chassis. Each of the outer brass blocks has a ¼-inch threaded hole running through it diametrically. Right-hand threads are used in one block and left-hand threads in the other. The center block has a smooth ¼-inch hole and acts simply as a support bearing.

To move the end insulators back and forth in their slots a piece of brass rod is threaded with a right-hand thread at one end, a left-hand thread at the other, and left unthreaded at the center. When this rod is run through the brass blocks after a collar is put on each side of the center block to prevent end-play (see figure 7), revolving the rod will cause the end insulators to move toward and away from each other, thus changing the length and turn spacing of the coil and altering its inductance. The threaded rod is connected to the knob at the side of the chassis by means of a short length of additional shafting and a shaft coupling.

To provide a fixed capacity across the tank coil, fixed vacuum condensers are used. These condensers are arranged to plug into fuse clips mounted on the

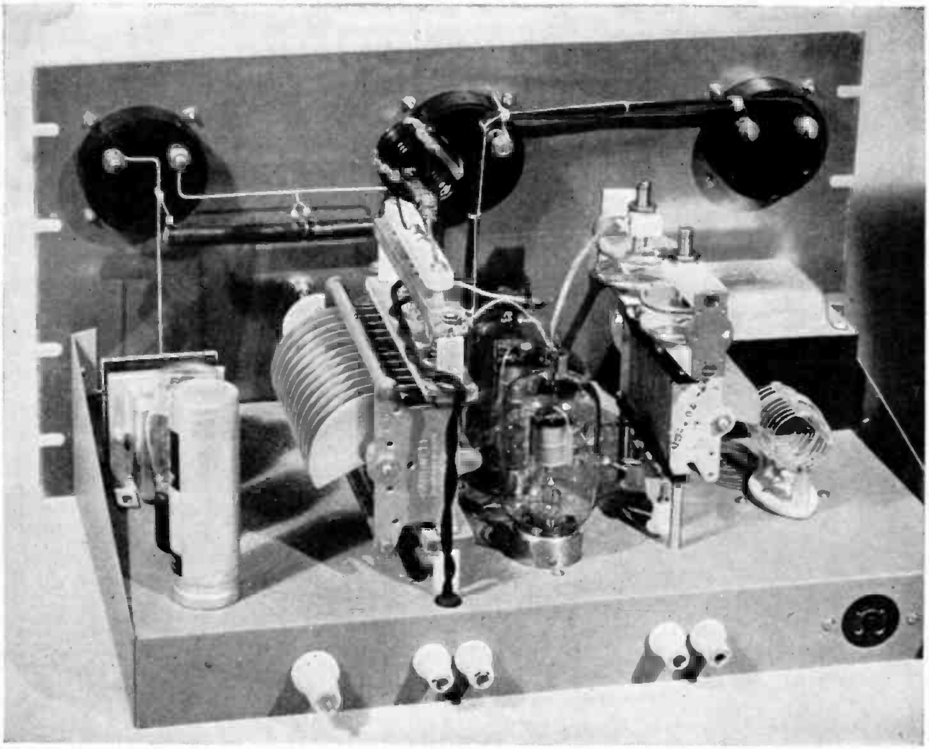


Figure 5.
400-WATT AMPLIFIER FOR RACK MOUNTING.
This amplifier has a more commercial appearance than a breadboard counterpart. The tubes are HK-54's. Both a filament transformer and a bias supply are included on the chassis. Terminals at the rear of the chassis are provided for antenna and power connections. The meters indicate grid current, plate current and filament voltage.

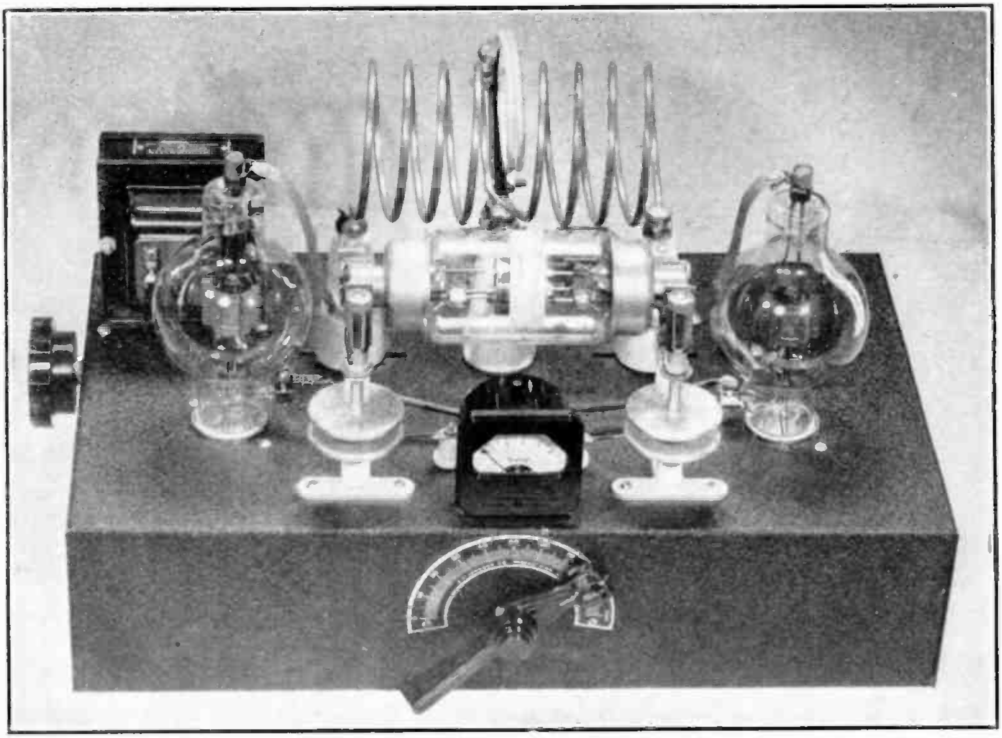
• • •

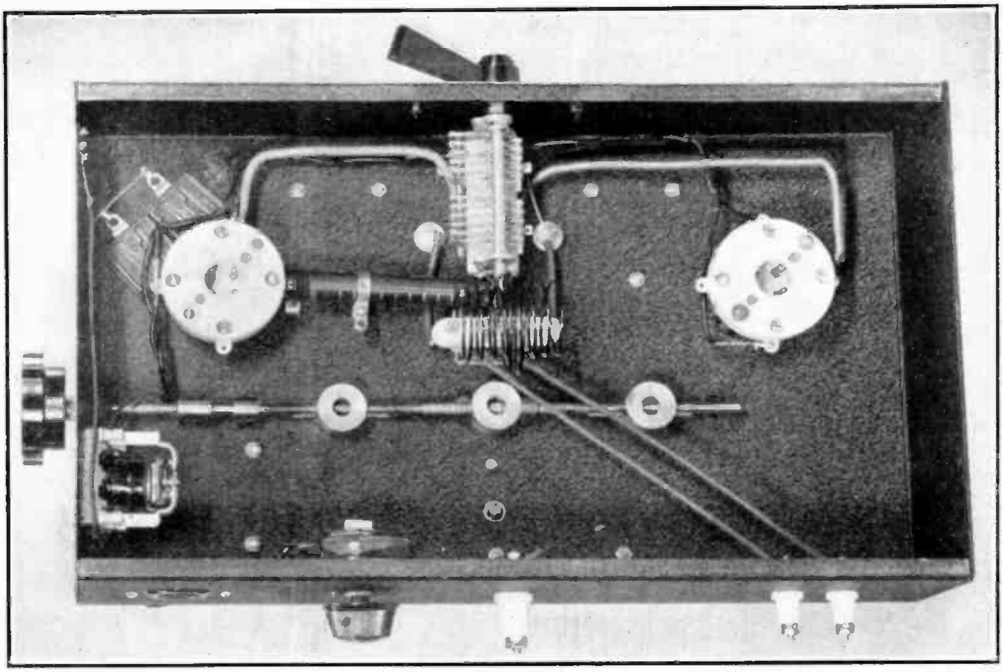
(ILLUSTRATED ON OPPOSITE PAGE.)

Figure 6.
"ACCORDION COIL" HIGH POWER AMPLIFIER.
This high power 10- and 20-meter amplifier utilizes a fixed vacuum tank condenser and variable inductance coil in the plate circuit. The control on the front of the chassis tunes the grid condenser. The knob on the right side of the chassis varies the spacing of the two outside cone insulators supporting the semi-rigid plug-in coil. A filament transformer may be seen to the left rear, a filament voltmeter between the two neutralizing condensers just in front of the plug-in vacuum condenser.

Figure 7.
UNDER-CHASSIS VIEW OF THE "ACCORDION COIL" AMPLIFIER.
The mechanism for providing adjustable spacing of the coil supports may be seen in this view. The operation is explained in the text. Next to the coil tuning knob may be seen an overload relay, to protect the tubes in the event of excitation failure. The rheostat on the back of the chassis is in the primary of the filament transformer.

The "Accordion Coil" Amplifier





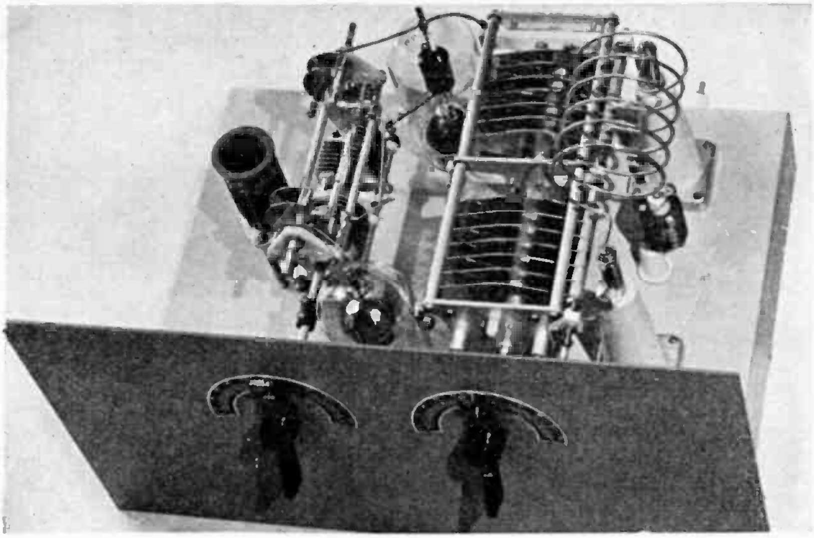


Figure 8.
PANEL AND CHASSIS CONSTRUCTION OF HIGH-POWER AMPLIFIER.
This high powered amplifier will take a full kilowatt input on c.w. if 75 watts of excitation is available. High-efficiency operation is required, as otherwise the plate dissipation of the tubes will be exceeded at 1-kw. input. The HK254's are fed 2500 volts and loaded to 400 ma. The physical layout illustrated permits an average r.f. lead length of slightly over 1 inch; no lead is over 2½ inches.

neutralizing condensers. The coils also are arranged to be plugged in for band change. 1/16-inch copper tubing is used for the coils on the 10- and 20-meter bands. It is not practical to use this type of variable inductance on lower frequencies as the coils would not be sufficiently rigid and self-supporting. A 6-$\mu\mu$fd. fixed vacuum condenser may be used for 10-meter phone and 20-meter c.w. work. For 20-meter phone use, a 12-$\mu\mu$fd. condenser should be substituted.

Single-Ended Amplifiers

While the push-pull circuit has many advantages over single-ended circuits for r.f. power amplification, it is sometimes desirable for one reason or another to use a single-ended stage. Often it is less expensive to buy one moderately large tube than two smaller tubes having an equivalent combined power rating.

Illustrated in figure 9 and diagrammed in figure 10 is a typical 10-, 20-, 40-, and 80-meter single-ended amplifier. Plate neutralization is used, as this type of neutralization is more satisfactory than grid neutralization on 10 meters.

For a single-ended amplifier it is necessary that the rotor of the plate tank condenser have an r.f. return to ground. This may be done either by grounding the rotor of the condenser directly or grounding it through a by-pass condenser. If it is grounded directly, as shown in the diagram, the condenser must have somewhat more spacing because both d.c. and r.f. are impressed across the condenser. If it is by-passed to ground through a high-voltage mica condenser of .002-μfd. to .004-μfd. capacity there will no longer be impressed, under steady carrier conditions, anything between the condenser plates except r.f. voltage. However, due to the "lag" in the condenser, transient peaks will be impressed across

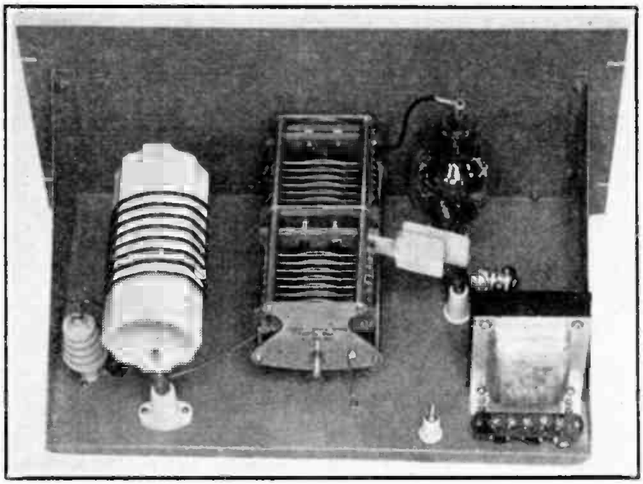


Figure 9.

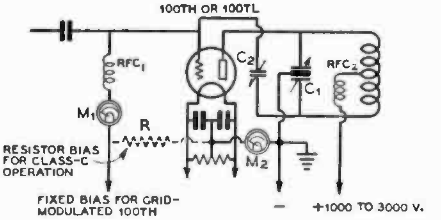
SINGLE-ENDED 300-WATT AMPLIFIER.
This single-ended amplifier is designed to be used with a 100-TH, 100-TL, HK-254, TW-150, or similar tube. It is arranged for capacity coupling to the buffer stage. The neutralizing condenser is an easily constructed one consisting of two small aluminum plates, one of which is mounted on the rear stator terminal of the plate condenser and the other mounted on a standard coil plug which revolves in a coil jack located on top of a short standoff insulator. Either standard type manufactured coils or home-built coils may be used in the plate circuit.

the variable condenser during plate modulation or primary keying of the stage. Hence, to remove all voltage from the variable condenser except the r.f. voltage across the coil, the rotor of the condenser should be connected to the positive high voltage lead at the power supply end of the plate r.f. choke. There can then be no a.f., d.c., or transient voltage impressed across the condenser sections because both the rotor and the stator sections are at the same potential except with respect to r.f. voltage across the coil. If the stage is *grid* modulated or if the stage is keyed in a low level stage so that plate voltage appears on the tank at all times, then there is no point in connecting the rotor of the condenser to positive high voltage; simply by-passing it to ground with a high voltage condenser will be sufficient.

Because the neutralizing capacity of a plate neutralized stage depends upon the ratio of the capacitance from either end of the plate coil to ground, the ratio must be maintained on different bands if the neutralization is to hold for different bands. If a tube has a plate-filament capacity of more than approximately 2 $\mu\mu$fd., it is desirable to connect across the section of the tuning condenser to which the neutralizing condenser is connected a capacitance exactly equal to the plate-filament capacity of the tube. The circuit will then be balanced regardless of the setting of the plate tank condenser, and neutralization will hold for all bands when once set for one of the higher frequency bands. With tubes such as the 100-TH the plate-filament capacity is sufficiently low that it can be ignored, as it will not materially affect the maintenance of the neutralization adjustment for different settings of the plate tank condenser.

Figure 10.

WIRING DIAGRAM OF TYPICAL SINGLE-ENDED AMPLIFIER.
This diagram is for the amplifier illustrated in figure 6. The tank condenser illustrated is for 10-, 20-, and 40-meter operation only.



C_1—100 $\mu\mu$fd. per section. Spacing depends upon class of operation. For 80 and 160 meters use auxiliary air padding condenser

C_2—3 $\mu\mu$fd. neutralizing condenser

R — Depends upon class of service and excitation available

THIRTEEN

Speech and Modulation Equipment

THIS chapter deals with the design, construction, and operation of speech amplifiers and modulators and with arrangements such as automatic modulation control circuits which are normally a portion of the modulation equipment.

The audio equipment required in a phone transmitter will vary widely with different types of microphones, different modulation systems, and different amounts of power to be modulated. Since it would be virtually impossible to show designs that would be suited to any type of application, a number of good designs of conventional type will be shown to indicate the method of approach to the problem. These particular designs should more or less completely solve the speech amplifier problem in 75 per cent of the usual amateur transmitter installations. For those special cases where the designs shown are not completely suitable, small variations in the necessary respects will almost surely adapt the designs to individual needs.

The amplifiers and modulators shown have been thoroughly proven in actual use in amateur stations. Consequently, if these designs are followed exactly, no trouble will be experienced either in getting them to work or in their subsequent application to the job at hand. However, when making alterations in the designs to adapt the equipment to slightly different applications, due caution and forethought should be used in making the changes.

It is more than likely that inductive hum pickup will be the problem most frequently encountered both in making alterations in amplifier design and in installing the speech equipment in the operating room or in the transmitter. The proximity of power supply equipment to the audio transformers or to the low-level grid leads should always be taken into consideration. Any chokes or transformers in the low-level audio stages should be mounted as far as possible from power transformers and input filter chokes, which have relatively large surrounding a.c. fields. The audio transformers and coupling chokes can be properly oriented on the chassis before the holes are drilled for their mounting. A pair of headphones should be connected across the winding of each audio transformer or choke; 110-volts a.c. is then supplied to the primaries of all power transformers, and the audio transformer or choke is then rotated to determine the center of the hum "null." It should be bolted to the chassis in this position even if it detracts from the neatness of the amplifier.

Some manufacturers offer special hum-bucking transformers for use in low-level audio stages; the transformers are so wound that they need not be specially oriented for minimum hum pickup.

Especial care need not be taken with high-level audio transformers such as class-B input and output transformers if they are well-shielded and are not mounted too close to any power transformers.

Use of resistance coupling in the low-level audio stages of a speech amplifier makes it unnecessary to take precautions against inductive hum pickup, but grid and plate leads should be shielded to prevent electrostatic pickup, resulting in a.f. feedback and hum pickup.

A separate ground lead from the speech amplifier to an external ground is strongly advisable when the speech amplifier is not integral with the rest of the transmitter. With relay construction, in which the rack frame constitutes a common ground for both r.f. and audio units, a heavy copper bus run as direct as possible to a good external ground will suffice.

Amplifier Input Circuits

Various types of input circuits for speech amplifiers have been shown in the chapter, *Radiotelephony Theory.* The majority of the speech amplifiers and modulators shown later on in this chapter have input circuits designed for the use of the diaphragm-type crystal microphone. This type of input circuit has been shown since that is the type of microphone most suited to amateur usage, and since the majority of amateurs now operating phone transmitters are using this type of microphone or are contemplating the purchase of one. For those amateurs who have a particular preference for another type, such as the dynamic or the condenser, or for those who have another type microphone in good condition and who do not desire to purchase another, the special input circuits to the first speech stage shown in chapter *Eight* can be adapted to the speech amplifiers to be described.

INEXPENSIVE 25-WATT MODULATOR

For plate modulation or combined plate and screen modulation of a low powered transmitter, a modulator with an output in the vicinity of 25 watts is usually required. Such a unit is pictured in figures 1 and 2, the schematic wiring diagram appearing in figure 3. This modulator is simple and inexpensive to construct, and will plate modulate inputs of 40 to 60 watts on voice with excellent quality; the maximum output of the modulator with voice frequency input and tolerable harmonic distortion is about 25 watts.

While the unit can be used to drive a class-B modulator or to grid modulate a high powered grid modulated transmitter simply by tying a 15,000-ohm 10-watt resistor between the plates of the push-pull 42's, the unit is not recommended for such work, as it does not work as well into a variable load as do some of the other units described in this chapter. In other words, the unit works best when the output feeds into a constant load such as

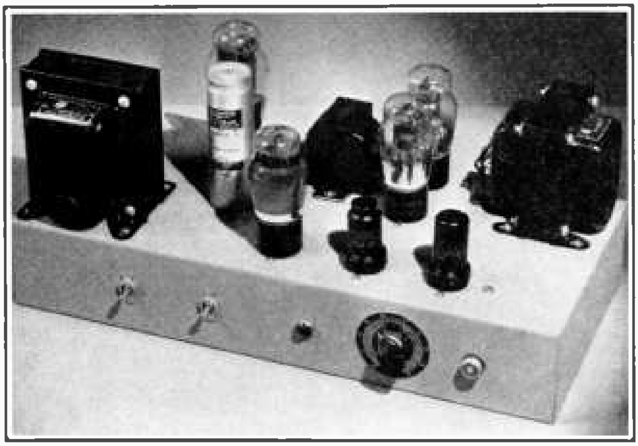


Figure 1.
INEXPENSIVE 25 WATT MODULATOR.
This unit will plate modulate any class C stage running from 40 to 60 watts input. It uses a pair of pentode-connected 42's in class AB with semi-fixed bias.

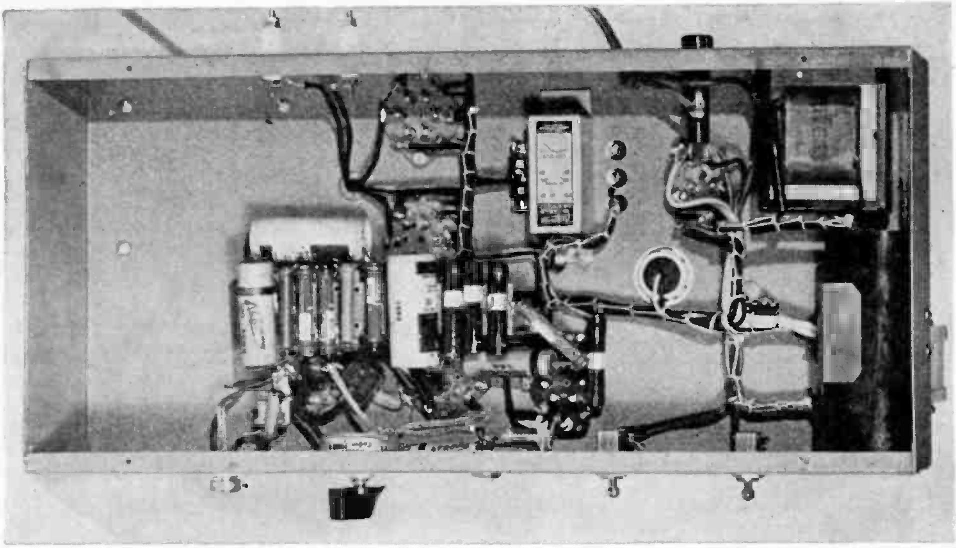


Figure 2.
UNDER-CHASSIS VIEW OF THE 25-WATT MODULATOR.
The filter choke and all resistors and condensers except C_{10} are mounted below the chassis. The use of a resistor strip adds to the appearance and facilitates checking and replacement of these units.

when it is used to plate modulate a low powered transmitter.

Tube Lineup

The first stage of the amplifier, a pentode-connected 6SJ7, is designed to operate from a crystal or other high impedance microphone. The input plug is of the shielded type, allowing a firm screw-on connection to the grounded side of the microphone cable.

A 6C5 in a conventional resistance coupled circuit amplifies the output of the 6SJ7 sufficiently to drive the triode-connected 42. The latter has more than sufficient output to swing the grids of the push-pull modulators with low distortion.

The values of the coupling condensers C_4 and C_6 were chosen with respect to R_5 and R_8 so that the gain will be attenuated in the extreme bass register (below 150 cycles). The advantages of bass suppression for voice transmission were covered in chapter *Eight*.

42's were chosen for use in the last two stages because they are inexpensive considering their power capabilities and because they will give long service under a moderate overload.

The output tubes are operated with semi-stabilized cathode bias. The resistor R_{11} stabilizes the screen voltage, the grid bias, and at the same time acts as a bleeder for the power supply.

Operation

The variable ratio output transformer makes the modulator adaptable to most any transmitter. The taps should be connected so that a load of approximately 10,000 ohms, plate to plate, is placed on the 42's when the modulated stage is drawing normal plate current. The correct method of connecting the transformer taps for any particular installation can be determined quite easily by referring to the impedance ratio chart supplied with the particular make of transformer used.

As an example, if the modulated stage draws 100 ma. at 500 volts (such as a single 809) the load on the secondary of the modulation transformer will be 5000 ohms. Look up on the transformer chart the closest combination which re-

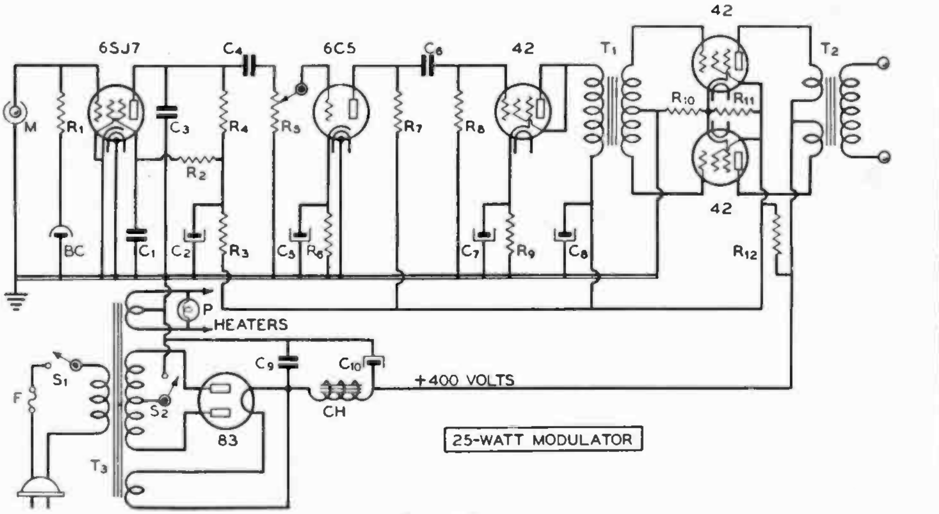


Figure 3.

Wiring Diagram of the 25-Watt Modulator.

C_1—0.25-μfd. 400-volt tubular
C_2—12-μfd. 450-volt electrolytic
C_3—.0001-μfd. mica
C_4—.01-μfd. 400-volt tubular
C_5—10-μfd. 25-volt electrolytic
C_6—.01-μfd. 400-volt tubular
C_7—10-μfd. 50-volt electrolytic
C_8—12-μfd. 450-volt electrolytic
C_9—4-μfd. 600-volt paper
C_{10}—8-μfd. 450-volt electrolytic
R_1—1 megohm, ½ watt
R_2—1 megohm, 1 watt
R_3—50,000 ohms, 1 watt
R_4—250,000 ohms, 1 watt
R_5—250,000-ohm potentiometer
R_6—2500 ohms, 1 watt
R_7—50,000 ohms, 1 watt
R_8—200,000 ohms, 1 watt
R_9—750 ohms, 10 watts
R_{10}—250 ohms, 10 watts
R_{11}—10,000 ohms, 10 watts
R_{12}—2000 ohms, 10 watts
T_1—3/1 pri.-to-½ sec. driver trans. (42 to 42's class A-B)
T_2—Variable ratio 30-watt output transformer
T_3—720 v., c.t., 125 ma.; 6.3 v., 4 a.; 5 v., 3 a.
CH—30-hy. 110-ma. choke (not over 200 ohms)
P—Pilot lamp
F—2-ampere fuse
BC—Bias cell
M—Shielded microphone connector

flects a 10,000-ohm plate-to-plate load on the primary when a 5000-ohm load is placed across the secondary of the transformer.

A 60-WATT T-21 MODULATOR INCORPORATING A.M.C.

The modulator illustrated in figure 4 is designed primarily for use as a complete speech amplifier and modulator to operate from a diaphragm-type crystal microphone and to plate modulate about 150 watts input to a class C amplifier. It could, of course, also be used as a cathode modulator for 400 to 500 watts input to the stage; or, with about 20 db of feedback to the grids of the 6J5 drivers, it could be used as a high-level driver for a high-power class-B stage.

Automatic modulation control has been incorporated into the design of the first stage of the amplifier. If it is desired to use the a.m.c. provision, and it is highly recommended that it be used, the a.m.c. rectifier may be coupled into the terminal marked "a.m.c. input." If it is not desired to use a.m.c. the terminal may be left open or grounded, as desired. Incidentally, there must be a biasing system incorporated into the a.m.c. rectifier, as shown in the one at the end of this chapter; some of the earlier a.m.c. systems had the biasing system incorporated into the speech amplifier and hence did not need any bias on the a.m.c. rectifier. If an unbiased rectifier is used with this arrangement, the a.m.c. action will not come into effect until 100 per cent modulation is reached.

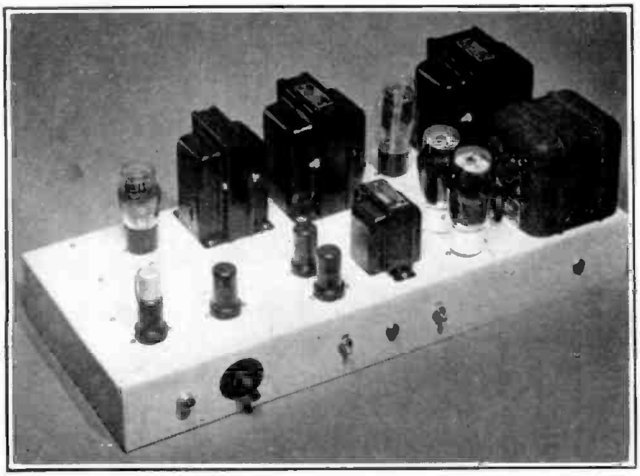


Figure 4.

TOP VIEW OF THE 60-WATT T-21 MODULATOR.

The power supply components are lined up along the rear half of the chassis, starting with the bias rectifier to the left and ending with the oversize power transformer on the right rear. The audio-frequency stages progress from left to right along the front of the chassis, ending up with the multiple-match output transformer on the right end.

A New Phase-Inverter Circuit

The 6J5 phase inverter operates in a new-type circuit which is quite simple and yet which gives a reasonable amount of gain. On first glance it might appear that the 6J5 operates in the conventional "hot cathode" circuit which has been used for some years with reasonable success. But while the old circuit gave practically no gain in voltage in the phase inverter, by the changing of a few values and the addition of a resistor and a condenser the voltage gain of the circuit has been increased to approximately 7 per side or a total gain of about 14. Quite a worthwhile improvement for the addition of only one resistor and a condenser.

The operation of the circuit is simple enough and should be apparent by inspection of the diagram. In the conventional arrangement, with C_7 and R_6 not in the circuit, when a voltage is impressed upon the grid of the 6J5 half the voltage output of the tube appears across the cathode return resistor R_{10}. This voltage is fed back 180° out of phase with the incoming voltage and in series with it. The resulting 50 per cent degenerative feedback reduces the gain of the stage to just more than one. But by isolating the cathode feedback voltage from the exciting voltage which appears across R_7, the plate circuit of the 6L7, the degenerative feedback is greatly reduced and the stage attains almost normal gain—in addition to its function as a phase inverter.

One consideration in the design is the shunt resistance of R_{10} and R_6 as compared to the resistance of R_{11} (R_{10} and R_6 are effectively shunted as far as audio frequencies are concerned by the effects of condensers C_7 and C_5). The shunt effect of the first two should be equal to R_{11}. The most satisfactory way of obtaining this is to make R_{10} and R_6 each twice the value of R_{11}. This allows an equal audio voltage division between the plate and cathode circuits of the inverter tube. The plate impedance of the 6L7 is so high (approximately 0.8 megohm) as not to disturb the balance of the circuit materially.

The driver stage for the T21's is perfectly conventional and consists of a pair of 6J5's operating into a 5:1 driver-to-6L6 class AB_2 transformer. The swamping resistors R_{15} and R_{16} across the secondary of the driver transformer serve to improve the audio regulation of the source. T-21's are used as the final modulator tubes with 400 volts on their plates and operating with fixed bias.

The bias supply uses a 45 with the grid and plate strapped together operating from the 30-volt tap on the power transformer. With the particular components that were used in the laboratory model of this modulator, when R_{17} was made a 1000-ohm 10-watt resistor the bias voltage was the proper value on the

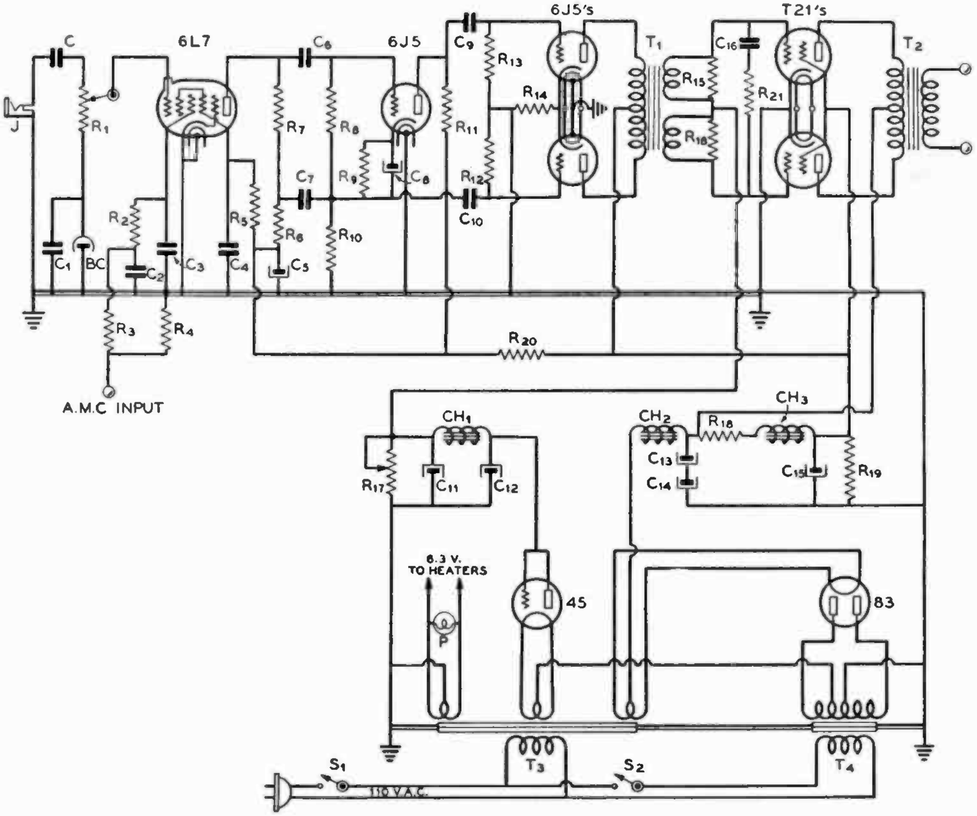


Figure 5.

WIRING DIAGRAM OF THE 60-WATT MODULATOR.

C_1 — 0.1-µfd. 400-volt tubular

C_2 — .005-µfd. 400-volt tubular

C_3 — 0.5-µfd. 400-volt tubular

C_4 — 0.1-µfd. 400-volt tubular

C_5 — 8-µfd. 450-volt elect.

C_6 — .01-µfd. 400-volt tubular

C_7 — 0.5-µfd. 400-volt tubular

C_8 — 10-µfd. 25-volt elect.

C_9, C_{10}—.01-µfd. 400-volt tubular

C_{11}, C_{12}—16-µfd. 100-volt elect.

C_{13}, C_{14}, C_{15} — 8-µfd. 450-volt elect.

C_{16}—.005-µfd. mica

R_1—1.0-megohm potentiometer

R_2 — 1.0 megohm, ½ watt

R_3—100,000 ohms, ½ watt

R_4—500,000 ohms, ½ watt

R_5 — 1.0 megohm, ½ watt

R_6—100,000 ohms, ½ watt

R_7, R_8—250,000 ohms, ½ watt

R_9—2500 ohms, ½ watt

R_{10}—100,000 ohms, ½ watt

R_{11}—50,000 ohms, ½ watt

R_{12}, R_{13}—250,000 ohms, ½ watt

R_{14}—600 ohms, 1 watt

R_{15}, R_{16}—10,000 ohms, 1½ watt

R_{17}—1500-ohm 10-watt slider or 1000-ohm 10-watt fixed

R_{18} — 2000 ohms, 10 watts

R_{19}—25,000 ohms, 20 watt

R_{20}—5000 ohms, 10 watt

R_{21} — 5000 ohms, 1½ watts

J—Microphone jack

BC—Bias cell

T_1 — 5:1 driver-to-6L6 trans.

T_2—Multi-match output trans.

T_3—2.5 v., 3.5 a.; 5 v., 3 a.; 6.3 v., 3 a. filament trans.

T_4—1030 v. c.t., 250 ma.; bias tap at 30 volts

CH_1 — 7.2-hy., 120-ma choke

CH_2 — 13-hy., 250-ma-choke

CH_3 — 15-hy., 85-ma choke

S_1—A.c. line switch

S_2—Plate on-off switch

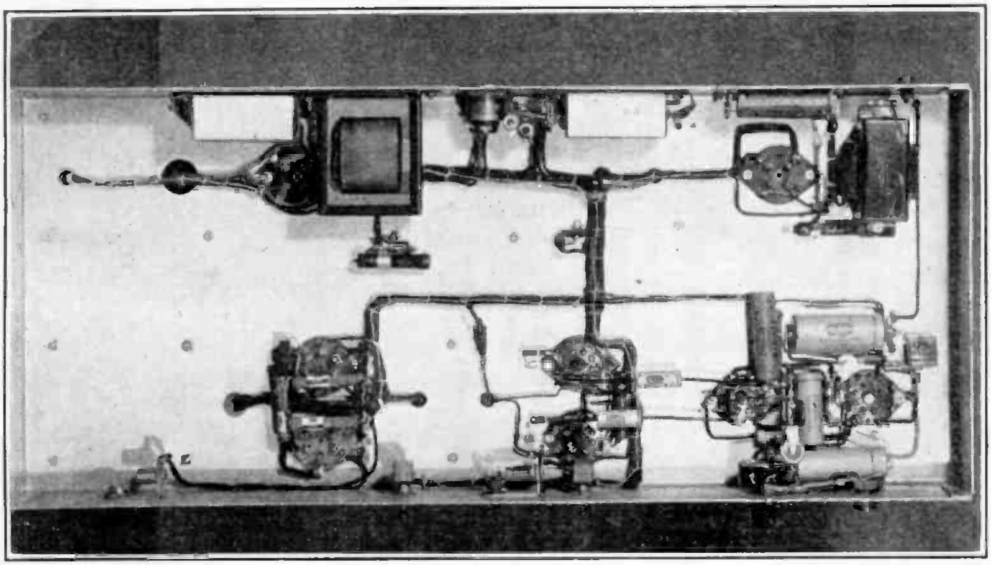


Figure 6.

UNDER-CHASSIS VIEW OF THE T-21 MODULATOR.

All power supply components are arranged along the rear side of the chassis and all audio components along the front. The single interconnecting cable between the two halves of the amplifier tends to minimize electrostatic coupling between them and hence to reduce hum pickup. However, to minimize electrostatic pickup from external sources it has been found desirable to place a metal cover on the bottom of the chassis. The chassis should be connected to external ground by an independent connection.

T-21's. However, to allow for variations in tubes and equipment it was felt best to specify a 1500-ohm adjustable resistor in this position. In any case the shorting tap on the resistor will be very near to 1000 ohms.

The resistor-capacity network from grid to grid on the T-21's, C_{16} and R_{21}, was placed in the circuit to improve the waveform of the output at speech frequencies. Through the use of comparatively low value of coupling condensers from stage to stage within the amplifier the frequency response of the amplifier drops quite sharply below 150 cycles. This reduces the difficulties resulting from hum pickup and allows a higher relative modulation percentage to be obtained on the voice frequencies above 150 cycles, those that contribute most to the intelligibility.

The primary and secondary of the multi-match output transformer should be strapped so as to present a plate-to-plate load of 4000 ohms to the T-21 tubes with the value of secondary load into which the tubes are working. Maximum output and maximum modulating ability with minimum harmonic distortion will be obtained from the amplifier under these operating conditions.

A 6-WATT GRID MODULATOR

Figure 7 illustrates a simple 6-watt amplifier specifically designed to operate from a crystal microphone and to be used as a grid modulator for a medium to high powered amplifier. A single-ended 6L6 is used as the output tube with degenerative feedback from its plate back to its grid circuit. The use of degenerative feedback greatly lowers the plate impedance of the 6L6 and considerably reduces any harmonic distortion that might be introduced as a result of the operation of a single-ended beam tetrode stage. The reduction in the plate impedance of the 6L6 by feedback improves the regulation of the output voltage with respect to such changes in loading as are had when grid modulating an amplifier.

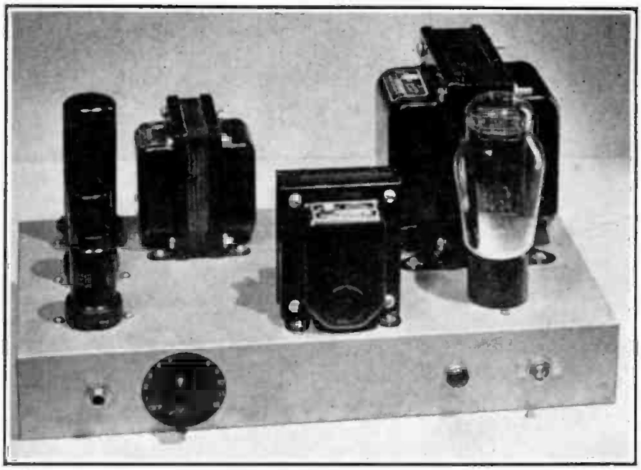


Figure 7.

FRONT VIEW OF THE SIMPLE 6-WATT GRID MODULATOR.

The three audio tubes, the 6J5 first stage, the 6SJ7 second, and the 6L6 power amplifier are lined up along the left end of the chassis. The output transformer is alongside the 6L6; the other components are those associated with the power supply. The jack for the crystal microphone and the volume control are on the front drop of the chassis.

The Feedback Circuit

The addition of the single resistor R_{11} from the plate of the 6L6 back to the plate of the 6SJ7 amplifier stage reduced the harmonic distortion, measured from the input of the 6SJ7 to the output of the amplifier, from approximately 11 per cent at 6.5 watts output to less than 3 per cent at 7 watts output. However, the amplifier is only rated at 6 watts output because of the power taken by the shunting resistor R_{13} which goes from the bottom end of the output transformer to

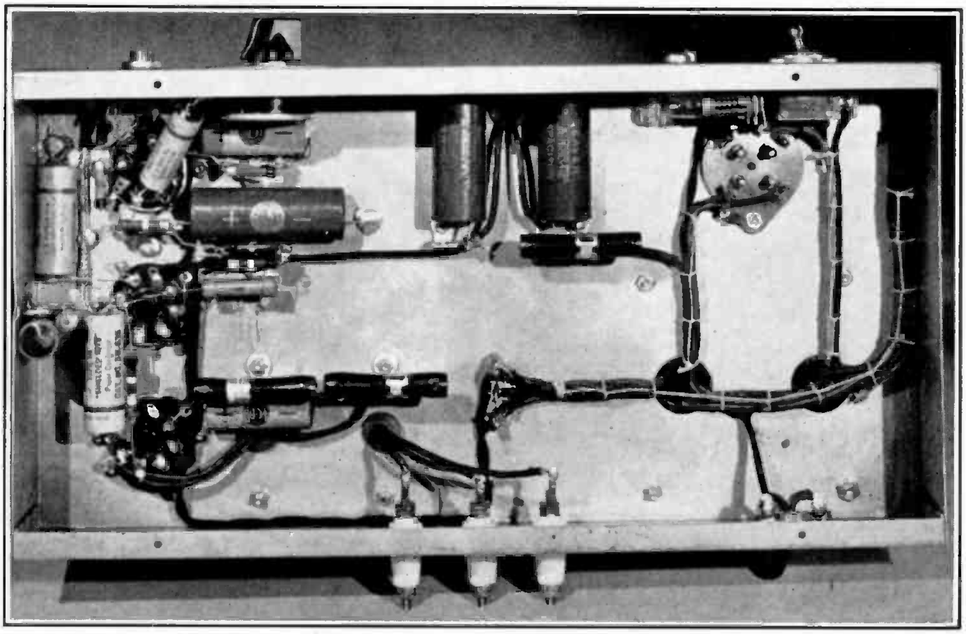


Figure 8.

UNDER-CHASSIS VIEW OF THE 6L6 GRID MODULATOR.

Under-chassis layout is comparatively simple and is made to present a neat appearance by cabling all the power supply leads. The three feed-through insulators on the back drop of the chassis are the three leads from the secondary of the grid-modulation transformer.

C_1—10-μfd. 25-volt elect.
C_2—8-μfd. 450-volt elect.
C_3 — .01-μfd. 400-volt tubular
C_4—10-μfd. 25-volt elect.
C_5 — 0.1-μfd. 400-volt tubular
C_6 — .05-μfd. 400-volt tubular
C_7—10-μfd. 25-volt elect.
C_8, C_9—8-μfd. 450-volt elect.
R_1—50,000 ohms, ½ watt
R_2—1.0 megohm, ½ watt
R_3—2000 ohms, ½ watt
R_4—25,000 ohms, 1 watt
R_5—250,000 ohms, ½ watt
R_6—500,000-ohm potentiometer
R_7—500 ohms, 1 watt
R_8—500,000 ohms, ½ watt
R_9—100,000 ohms, ½ watt
R_{10}—250,000 ohms, ½ watt

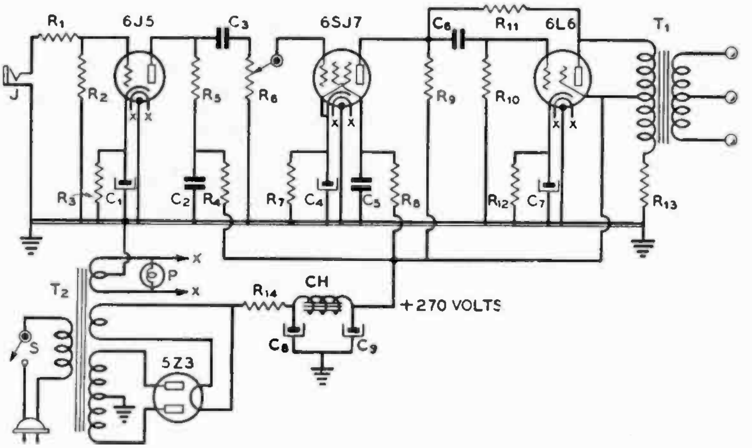


Figure 9.
WIRING DIAGRAM OF THE 6L6 GRID MODULATOR.

R_{11}—500,000 ohms, ½ watt
R_{12}—200 ohms, 10 watts
R_{13}—10,000 ohms, 10 watts
R_{14}—600 ohms, 10 watts
J—Microphone jack
P—6.3-volt pilot lamp

T_1—Driver trans., p.p. 2A3's to 801's
T_2—720 v. c.t., 125 ma.; 5 v. 3 a.; 6.3 4 a.
CH—25-hy. 140-ma choke
S—A.c. line switch

ground. The addition of the resistor for the shunt feedback circuit reduces the gain of the amplifier only a small percentage; there is ample gain to give full output when using a diaphragm-type crystal microphone on the input.

The shunt resistor R_{13} serves a triple purpose. In the first place it acts as a load upon the output of the 6L6 to stabilize its output with respect to variations in load. Second, it acts as a bleeder upon the power supply to reduce the possibility of blowing the filter condensers in the interval between the heating up of the filament of the 5Z3 and the coming to operating temperature of the cathode of the 6L6. Third, its drain through the secondary of the output transformer opposes that of the 6L6 and tends to cancel the saturating action of the plate current of the 6L6 upon the core of the transformer.

The power supply uses an input resistor instead of the more common input condenser or choke. The resistor serves to limit the voltage of the power supply to the proper value both because of its action as a resistance and because it acts as an input impedance ahead of the first condenser. It also contributes to the filtering action.

The output transformer T_1 is a unit designed to be used as a driver transformer between push-pull 2A3's and the grids of a pair of 801's in class B. However, by using it in the amplifier as shown it is possible to obtain a selection of four different impedance ratios from the plate of the 6L6 to the grid of the tube being modulated. If the 6L6 is fed into the side of the transformer originally meant for the 2A3's the use of the full secondary will give a ratio of 2.35 to 1 step up; the use of half of the secondary will give about 1.2 to 1 step up. Then if the 6L6 is operated into the side designed for the 801's, the use of the total secondary will give a ratio of 1.7 to 1 step up, the use of half of the secondary will give a ratio of 1 to 0.85 step down. This latter ratio is the one most likely to be used when modulating medium-μ tubes at normal plate voltages. The step-up ratios would be used with medium-μ or low-μ tubes at comparatively high plate voltages and plate inputs up to one kilowatt.

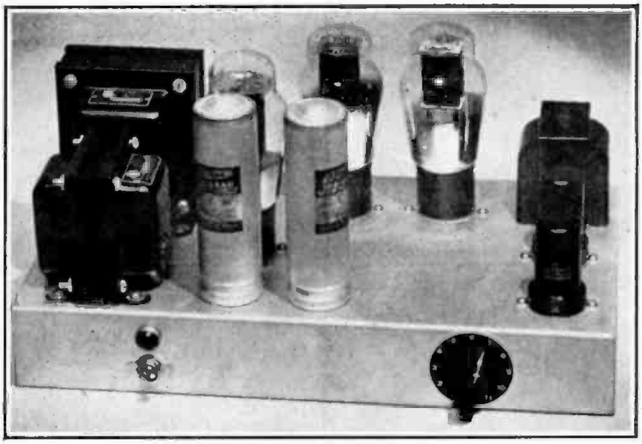


Figure 10.
FRONT VIEW OF THE 2A3 SPEECH AMPLIFIER-DRIVER.
The jack for the diaphragm-type crystal microphone is mounted on the right drop of the chassis directly alongside the grid lead of the 6SJ7 first stage of speech. The low plate impedance of the 2A3's makes this amplifier an ideal driver for any medium-power class B modulator.

PUSH-PULL 2A3 AMPLIFIER-DRIVER

A speech amplifier-driver for a medium powered class B modulator is shown in figures 10 and 11. The amplifier is designed to work out of a diaphragm-type crystal microphone, although any other type of input circuit could be used with equally good results. Alternative input circuits have been shown in chapter *Eight*.

The first stage utilizes one of the new single-ended metal pentodes, a 6SJ7. The gain control is between its plate circuit and the grid of the 6C5 second stage. The output tubes are a pair of 2A3's operating with a self-bias resistor in their common filament return. Operating in this manner the 2A3's have an undistorted output of approximately 10 watts.

A pair of 2A3's operating in this manner will have ample output to drive most any class-B modulator whose output is 300 watts or less. The driver transformer for coupling the plates of the 2A3's to the grids of the class B stage is not shown since it has been found best to have this transformer at the grids of the driven tubes rather than at the plates of the drivers. The correct transformer step-down ratios for driving almost any class B tube have been set down in tabular form by the various transformer manufacturers. When the driver transformer is purchased one should be obtained which has the proper ratio for the tubes to be used. Some manufacturers make multiple-ratio transformers which allow a proper match to be obtained for a large number of tubes.

A three-wire shielded cable should be run from the output of the 2A3 tubes to the driver transformer at the grids of the class B tubes. This cable may be made any reasonable length up to 25 or 30 feet. Make sure that the insulation from the three wires to ground is ample to withstand about twice the d.c. voltage on the tubes.

For driving a class B modulator of less than 75 watts output, type 45's may be substituted for the 2A3's with no changes in circuit constants. The 45's are less expensive.

CLASS B 809 MODULATOR

Figures 12 and 13 illustrate and show the schematic of a class B modulator using a pair of 809's. This modulator is designed to be driven by the push-pull 2A3 speech amplifier-driver shown above. A pair of 45's also could be used as drivers but the 2A3's will have a reserve of driving power that will make for better quality from the modulator.

With the 809's operating at 750 volts plate and 4.5 volts of bias the plate-to-plate load should be 4800 ohms for maximum speech-waveform peak audio output. Under these conditions of operation the instantaneous peak output from the tubes will be about 300 watts which

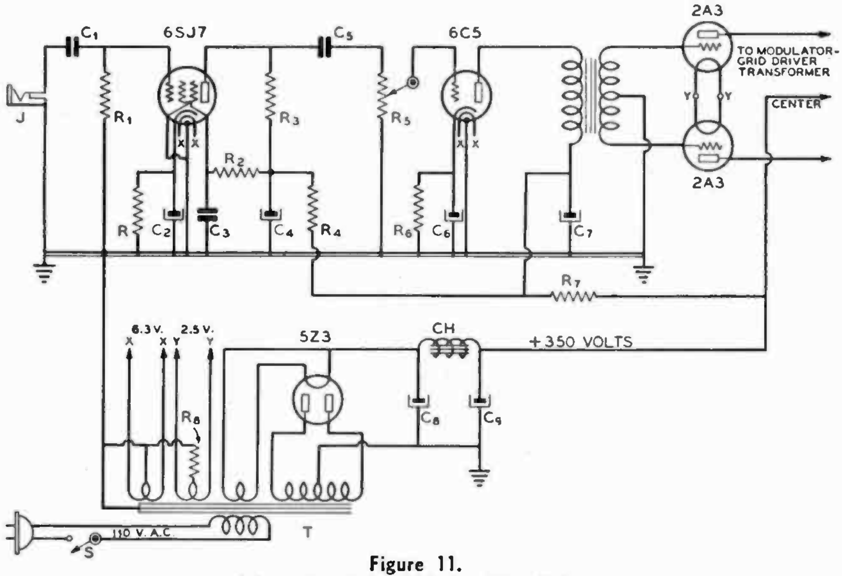


Figure 11.
Schematic of the 2A3 Amplifier-Driver.

C_1 — .01-μfd. 400-volt tubular
C_2 — 10-μfd. 25-volt elect.
C_3 — 0.1-μfd. 400-volt tubular
C_4 — 8-μfd. 450-volt elect.
C_6 — .01-μfd. 400-volt tubular
C_6 — 10-μfd. 25-volt elect.
C_7, C_8, C_9—8-μfd. 450-volt elect.
R—1000 ohms, ½ watt
R_1 — 1.0 megohm, ½ watt
R_2 — 1.0 megohm, ½ watt
R_3—250,000 ohms, ½ watt
R_4 — 10,000 ohms, ½ watt
R_5—500,000-ohm potentiometer
R_6—2500 ohms, ½ watt
R_7 — 5000 ohms, 10 watts
R_8—750 ohms, 10 watts
P.p. input trans. — 2:1 overall
T—700 v. c.t., 110 ma.; 5 v., 3 a.; 2.5 v., 14 a.; 6.3 v., 4.5 a.
CH — 25-hy. 140-ma. choke
J—Microphone jack
S—A.c. line switch

will allow the 809's to modulate an input of 300 watts to the class C amplifier. With 900 volts on the 809's the proper plate-to-plate load resistance is 6200 ohms and the peak output will be approximately 350 watts. If the plate voltage is raised to 1000 and the bias to 8 or 9 volts, the proper plate-to-plate load value is 7200 ohms and the tubes will deliver a peak output of 400 watts, allowing them to voice modulate an input of 400 watts to the final stage.

Under all the above conditions of operation full output from the 809's will be obtained when they are driven to an average plate current of approximately 160 ma. as indicated by the milliammeter M in the plate circuit. Testing of the modulator with sine-wave audio as generated by an audio oscillator is not to be recommended except for a very short period of time, just long enough to make the measurement. If continuous modulation with a sine-wave tone is attempted the maximum plate dissipation ratings of the 809's will be exceeded.

The input transformer ratio of total

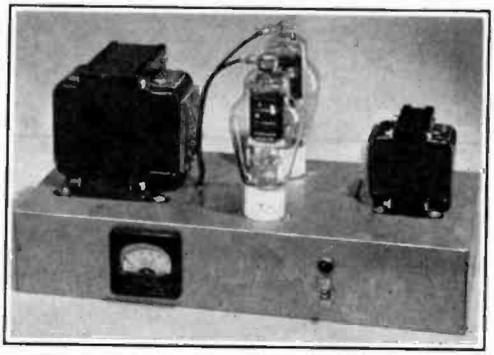


Figure 12.
The class B 809 modulator with multiple-ratio input and output transformers.

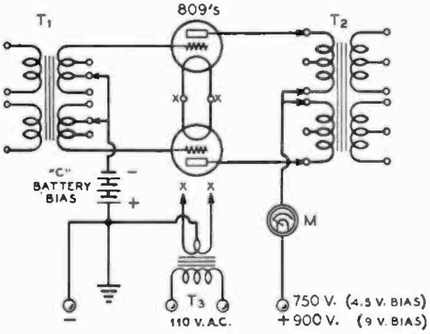


Figure 13.

SCHEMATIC DIAGRAM OF THE 809 MODULATOR.

T_1—Multiple-ratio input transformer, 4.5:1 step-down ratio is used
T_2—Multiple-impedance output transformer
T_3—6.3-volt 5-ampere filament transformer
M—0.250 d.c. milliammeter

primary to half secondary should be approximately 4.5 to 1 for all conditions of operation.

If it is desired to operate the 809's under the sine-wave audio conditions for modulating a smaller input to the class C stage the following conditions will apply: plate voltage, 500; grid bias, 0; plate-to-plate load impedance, 5200 ohms; power output 60 watts (which will modulate an input of 120 watts to the class C stage); maximum signal plate current, 200 ma. Another set of conditions recommended for somewhat greater power output with sine-wave audio are: plate voltage, 750; grid bias, 4½; plate-to-plate load, 8400 ohms; power output, 100 watts (which will sine-wave modulate 200 watts input to class C stage); maximum signal plate current, 200 ma. The correct driver transformer step-down ratio for these operating conditions is also 4.5:1.

AN 8-WATT A.C.-D.C. AMPLIFIER

Quite a number of amateurs are "stranded" in districts where only d.c. is available. Heretofore these amateurs have been very much limited in the amount of power they could obtain by direct use of the 110-volt d.c. line. But the 25L6 beam power tube has made it possible to obtain a goodly number of audio watts in straight 110-volt operation, without benefit of filament and plate power transformers. At the same time this remarkable tube has offered numerous obvious advantages not afforded by its predecessors, the 43, 48 and 25A6. Hams in d.c. districts should welcome the 25L6.

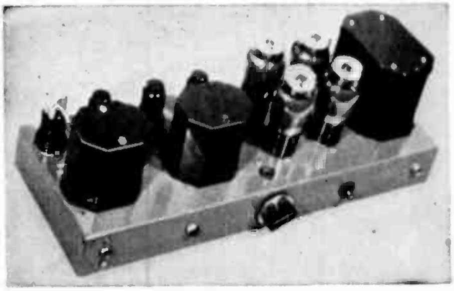


Figure 14.

THE 8-WATT A.C.-D.C. AMPLIFIER.

Four 25L6G's in push-pull parallel operating from 110 volts a.c. or d.c. give approximately 8 watts of useful audio output. Ample gain is provided for operation of the amplifier either from a velocity or a diaphragm-type crystal microphone.

The beam power amplifier described employs four 25L6 tubes in push-pull parallel in the output stage to give an output of approximately eight watts. The four 25-volt heaters of these tubes are wired in series and connected across the 110-volt line through a 6.3-volt pilot

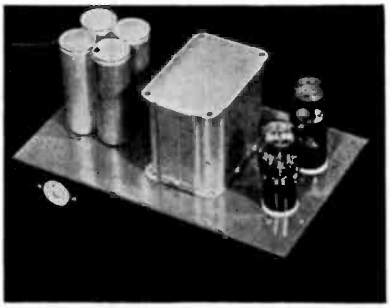


Figure 15.

THE POWER SUPPLY FOR THE A.C.-D.C. SPEECH AMPLIFIER.

The power supply is made external to minimize hum. Two 25Z5's in parallel are used as rectifiers to provide sufficient current carrying capacity for the amplifier.

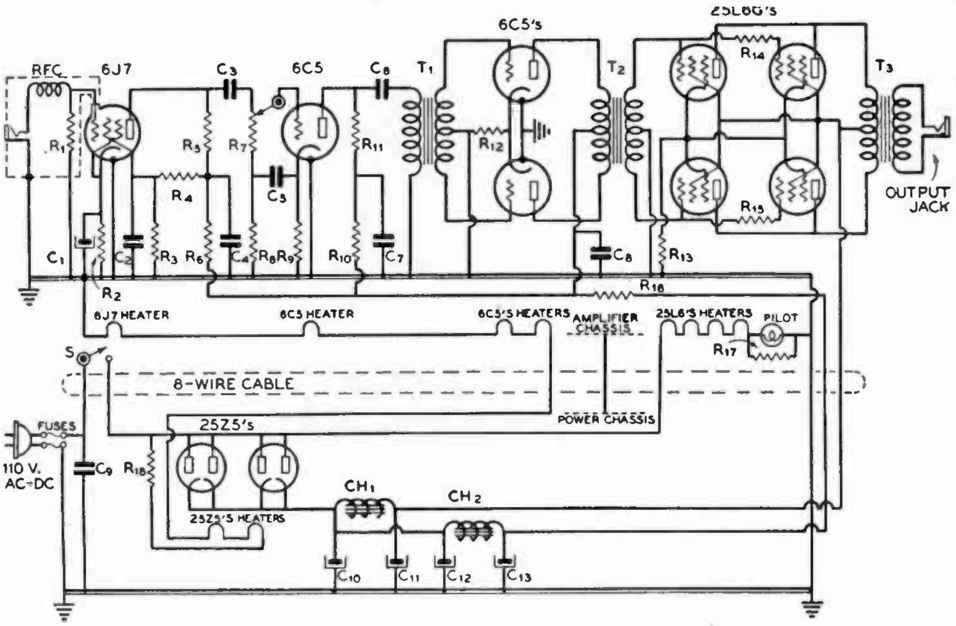


Figure 16.
SCHEMATIC DIAGRAM OF THE AMPLIFIER AND POWER SUPPLY.

C_1—10-μfd. 25-volt electrolytic
C_2—2-μfd. 200-volt paper
C_3 — 0.1-μfd. 200-volt tubular
C_4—2-μfd. 200-volt paper
C_5 — 0.5-μfd. 200-volt tubular
C_6 — 0.1-μfd. 200-volt tubular
C_7, C_8—4-μfd. 200-volt tubular
C_9 — 0.1-μfd. 400-volt tubular
C_{10}, C_{11}, C_{12}, C_{13}—16-μfd. 250-volt electrolytic
R_1—5 megohms, ½ watt
R_2—3500 ohms, ½ watt
R_3—50,000 ohms, ½ watt
R_4, R_5 — 250,000 ohms, ½ watt
R_6—50,000 ohms, ½ watt
R_7 — 500,000-ohm potentiometer
R_8 — 100,000 ohms, ½ watt
R_9—3500 ohms, ½ watt
R_{10}—10,000 ohms, ½ watt
R_{11}—50,000 ohms, ½ watt
R_{12}—500 ohms, ½ watt
R_{13} — 40 ohms, 10 watts
R_{14}, R_{15}—100 ohms, ½ watt
R_{16}—2500 ohms, 1 watt
R_{17}—63 ohms
R_{18} — 116 ohms, 25 watts
T_1—Single-plate-to-p.p.-grids, 1:2 ratio
T_2 — Push-pull-plates-to-push-pull-grids, class-A
T_3 — Variable-match 10-watt output transformer
CH_1—20 henry, 225 ma.
CH_2—30 henry, 75 ma.
RFC — 2.5-mh. r.f. choke
S — S.p.s.t. toggle switch
Fuses—5-amp. glass cartridge type

lamp. Two 25Z5 rectifiers are used in the "transformerless" power supply, and the 25-volt heaters of these tubes are wired in series with the 6.3-volt heaters of the four other tubes in the amplifier (a single 6J7 and three 6C5's) and connected across the 110-volt line through a 116-ohm 25-watt fireproof wirewound resistor. In every other respect the amplifier resembles any conventional speech amplifier with the same number of resistance-coupled and transformer-coupled stages.

Hum pickup is a serious problem in an amplifier of this type. Grounding and shielding in all stages is very important, particularly so in the low-level ones. The power supply and the amplifier have been mounted upon separate chassis to reduce further the difficulties arising from intercoupling. An 8-wire cable connects the two chassis.

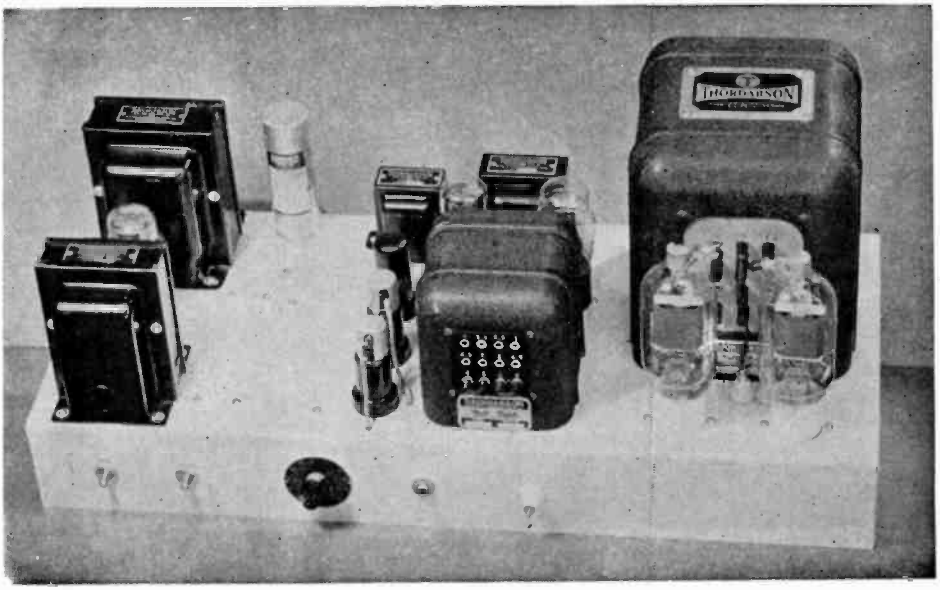


Figure 17.
TOP VIEW OF THE TZ 40 CLASS B MODULATOR
This combined speech amplifier and class B modulator will modulate up to 600 watts on voice. It incorporates inverse feedback, a.m.c., and other modern features.

The amplifier has ample gain for operation from a crystal microphone or from a velocity microphone with high-impedance output. The output transformer from the plates of the push-pull parallel 25L6G's is a universal affair designed to work into any voice-coil impedance or into a 500 or 200 ohm line. If desired, a driver transformer or one designed to be used for coupling to a class C stage could be substituted.

COMPLETE SPEECH AND MODULATOR UNIT WITH TZ-40's FOR 600 WATTS INPUT

Illustrated in figures 17 and 18 and diagrammed in figure 19 is a complete speech channel capable of plate-modulating an input of between 500 and 600 watts on voice. It incorporates a.m.c., inverse feedback and other desirable modern features.

The combined speech amplifier-class-B modulator, with the associated power supply for the speech amplifier, is built upon one 24"x10"x3" metal chassis. The under side of the chassis is not painted; the plated cadmium finish on this side facilitates the grounding of the various components.

The power supply for the speech stages is mounted along the left hand side of the chassis. Then there are mounted, in a row, the 6J7 first audio stage, the 6L7 a.m.c. amplifier and the 6F6 last audio. Then, in the next row, in front is the multitap driver transformer for the class B stage, then the two 6V6 drivers and, in back, the coupling transformer between the 6F6 and the two 6V6G's. On the right hand end of the chassis are mounted the two TZ40 modulators and their associated class B output transformer.

Looking at the front of the chassis can be seen at the extreme left, the on-off switch for all filaments and for the plate supply for the speech amplifier. The plate supply for the TZ40's is controlled at the transmitter proper. The next switch is the on-off switch for the a.m.c. circuit. Then comes the gain control, the microphone input jack and the

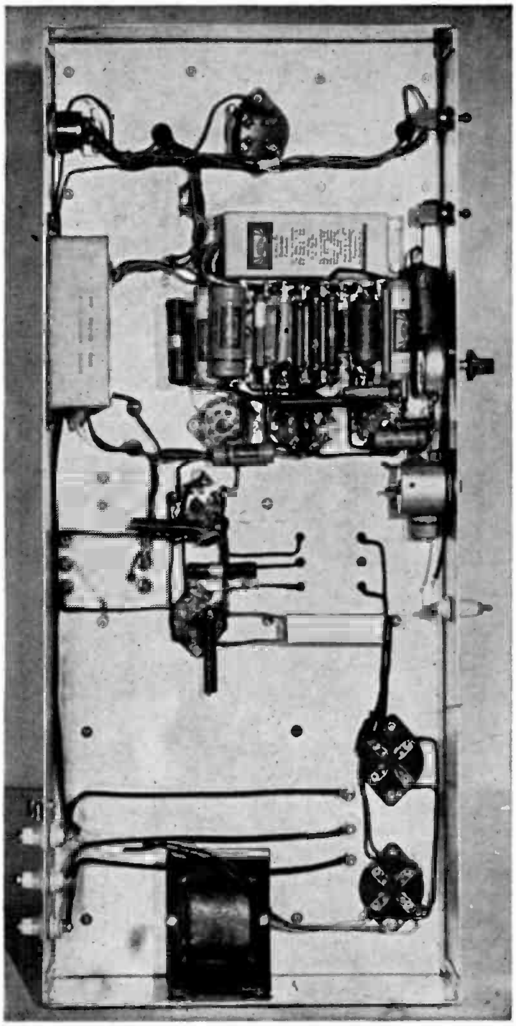


Figure 18.
THE TZ40 MODULATOR TIPPED UP ON EDGE TO SHOW THE PLACEMENT OF THE COMPONENTS UNDER THE CHASSIS.

binding post for connection to the a.m.c. peak rectifier.

The under-chassis view is practically self-explanatory. At the extreme right end of the chassis is the 7.5-volt filament transformer for the TZ40's and to the left of the center of the chassis are mounted the resistor plates. Only the upper one can be seen as the two are mounted one above the other.

The speech amplifier uses a 6J7 metal tube connected as a high-gain pentode in the input. The circuit is conventional and the tube is designed to operate from a diaphragm-type crystal microphone. The closed circuit jack on the input of the amplifier is shielded by a small metal can to eliminate any possibility of coupling between the output of the amplifier and the input circuit. Since the large metal spring of the jack is at grid potential, it is desirable to shield it from the output circuit of the 6V6G's and from the a.m.c. lead which runs very close to the jack.

Automatic Modulation Control

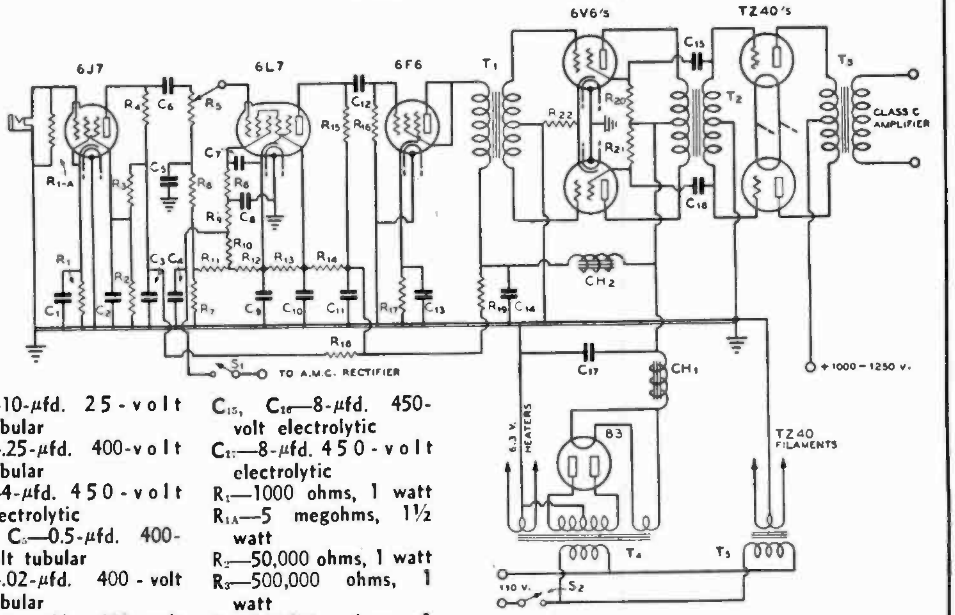
The second stage of the amplifier—the a.m.c. stage—utilizes a 6L7 tube. The 500,000-ohm volume control is placed between the plate circuit of the 6J7 and the control grid of the 6L7. It is important that this potentiometer be of the insulated-shaft type since the entire 6L7 circuit operates considerably above ground potential.

The 879 reverse peak rectifier should be connected as follows: the plate of the tube should be connected directly to the a.m.c. binding post on the amplifier, and the filament of the tube should be connected to the lead that goes to the plates of the modulated class C amplifier. The filament should be lighted from a 2.5-volt filament transformer that is adequately insulated for twice the average plate voltage of the modulated amplifier plus 1000 volts. Also, it is often a good idea to remove the negative peak rectifier as far as conveniently possible from both the speech amplifier and the class C final.

Since the injection grid of the 6L7 a.m.c. amplifier is 70 to 90 volts above ground potential (the whole a.m.c. stage is, as mentioned before, at this poten-

Figure 19.

GENERAL WIRING DIAGRAM OF THE TZ40 MODULATOR AND ASSOCIATED A.M.C. SPEECH AMPLIFIER.



C_1—10-μfd. 25-volt tubular
C_2—.25-μfd. 400-volt tubular
C_3—4-μfd. 450-volt electrolytic
C_4, C_5—0.5-μfd. 400-volt tubular
C_6—.02-μfd. 400-volt tubular
C_7—0.1-μfd. 400-volt tubular
C_8—.002-μfd. 400-volt tubular
C_9—8-μfd. 450-volt electrolytic
C_{10}—0.5-μfd. 400-volt tubular
C_{11}—8-μfd. 450-volt electrolytic
C_{12}—.05-μfd. 400-volt tubular
C_{13}—10-μfd. 25-volt tubular
C_{14}—8-μfd. 450-volt electrolytic
C_{15}, C_{16}—8-μfd. 450-volt electrolytic
C_{17}—8-μfd. 450-volt electrolytic
R_1—1000 ohms, 1 watt
R_{1A}—5 megohms, 1½ watt
R_2—50,000 ohms, 1 watt
R_3—500,000 ohms, 1 watt
R_4—250,000 ohms, 1 watt
R_5—500,000-ohm potentiometer
R_6—500,000 ohms, 1 watt
R_7—4500 ohms, 5 watts
R_8—1 megohm, 1 watt
R_9—100,000 ohms, 1 watt
R_{10}—500,000 ohms, 1 watt
R_{11}—350 ohms, 1 watt
R_{12}—150 ohms, 1 watt
R_{13}—5000 ohms, 5 watts
R_{14}—7500 ohms, 5 watts
R_{15}—100,000 ohms, 1 watt
R_{16}—100,000 ohms, 1 watt
R_{17}—750 ohms, 10 watts
R_{18}—10,000 ohms, 5 watts
R_{19}—2000 ohms, 5 watts
R_{20}, R_{21}—5000 ohms, 3 watts
R_{22}—300 ohms, 10 watts
T_1—Triode power tube to p.p. power tube driver transformer
T_2—Multi-match class-B input transformer
T_3—Multi-match class-B output (300 watt)
T_4—745 c.t., 145 ma.; 5 v. 3 a.; 6.3 v., 4.5 a.
T_5—7.5 volts, 4 amperes
CH_1—10-hy., 150-ma. filter choke
CH_2—10-hy., 65-ma. filter choke
S_1—A.m.c. on-off switch
S_2—110-v. a.c. switch

tial above ground), the 879 peak rectifier will begin to operate when the plate voltage on the class C amplifier becomes less than 70 or 90 volts, whatever the case may be. Then, as the modulator tends to drive the plate voltage lower than this, the gain on the speech amplifier will be reduced as the injector-grid bias on the 6L7 becomes negative. As this negative bias is increased, the signal output of the modulator is reduced. The final result: the output voltage of the modulator is reduced to an amount that will not cut the negative-peak plate voltage on the class C stage to zero; consequently, there is no overmodulation.

The gain on the speech amplifier may be run up to an amount which will permit a higher average voice level from the transmitter without any chance of overmodulation under any case. When the resulting signal is heard over the air, the transmitter seems to be modulated at a much higher percentage although there is no tendency toward overmodulation splatter or hash.

The 6V6G Drivers

A pair of 6V6's or 6V6G's are connected as tetrodes with degenerative feedback coupled into their screen circuits. This method of connection for the 6V6G's adapts them very well as drivers for the TZ40's since the plate impedance of the tubes is considerably lowered by this method of connection.

Beam tetrodes when connected in the conventional manner are not particularly well-suited as drivers for a class-B stage unless a considerable amount of swamping is used. The high plate resistance of the tubes in the conventional method of connection causes a large drop in output voltage when any increase in load is placed upon them.

When first placing the amplifier in operation, it is very important that the screens be connected to the proper side of the class B modulation transformer secondary. The only way of finding out which side is the proper one is to connect up the amplifier and try it out. It is best not to have the plate voltage on the TZ40's when this test is made—something may flash over. Should the 6V6G's oscillate, reverse the connections between the screen grid coupling condensers and the class B grids, and the correct phase relation between the screen and plate voltages will be obtained.

The TZ40's operate with zero bias under the conditions recommended by the manufacturers. The standing plate current on the two tubes is approximately 45 ma. with an applied plate voltage of 1000 volts. It will be somewhat higher, in the vicinity of 60 ma., if the full rated plate voltage of 1250 volts is used. Since this value of standing plate current results in an appreciable amount of plate dissipation, a small amount of grid bias is desirable in order to lower the plate current under no-signal conditions. A pair of 4½-volt batteries in series to give 9 volts is suitable as bias for 1250-volt operation.

For maximum peak power output from the TZ40's (for the adjustment which will modulate the greatest class C input with voice) the plate-to-plate load impedance for the 1000-volt conditions would be 5100 ohms. Under these conditions of operation, the modulator would be capable of 100 per cent voice-modulating at input of 500 watts to the class C stage; the plate current on the TZ40's should kick up to 200 to 250 ma. under normal modulation.

For maximum peak modulating capabilities at 1250 volts, the plate-to-plate load value should be 7400 ohms; the unit would be capable of fully modulating 600-watts input and the plate current would kick up to 175 to 225 ma. under full modulation.

If it is desired to operate the class B stage under the conventional conditions for maximum *sine-wave* audio output, the plate-to-plate load resistance would be 6800 ohms under the 1000-volt conditions; the power output would be 175 rated watts and the plate current would kick up to 250 to 275 ma. on peaks.

COMPLETE 203Z MODULATOR AND SPEECH AMPLIFIER FOR INPUTS UP TO 800 WATTS

Figures 20 and 21 show a speech amplifier and class B modulator suitable for modulating inputs from 400 to 800 watts input to the class C final stage. The speech amplifier portion of the modulator is more or less conventional except for the inclusion of automatic peak compression to allow a higher average percentage of modulation without the danger of overmodulation on occasional loud voice peaks. The delay action in the compressor (the percentage of modulation at which compression starts) can be controlled by means of the potentiometer R_{14}. All components in the 6J7 first speech stage should be thoroughly shielded to prevent grid hum and to reduce the possibility of either r.f. or audio feedback.

Operation of the Class B 203Z's

The class B operating conditions recommended by the manufacturer for sine-wave audio output are 7900 ohms

Figure 20.

THE 203Z SPEECH-MODULATOR FOR INPUTS TO 800 WATTS

The complete speech amplifier and class-B output stage is built upon a single relay-rack panel and its associated chassis. The speech amplifier incorporates automatic peak limiting and uses a pair of 2A3's as drivers for the 203Z's.

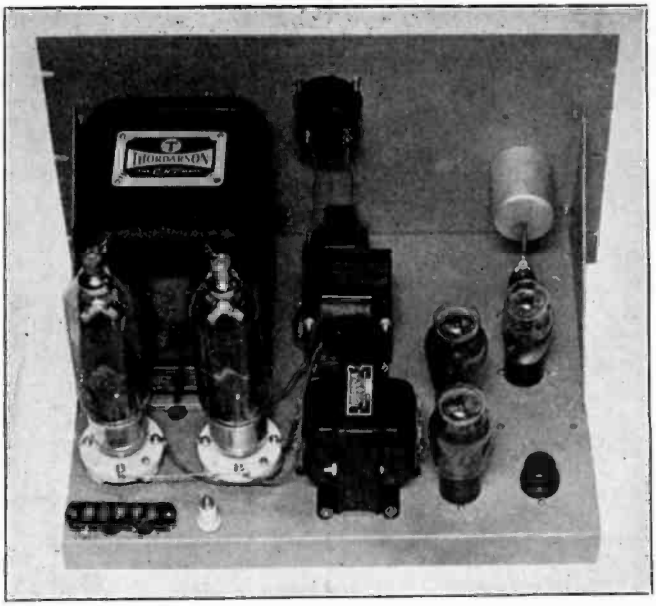


plate to plate at 1250 volts on the plate and 4½ volts of grid bias. Under these conditions the tubes will deliver 300 watts of sine-wave audio. For maximum speech audio output the plate-to-plate load resistance should be reduced to 5500 ohms. Under these conditions the tubes will modulate an input of 800 watts as compared to the 600 watts they will modulate under sine-wave audio operating conditions.

Power supplies both for the speech amplifier portion and for the class B stage are external. 1250 volts will be required for the 203Z's and about 350 volts for the speech amplifier portion. The 1250-volt supply should have good regulation up to a maximum drain of 350 ma. and the 350-volt supply should be capable of handling 125 ma. continuously.

SIMPLIFIED AUTOMATIC MODULATION CONTROL

Figure 22 shows the circuit of a simplified method of obtaining the necessary bias required for an automatic-modulation-control system. This rectifier circuit must be used with the 60-Watt T-21 Modulator shown earlier in this chapter if satisfactory a.m.c. action is desired. Through the use of the circuit illustrated the bias required for all a.m.c. systems is placed on the rectifier tube itself instead of being placed on the cathode of the a.m.c. tube in the speech amplifier. This greatly simplifies the design of the a.m.c. stage in the speech system.

In the circuit diagram, this "advance" bias is obtained by means of a voltage divider consisting of a 50,000-ohm and a 500,000-ohm resistor which reduces the d.c. plate voltage applied to the diode cathode about 9%. This acts as the "advance" bias. The resistor R_1 can be of the 1-watt size for plate supplies up to 1000 volts and a 2-watt for up to 2000 volts. The 500,000-ohm resistor can be made of ten similar carbon resistors wired in series and well insulated from the chassis. C_1, R_1 and R_2 can be mounted on bakelite resistor mounting strips or panels about one inch away from the chassis with the strip mounted on standoff insulators. The diode filament transformer must also be well insulated between windings in order to withstand the peaks in the positive direction. The diode itself must have sufficient inverse peak rating, which means that an 866 Jr. is suitable for use in sets with plate supplies up to 1000 volts, an 866 up to 2500

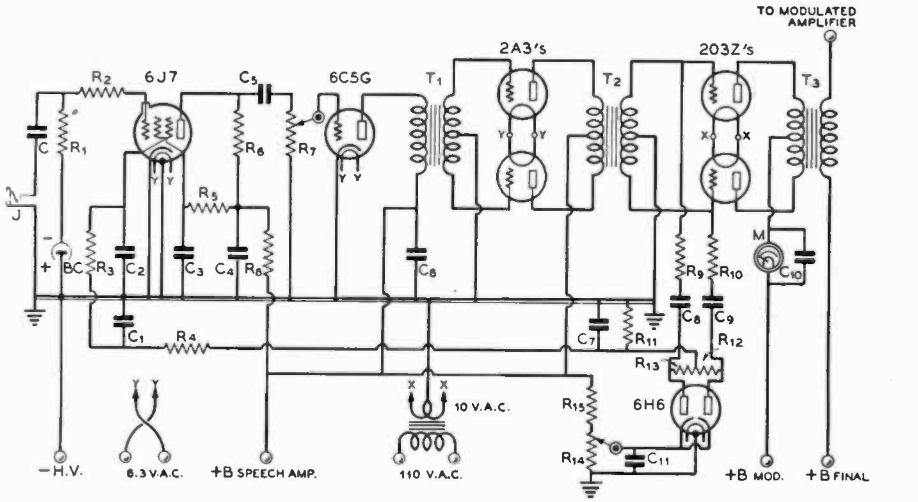


Figure 21.

SCHEMATIC OF THE CLASS B 203Z MODULATOR.

C—.01-µfd. 400-volt tubular
C_1—0.1-µfd. 400-volt tubular
C_2—0.1-µfd. 400-volt tubular
C_3—.25-µfd. 400-volt tubular
C_4—0.5-µfd. 400-volt tubular
C_5—.01-µfd. 400-volt tubular
C_6—0.5-µfd. 400-volt tubular
C_7—0.25-µfd. 400-volt tubular
C_8 C_9—0.1-µfd. 400-volt tubular
C_{10}—.002-µfd. mica
C_{11}—1.0-µfd. paper, 400 volt
R_1—1.0 meghom, ½ watt
R_2—50,000 ohms, ½ watt
R_3—250,000 ohms, ½ watt
R_4—300,000 ohms, ½ watt
R_5—1.0 megohm, ½ watt
R_6—250,000 ohms, ½ watt
R_7—1.0-megohm potentiometer
R_8—50,000 ohms, ½ watt
R_9, R_{10}—2.0 megohms, ½ watt
R_{11}, R_{12}, R_{13} — 100,000 ohms, 1 watt
R_{14}—50,000-ohm potentiometer
R_{15}—100,000 ohms, 1 watt
J—Microphone jack
BC—Bias cell
T_1—Push-pull input trans.
T_2—Class-B input for 203Z's
T_3—300-watt variable-ratio modulation trans.
M—0-500 d.c. milliammeter

volts and an 879 for higher plate supplies. Mercury vapor in the rectifiers seems to make no difference in operation at the low currents used in a.m.c. circuits.

The purpose of C_1 in the circuit diagram is to by-pass the audio peak overload voltage into the diode cathode. The diode then has the full amount of a.c. peak across it and a little over 90% of the d.c. plate voltage. C_1 can be a one-half or one µfd. 400- or 600-volt paper condenser as long as it is mounted well in the clear of nearby grounds.

The control bias is developed across R_3 which can be of any value between 100,000 and 250,000 ohms. No condenser should be connected across this resistor unless there is some stray r.f. present. If there should be any it must be bypassed with a small .002-µfd. condenser. The time delay circuit should be confined mainly to C_3 and R_5, which can have values of 0.5 µfd. and 1 megohm in most speech transmitters. Additional audio filter in the form of C_2, 0.1 µfd., and R_4, half megohm, is generally necessary to prevent audio feedback and a "blurbing" effect on high levels of speech input. These resistors can be of one-half or one watt size.

It is possible to supply a.m.c. voltage to the control grid of an amplifier such as to a 6K7 or even a 6N7. The suppressor grid of a 6C6, 6J7 or 6K7, requires about twice as much negative bias for the same reduction in gain as does the injector grid of a 6L7. It is advisable to use a 6L7 whenever possible. However, this a.m.c. circuit can be applied to near-

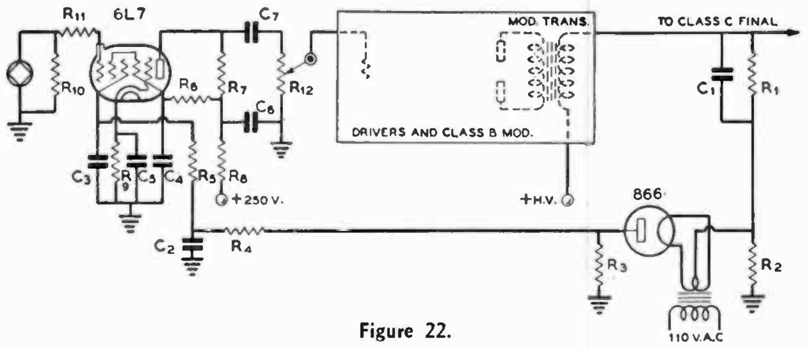


Figure 22.

OBTAINING FIXED BIAS FOR THE A. M. C. RECTIFIER.

C_1—0.5-μfd. 600-volt tubular
C_2—0.1-μfd. 400-volt tubular
C_3, C_4—0.5-μfd. 400-volt tubular
C_5—10-μfd. 25-volt electrolytic shunted by .01-μfd. 400-volt tubular
C_6—0.5-μfd. 400-volt tubular
C_7—.02-μfd. 400-volt tubular
R_1—50,000 ohms, 2 to 20 watts (see text)
R_2—500,000 ohms, 10 watts
R_3—100,000 ohms, 1 watt
R_4—500,000 ohms, ½ watt
R_5—1.0 megohm, ½ watt
R_6—250,000 ohms, 1 watt
R_7—200,000 ohms, 1 watt
R_8—30,000 ohms, 1 watt
R_9—1000 ohms, ½ watt
R_{10}—1.0 megohm, ½ watt
R_{11}—25,000 ohms, ½ watt
R_{12}—500,000-ohm potentiometer

ly any existing phone transmitter with hardly any changes in the speech amplifier.

A.m.c. practically eliminates sideband splatter in all cases and prevents modulation in excess of 100 per cent. In addition it allows an average higher level of modulation which results in better signal at the receiver. Two phone transmitters of the same carrier output, one with a.m.c. and one without, both not overmodulated will have about 2 to 3 db difference in level. The 3 db increase available from the use of a.m.c. is equivalent to doubling the carrier signal in effect.

One other point should be mentioned; a.m.c. will handle only from 15 to 20 db excessive level peaks without considerable audio distortion. So don't try to push the average modulation level up to 99% at all times. Use the manual gain control, too, and keep the level of modulation down to a point where it sounds right in a monitor. An oscilloscope will usually indicate 100% modulation many times a minute on an average speech when the gain adjustment is correct for good monitor quality.

The a.m.c. circuit shown in figure 22, however, is *not* suitable for use with the TZ40 speech amplifier-modulator shown in figure 17. All this speech amplifier requires is a half-wave rectifier. The same voltage ratings apply for this rectifier as for the one just described, with the c.t. of its filament connected directly to the plate voltage lead to the plate modulated stage, and the plate connected to the input terminal on the amplifier.

TROUBLE SHOOTING IN THE SPEECH AMPLIFIER

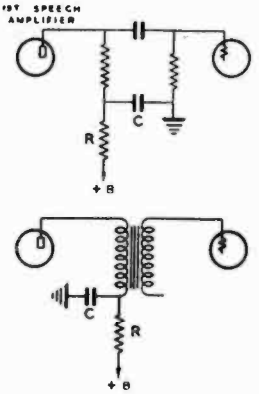
Great care is necessary in the design of speech amplifiers in order to prevent hum, distortion and feedback at radio- or audio-frequencies. Certain precautions can be taken in building the speech amplifier, as related here: (1) Shield all low-level grid and plate leads. (2) Avoid overheating the shielded wires (rubber insulation) when soldering ground connections to the shield. (3) Shield all input and microphone connections. (4) Wire the filaments with twisted conductors. (5) Mount resistors and condensers as near as possible to socket terminals. (6) Orient the input and low-level audio transformers in a position of minimum hum when a.c. power is applied to the primaries of the power supply transformers. (7) Shield the input and low-level stage tubes. (8) Use a good ground connection to the metal chassis (water-pipe or ground rod connection). (9) Ground all transformer and choke coil cores. (10) Use metal cabinets and chassis, rather than breadboard construction. (11) By-pass low-level audio stage cathode resistors with a .002-μfd. mica condenser for the purpose of preventing rectification of stray r.f. energy which will sometimes produce hum.

The power supply for a speech amplifier should be exceptionally well filtered. This may require three sections of filter, consisting of three high-capacity condensers and two or three filter chokes. When space permits, the power supply should be placed several feet from the speech amplifier.

The speech amplifier and microphone leads should be completely shielded for the elimination of r.f. feedback. A concentric or a *balanced* two-wire r.f. transmission line to a remotely located antenna is the most effective method of preventing r.f. feedback into the microphone or speech amplifier circuits in the range of from 5 to 20 meters.

The impedance of ground leads at such short wavelengths makes it impossible completely to eliminate stray r.f. currents. End-fed antennas and single-wire fed systems are particularly troublesome with respect to r.f. feedback.

Audio feedback may cause motor-boating, whistling or howling noises in the audio amplifiers. Insufficient by-pass capacity across the plate supply of a multistage speech amplifier is one cause of motor-boating. The first stage of a speech amplifier should have a resistance filter in its plate supply lead, which may consist of a 10,000- to 50,000-ohm 1-watt resistor in series with the positive B lead, with a ½-μfd. condenser connected to ground from the amplifier side of the series resistor. (See figure 23.)



R-C FILTER CIRCUITS

FIGURE 23.

A defective tube will introduce hum or distortion, as well as affect the overall gain or power output of an audio amplifier. Incorrect bias on any amplifier stage will produce harmonic distortion, which changes the quality of speech. This bias voltage should be of the correct value for the actual plate-to-cathode voltage, rather than the plate supply output voltage (these may be widely different in a resistance-coupled stage). Excessive audio input to any amplifier stage will produce amplitude distortion. Incorrect plate coupling impedances or resistances will cause distortion. A damaged or inferior microphone is another source of distortion. Cathode resistors should be by-passed with ample capacity to provide a low impedance path for the lowest frequencies. Push-pull and especially class B amplifiers require balanced tubes.

POWER SUPPLIES FOR RADIOTELEPHONY

A power supply for a radiotelephone transmitter should furnish nonpulsating d.c. voltage to the crystal oscillator or other source of frequency control. The amount of pulsation or ripple voltage should be less than 1 per cent of the d.c. voltage, especially for radio transmitters operating on very high frequencies. Hum or ripple voltage in the plate supply to the oscillator will frequency-modulate the r.f. output slightly. Each frequency multiplier stage increases the frequency modulation, until the carrier hum becomes objectionable in high-frequency transmitters. Many amateur 10-meter phones suffer from this difficulty, noticed especially with selective receivers.

The power supply for the front end of the speech channel must be thoroughly filtered in order to avoid amplification of the ripple in the succeeding audio or speech amplifier stages. The plate supply for the final audio amplifier stage does not require as much filter as the preceding stages, and, in the case of a push-pull audio modulator stage, a single-section filter will suffice.

Buffer stages of a control-grid modulated transmitter must have very well-filtered plate supplies (more than the buffers in a plate-modulated transmitter) in order to prevent hum modulation in the grid circuit on which the speech audio frequencies are impressed. On the other hand, the plate supply for the grid-modulated stage itself does not require quite as much filter as does a comparable plate-modulated stage. This indicates that a single-section filter will suffice for a grid-modulated stage, whereas a two-section filter is desirable for plate modulation. In the event that only a single-section filter is used for a grid-modulated stage, condenser input is desirable. A single-section choke input filter does not furnish sufficient ripple suppression except for a c.w. amplifier or push-pull (or push-push class-B) modulator stage.

Class-B Modulator Voltage Regulation

Power supply voltage regulation of class-B modulators is of great importance because the plate current varies appreciably with the amount of speech input. Choke input, utilizing preferably a *swinging-choke* with high no-current inductance rating (25 hy. or more) and low d.c. resistance, in conjunction with mercury vapor rectifiers and a husky filter condenser (at least 4 μfd.) will make a good power supply. Such a supply is illustrated in figure 28, chapter Fourteen. If the resting plate current of the modulator tubes is high, as is the case with some of the zero bias, class-B tubes, a swinging type choke is not essential; however, even so, the choke should have high inductance (10 or 20 hy.).

A comparatively high degree of ripple as compared to a modulated amplifier power supply can be tolerated in a power supply feeding a push-pull audio or modulator stage, because a good percentage of the hum is cancelled out in the coupling transformer if the modulator tubes are well matched.

FOURTEEN

Power Supplies

ANY device which incorporates vacuum tubes requires a power supply for the filament and plate circuits of the tube or tubes. The filaments of the tubes must be heated in order to produce a source of electrons within the vacuum tubes; direct-current voltages are needed for the other electrodes in order to obtain detection, amplification, oscillation and rectification.

Either a.c. or d.c. voltage may be used for filament power supply in most applications; however, the a.c. power supply is the more economical and can be used with most tubes without introduction of hum in the output of the vacuum tube device. The plate potential must be secured from a d.c. source, such as from batteries or a rectified and filtered a.c. power supply.

The a.c. first must be converted into a unidirectional current; this is accomplished by means of vacuum tube *rectifiers*, of either the *full-* or *half-wave* type.

A half-wave rectifier passes one half of the wave of each alteration of the a.c. current and blocks the other half. The output current is of a *pulsating* nature, which can be smoothed into pure, direct current by means of *filter* circuits. Half-wave rectifiers produce a pulsating current which has zero output during one half of each a.c. cycle; this makes it difficult to filter the output properly into d.c. and also to secure good voltage regulation for varying loads.

A full-wave rectifier consists of two half-wave rectifiers working on opposite halves of the cycle, connected in such a manner that each half of the rectified a.c. wave is combined in the output as shown in figure 1. This pulsating unidirectional current can be filtered to any desired degree, depending upon the particular application for which the power supply is designed.

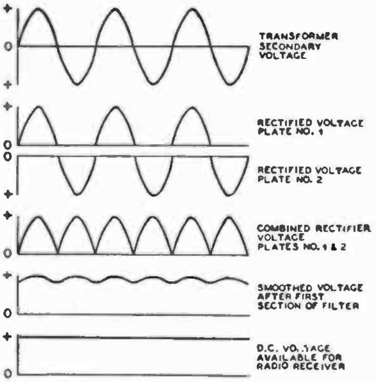


Figure 1.
FULL WAVE RECTIFICATION.
Showing effects of rectification and filtering of an alternating current.

A full-wave rectifier consists of two plates and a filament, either in a single glass or metal envelope for low-voltage rectification or in the form of two separate tubes, each having a single plate and filament for high-voltage rectification. The plates are connected across the high-voltage a.c. power transformer winding, as shown in figure 2. The power transformer is for the purpose of transforming the 110-volt a.c. line supply to the desired secondary a.c. voltages for filament and plate supplies. The transformer delivers alternating current to the two plates of the rectifier tube; one of these plates is positive at any instant during which the other is negative. The center point of the high-voltage transformer winding is usually grounded and is, therefore, at zero voltage, thereby constituting the *negative B connection.*

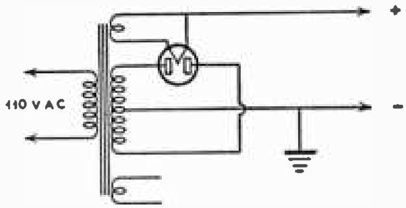


Figure 2.

FULL-WAVE SINGLE-PHASE RECTIFIER CIRCUIT.

When one plate of the rectifier tube is conducting, the other is inoperative, and vice versa. The output voltages from the rectifier are connected together through a common rectifier filament circuit, and thus the plates alternately supply pulsating current to the output circuit. The rectifier tube filaments are always positive in polarity with respect to the output.

The output current pulsates 120 times per second for a full-wave rectifier connected to a 60-cycle a.c. line supply, and the output from the rectifier must connect to a *filter,* which will smooth the pulsations into direct current. Filters are designed to select or reject alternating currents; those most commonly used in a.c. power supplies are of the *low-pass* type. This means that pulsating currents which have a frequency below the cutoff frequency of the filter will pass through the filter to the load. Direct current can be considered as alternating current of zero frequency; this passes through the low-pass filter. The 120-cycle pulsations are similar to alternating current in characteristic, so that the filter must be designed to have a *cutoff* at a frequency *lower than 120 cycles.*

FILTER CIRCUITS

A low-pass filter consists of combinations of inductance and capacitance. An inductance or *choke coil* offers an impedance to any change in the current that flows through it. A high-inductance choke coil offers a relatively high resistance to the flow of pulsating current, with the result that the *a.c. component* or *ripple* passes from the rectifier tube through the load only with the greatest of difficulty. A capacitance has exactly the opposite action to that of an inductance. It offers a low impedance path to the flow of alternating or pulsating current, but presents practically infinite resistance to the flow of direct current. Inductance coils are usually connected in series with the rectifier outputs, while condensers are connected across the positive and negative leads of the output circuit. A simple filter circuit is shown in figure 3.

Electricity always follows the path of least resistance or impedance. The direct current will travel through the choke and back to the ground (negative B) connection through the *external load,* which normally consists of the plate circuits of vacuum tubes. The a.c. component, or ripple, tends to be impeded by the choke and short-circuited by the condensers across the filter, which offer a lower reactance to the pulsating voltage than that offered by the load. The *load impedance* across the output of most filter systems is generally high, usually from 5,000 to 10,000 ohms. This load resistance can be calculated by dividing the output voltage by the total load current; this value is necessary in making calculations for low-pass resonant types of filter circuits.

A resonant type filter is shown in figure 4, in which the condenser C_1 tunes

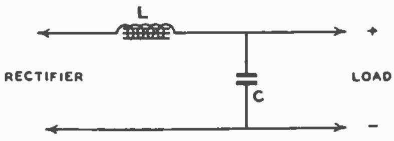


Figure 3.

SIMPLE, SINGLE-SECTION CHOKE-INPUT FILTER.

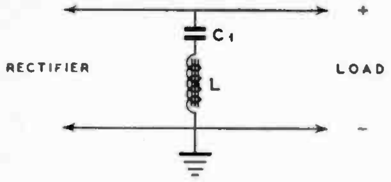


Figure 4.
SERIES RESONANT FILTER CIRCUIT.

the choke coil inductance to series resonance at the ripple frequency. Series resonance provides a very low impedance to the resonant frequency limited only by the actual resistance of the choke coil (since the reactance of both the condenser C_1 and the choke coil cancel each other).

The filter circuit in figure 4 accomplishes the same purpose as a large shunt condenser at the ripple frequency, but is not effective in short-circuiting the higher harmonics in the output of the rectifier system. Additional low-pass filter circuits are needed to remove these harmonic components, which are of great enough magnitude to produce objectionable high-pitched hum in the vacuum tube amplifier circuits.

A typical *low-pass* filter is diagrammed in figure 5. The combination of C_1, C_2 and L should give a cutoff frequency below that of the rectified output pulsation frequency.

This type of filter is very effective because the circuit can be designed with *any* cutoff frequency, as long as the attention or rejection at the 120-cycle-and-higher harmonic frequencies is great. This type of filter is sometimes called a *"brute force" filter,* because large values of inductance and capacitance are normally used without much attention being paid to the actual cutoff frequency. Inductance values of 10 to 30 henrys are used for filter chokes, and shunt capacities of from 2 to 16 microfarads are used for C_1 and C_2 in figure 5.

A *resonant trap circuit,* such as shown in figure 6, is sometimes used to increase the impedance of the choke L at some particular frequency, such as 120 cycles per second.

Parallel resonance of C_2 and L provides a very high impedance at the resonant frequency. The condenser C tends to by-pass the higher ripple harmonics that get through the trap cir-

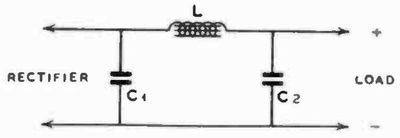


Figure 5.

Single-section condenser input or π-type filter, also known as low-pass or "brute force" filter.

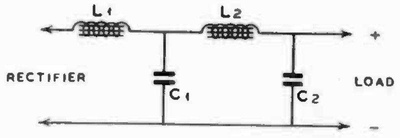


Figure 7.

Adding an input choke to the "brute force" filter improves both regulation and filtering at a sacrifice in output voltage.

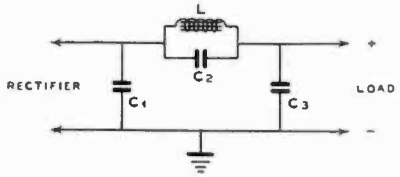


Figure 6.

"Brute force" filter with choke resonated to ripple frequency to increase impedance.

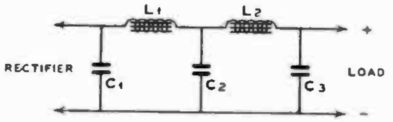


Figure 8.

Two-section low-pass filter for use where very pure d.c. is required, as in low-level speech amplifiers.

cuit. This type of filter is often used in conjunction with an additional section of filter of the type shown in figure 3.

The single-section, low-pass filter in figure 5 is often combined with an additional choke coil as shown in figure 7. The additional choke coil L_1 is an aid in filtering and also provides better voltage regulation for varying d.c. loads, such as presented by a class-B audio amplifier.

A two-section, low-pass filter with condenser input is shown in figure 8. In some cases, additional sections of choke coils and condensers are added for the purpose of obtaining very pure direct current.

Resistors may be used in place of inductances in circuits where the load current is of low value, or where the applied d.c. voltage must be reduced to some desired value.

The ripple in the output of a filter circuit can be measured with an oscilloscope or by means of the simple circuit in figure 9. A high-voltage condenser C_3, having a capacity of from ¼ to 1 μfd., and a high-resistance copper-oxide a.c. voltmeter provides a method of measuring the actual *ripple voltage.*

The voltmeter should be plugged into the measuring jack after the power supply and external load circuit are in *normal operating condition,* and the meter should be removed from the shorting type jack before turning off the power supply or removing the load. The charging current through condenser C_3 would tend to burn out the meter if it were left in the circuit at all times.

Filter Circuit Considerations

The shunt condensers in a filter system serve a dual purpose. They provide: (1) a low impedance path for ripple, (2) an energy-storing system for maintaining constant power output from the power supply. The condensers are charged when the peak voltage is applied across them from the output of the rectifier; during the time in which the rectifier output decreases to zero, the filter condensers supply output current to the load. This action provides a constant output voltage.

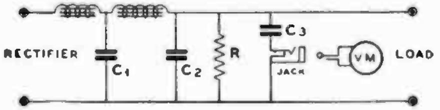


Figure 9.

CIRCUIT FOR MEASURING A.C. RIPPLE.

In an a.c. circuit, the maximum peak voltage or current is the square root of 2 or 1.41 times that indicated by the a.c. meters in the circuit. The meters read the *root-mean-square* (r.m.s.) values, which are the peak values divided by 1.41 for a sine wave.

If a potential of 1,000 r.m.s. volts is obtained from a high-voltage secondary winding of a transformer, there will be 1,410-volts peak potential from the rectifier plate to ground. The rectifier tube has this voltage impressed on it, either positively when the current flows or *"inverse"* when the current is blocked on the other half-cycle. The *inverse peak voltage* which the tube will stand safely is used as a rating for rectifier tubes. At higher voltages the tube is liable to arc back, thereby destroying it. The relations between peak inverse voltage, total transformer voltage and filter output voltage depend upon the characteristics of the filter and rectifier circuits (whether full- or half-wave, bridge, etc.).

Rectifier tubes are also rated in terms of *peak current load.* The actual direct load current which can be drawn from a given rectifier tube or tubes depends

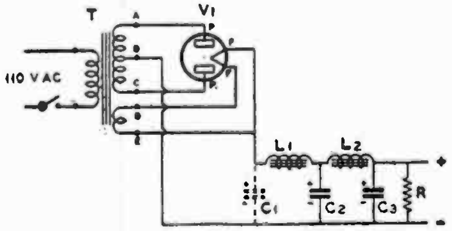


Figure 10.

WHEN C_1 IS CONNECTED IN THE CIRCUIT, THE FILTER IS TERMED "CONDENSER INPUT." IF C_1 IS OMITTED, THE FILTER IS CALLED "CHOKE INPUT."

upon the type of filter circuit. A full-wave rectifier with condenser input may be called upon to deliver a peak current several times the direct load current.

In a filter with choke input, the peak current is not much greater than the load current if the inductance of the choke is fairly high.

A full-wave rectifier with two rectifier elements requires a transformer which delivers twice as much a.c. voltage as would be the case with a half-wave rectifier or bridge rectifier. The bridge rectifier is another type of full-wave circuit in which four rectifier elements or tubes are operated from a single high-voltage winding on the power transformer.

While twice as much output voltage can be obtained from a bridge rectifier as from a center-tapped circuit, the permissible output current it only one-half as great for a given power transformer. In the bridge circuit, four rectifier and three filament heating transformer windings are needed, as against two rectifiers and one filament winding in the center-tapped full-wave circuit. In a bridge rectifier circuit, the inverse peak voltage impressed on any one rectifier tube is halved, which means that tubes of lower peak voltage rating can be used for a given voltage output.

The output voltage across the filter circuit depends upon the design of the filter, resistance of rectifier power transformer and load resistance. A low-resistance rectifier, such as the mercury-vapor type 83 or 866, has very low voltage drop in comparison with most *high-vacuum* (not mercury-filled) rectifiers. The filter circuit with *condenser input,* i.e., a condenser across the rectifier output, will deliver a higher d.c. voltage than one with *choke input,* but with a sacrifice both in voltage regulation and the amount of available load current.

The d.c. voltage across the load circuit of a condenser-input filter may be as high as 1.4 times the a.c. input voltage (r.m.s.) across one of the rectifier tubes if the input condenser capacity is large and the current drain small. Low values of load resistance (heavy current drain) will cause this type of power supply to have a d.c. voltage output as low or even lower than the a.c. input to the rectifier. The maximum permissible load current in this same circuit is less for a given transformer-secondary wire size and rectifier tube peak current rating than would be the case for a choke-input filter.

A choke-input filter will reduce the d.c. voltage to a value of 0.9 the a.c., r.m.s. value, but the output voltage with choke input is fairly constant over a wide range of load resistances, and the allowable load current is greater than with condenser input for a given rectifier tube and power transformer.

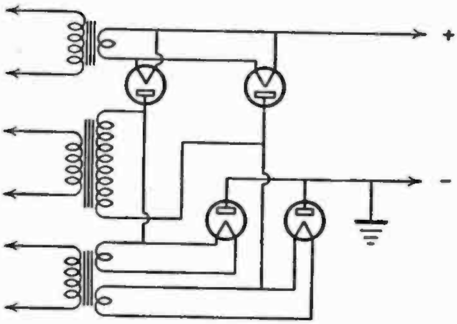


Figure 11.

BRIDGE RECTIFIER CIRCUIT.

Types of Chokes

A *filter choke coil* consists of a coil of wire wound on a laminated iron or steel core. The size of wire is determined by the amount of direct current which is to flow through the choke coil. This direct current magnetizes the core and reduces the inductance of the choke coil; therefore, filter choke coils of the "smoothing" type are built with an air gap, a small fraction of an inch in the iron core, for the purpose of preventing saturation when maximum d.c. flows through the coil winding. This "air gap" is usually in the form of a piece of fiber inserted between the ends of the laminations. The air gap reduces the initial inductance of the choke coil, but keeps it at a higher value under maximum load conditions. The coil must have a great many more turns for the same initial inductance when an air gap is used.

As explained earlier in this chapter, choke input tends to keep the output voltage of the filter at approximately 0.9 of the r.m.s. voltage impressed upon the filter from the rectifiers. However, this effect does not take place until the load current exceeds a certain minimum value. In other words, as the load current is decreased, at a certain critical point the output voltage begins to soar. This point is determined by the inductance of the input choke. If it has high inductance, the current can be reduced to a very low value before the output voltage begins to rise. Under these conditions, a low-drain bleeder resistor will keep the current in excess of the critical point and the voltage will not soar even if the external load is removed. For this purpose, chokes are made with little or no air gap in order to give them more inductance at low values of current. Their filtering effectiveness at maximum current is impaired somewhat, but it permits use of a smaller bleeder to keep the current in excess of the critical value. Such chokes are called *swinging chokes* because, while they have high initial inductance, the inductance rapidly falls to a comparatively low value as the current through the choke is increased.

The d.c. resistance of any filter choke should be as low as possible in conjunction with the desired value of inductance. Small filter chokes, such as those used in radio receivers, usually have an inductance of from 20 to 30 henrys, and a d.c. resistance of from 200 to 400 ohms. A high d.c. resistance will reduce the output voltage, due to the voltage drop across each choke coil. Filter choke coils for radio transmitters and class-B amplifiers usually have less than 100-ohms d.c. resistance.

Types of Filter Condensers

There are two types of filter condensers: (1) paper dielectric type, (2) electrolytic type.

Paper condensers consist of two strips of metal foil separated by several layers of waxed paper. Some types of paper condensers are wax-impregnated; others, especially the high-voltage types, are oil-impregnated. High voltage filter condensers which are oil-impregnated will withstand a greater peak voltage than those impregnated with wax, but they are more expensive to manufacture. Condensers are rated both for *flash* test and normal operating voltages; the latter is the important rating and is the maximum voltage which the condenser should be required to withstand in service.

The condenser across the rectifier circuit in a condenser-input filter should have a working voltage rating equal to at least 1.41 times the r.m.s. voltage output of the rectifier. The remaining condensers may be rated more nearly in accordance with the d.c. voltage.

Electrolytic condensers are of two types: (1) wet, (2) dry. The wet electrolytic condenser consists of two aluminum electrodes immersed in a solution called an *electrolyte*. A very thin film of oxide is formed on the surface of the metal; this acts as the dielectric. The electrolytic condenser must be correctly connected in the circuit because it has positive and negative electrodes, and a reversal of the polarity will ruin the condenser. The dry type of electrolytic condenser uses an electrolyte in the form of paste. The dielectric in both kinds of electrolytic condensers is not perfect; these condensers have a much higher direct current leakage than the paper type. The leakage current is greater in the wet electrolytic than in the dry types.

The high capacitance of electrolytic condensers results from the thinness of the film which is formed on the plates. The maximum voltage that can be safely impressed across the average electrolytic filter condenser is between 450 and 600 volts; the working voltage is usually rated at 450. When electrolytic condensers are used in filter circuits of high-voltage supplies, the condensers should be connected in series. The positive terminal of one condenser must connect to the negative terminal of the other, in the same manner as dry batteries are connected in series.

It is not necessary to connect shunt resistors across each electrolytic condenser section as it is with paper capacitors connected in series, because electrolytic capacitors have fairly low internal d.c. resistance as compared to paper condensers. Also, if there is any variation in resistance, it is that electrolytic unit in the poorest condition which will have the highest leakage current, and therefore the voltage across this condenser will be lower than that across one of the series connected units in better condition and having higher internal resistance. Thus we see that equalizing resistors are not only unnecessary across series connected electrolytic condensers but are actually undesirable. This assumes, of course, similar capacitors by the same manufacturer and of the same capacity and voltage rating. It is *not advisable* to connect in series electrolytic condensers of different make or ratings.

There is very little economy in using electrolytic condensers in series in circuits where more than two of these condensers would be required to prevent voltage breakdown.

Bleeder Resistors

A heavy-duty resistor should be connected across the output of a filter in order to draw some load current at all times. This resistor avoids soaring at no load when swinging choke input is used and also provides a means for discharging the filter condensers when no external vacuum-tube circuit load is connected to the filter. This *bleeder* resistor should normally draw approximately 10 per cent of the full load current. The power dissipated in the bleeder resistor can be calculated by dividing the square of the d.c. voltage by the resistance. This power is dissipated in the form of heat, and, if the resistor is not in a well-ventilated position, the wattage rating should be higher than the actual wattage being dissipated. High voltage, high capacity filter condensers can hold a dangerous charge if not bled off. Hence it is wise to place carbon resistors in series across the regular wire wound bleeder as explained in chapter 10 under *safety precautions.*

GLOW-DISCHARGE VOLTAGE REGULATORS

Two very useful tubes for stabilizing the voltage on receivers, electron coupled oscillators in exciters, frequency meters, and other devices requiring a constant source of voltage of between 100 and 300 volts are the VR-105-30 and VR-150-30 glow-discharge type voltage-regulator tubes. Both of these tubes are the same except that the VR-105 has a lower voltage drop (105 volts) than the VR-150 (150 volts). The remarks following apply generally to both, though the examples apply specifically to the VR-150. Both tubes have the same current rating.

The VR-105 is useful for stabilizing the voltage on the oscillator section of 6J8, 6K8 and similar mixer tubes, for use in the cathode of the feedback tube in a 2A3 type voltage regulated power supply, and many other applications. The VR-150 is suited where higher voltage is desirable.

Two VR type tubes may be connected in series to regulate 210 volts, 255 volts, or 300 volts when more than 150 volts are required.

A VR type tube may be used to stabilize the voltage across a variable load or the voltage across a constant load fed from a varying source of voltage. Thus can be seen their many possible applications and wide range of usefulness.

A device requiring, say, only 50 volts can be stabilized against *supply voltage* variations by means of a VR-105 simply by putting a suitable resistor in series with the regulated voltage and the load, dropping the voltage from 105 to 50 volts. However it should be borne in mind that under these conditions the device will *not* be regulated for *varying load;* in other words if the *load resistance* varies, the voltage across the load will vary, even though the regulated voltage remains at 105 volts. To maintain constant voltage across a *varying load resistance* there must be *no* series resistance between the regulator tube and the load. This means that the device must be operated exactly at one of the five voltages mentioned if regulation is to be obtained with not more than two VR tubes.

Operation

A VR-150 may be considered as a stubborn variable resistor having a range of from 30,000 to 5000 ohms and so intent upon maintaining a fixed voltage of 150 volts across its terminals that when connected across a voltage source having *very poor regulation* it will instantly vary its own resistance within the limits of 5000 and 30,000 ohms in an attempt to maintain the same 150 volt drop across its terminals when the supply voltage is varied. The theory upon which a VR tube operates is covered under the subject of gaseous conduction in the chapter on *Vacuum Tube Theory*, and will not be discussed here.

It is paradoxical that in order to do a good job of regulating, the regulator tube must be fed from a voltage source having poor regulation (high series resistance). The reason for this presently will become apparent.

If a high resistance is connected across the VR tube, it will not impair its ability to maintain a 150 volt drop. However, if the load is made too low, a variable 5000 to 30,000 ohm shunt resistance (the VR-150) will not exert sufficient effect upon the resulting resistance to provide constant voltage except over a *very limited* change in supply voltage or load resistance. The tube will supply maximum regulation, or regulate the largest load, when the source of supply voltage has high internal or high series resistance, because a variation in the effective internal resistance of the VR tube will then have more controlling effect upon the load shunted across it.

To provide greatest range of regulation, a VR tube (or two in series) should be used with a series resistor (to effect a poorly regulated voltage source) of such a value that it will permit the VR tube to draw from 15 to 20 ma. under normal or average conditions of supply voltage and load impedance. For maximum control range the series resistance should be not less than approximately 20,000 ohms, which will necessitate a source of voltage considerably in excess of 150 volts. However, where the supply voltage is limited, good control over a limited range can be obtained with as little as 3000 ohms series resistance. If it takes less than 3000 ohms series resistance to make the VR tube draw 15 to 20 ma. when the VR tube is connected to the load, then the supply voltage is not high enough for proper operation.

If the current through a VR-150 or VR-105 is allowed to exceed 30 ma., the life of the tube will be shortened. If the current falls below 5 ma., operation will become unstable. Therefore the tube must operate within this range, and within the two extremes will maintain the voltage within 1.5 per cent. It takes a voltage excess of at least 10 or 15 per cent to "start" a VR type regulator; and to insure positive starting each time, the voltage supply should preferably exceed the regulated output voltage rating by about 20 per cent or more. This usually is automatically taken care of by the fact that if sufficient series resistance for good regulation is employed, the voltage impressed across the VR tube before the VR tube ionizes and starts passing current is quite a bit higher than the starting voltage of the tube.

When a VR tube is used to regulate the voltage applied to a circuit drawing *less than 15 ma.* normal or average current, the simplest method of adjusting the series resistance is to remove the load and vary the series resistor until the VR tube draws exactly 30 ma. Then connect the load, and that is all there is to it. This method is particularly recommended when the load is a heater type vacuum tube, which may not draw cur-

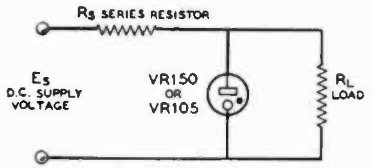


Figure 12.

STANDARD CIRCUIT FOR GLOW-DISCHARGE REGULATOR.
The regulator tube will maintain the voltage across its terminals constant to within 1 or 2 volts for moderate variations in R_L or E_B.

rent for several seconds after the power supply is turned on. Under these conditions the current through the VR tube will never greatly exceed 30 ma. even when it is running unloaded (while the heater tube is warming up and the power supply rectifier has already reached operating temperature).

Figure 12 illustrates the standard glow discharge regulator tube circuit. The tube will maintain the voltage across R_L constant to within 1 or 2 volts for moderate variations in R_L or E_S.

Voltage Regulated Power Supplies

When it is desired to stabilize the potential across a circuit drawing more than a few milliamperes, it is advisable to use a voltage regulated power supply of the type shown in figure 13 rather than glow discharge type tubes. The power pack illustrated will deliver up to 300 volts of well-regulated voltage, the output voltage holding within one volt for variations in line voltage or load resistance of 25 per cent. The maximum current that may be drawn from the supply without detrimentally affecting the regulation is determined by the desired output voltage, the latter being adjustable by variation of R_3. At 200 volts the output voltage is constant up to 100 ma., the maximum current which the 2A3 and power transformer will stand. At 300 volts, the maximum usable output voltage, the useful range is from 0 to 50 ma. At the latter voltage the regulator begins to lose control when more than 50 ma. is drawn from the supply.

The system works by virtue of the fact that the 2A3 acts as a variable series resistance or losser, and is controlled by a regulator tube much in the manner of a.v.c. circuits or inverse feedback as used in radio receivers and a.f. amplifiers. The 6SJ7 amplifier controls the bias on the 2A3, which in turn controls the resistance of the 2A3, which in turn controls the output voltage, which in turn controls the plate current of the 6SJ7, thus completing the cycle of regulation. It is readily apparent that under these conditions any change in the output voltage will tend to "resist itself," much as the a.v.c. system of a receiver resists any change in signal strength delivered to the detector.

Because it is necessary that there always be a moderate voltage drop through the 2A3 in order for it to have proper control, the rest of the power supply is designed to deliver as much output volt-

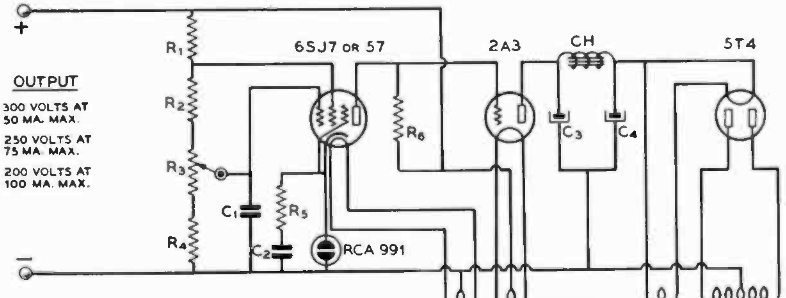


Figure 13.

VOLTAGE REGULATED POWER SUPPLY

R_1—10,000 ohms, 2 watts

R_2—25,000 ohms, 2 watts

R_3—15,000 ohm wire wound potentiometer of good quality (not midget type)

R_4—5000 ohms, 1 watt

R_5—50,000 ohms, 1 watt

R_6—250,000 ohms, 1 watt

C_1—.002-μfd. tubular

C_2—.01-μfd. tubular

C_3, C_4 — 16-μfd. electrolytics, 450 w.v.

CH—20 hy. 100 ma. choke, low d.c. resistance

T—325 v. each side c.t., 100 ma., and filament windings indicated.

age as possible considering the r.m.s. voltage of the b.c.l. type power transformer. This calls for a low resistance full-wave rectifier, a high capacity input condenser, and a low d.c. resistance filter choke. A 5Z4 rectifier is used in place of an 83 or other mercury vapor tube to avoid possible "hash" in any nearby receiver. This tube has lower resistance than an 80 or 5Z3.

The condenser C_1 is for the purpose of bypassing to ground any stray r.f. that might be picked up by the output voltage leads, as any r.f. reaching the grid of the 6SJ7 will have an adverse effect upon the regulation. The resistor R_5 and condenser C_2 are for the purpose of suppressing possible oscillation of the 991 neon regulator.

It should be noted that the power transformer must have either two 2.5 volts windings or else a 6.3 volt winding and a 2.5 volt winding in addition to the usual 5 volt rectifier winding. The winding that supplies the 6SJ7 or 57 may be used to supply filament current to other equipment, but the 2.5 volt 2A3 winding must not be used to supply other tubes.

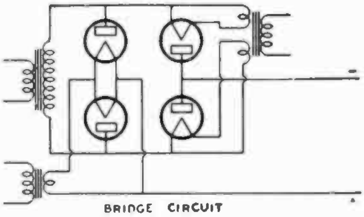
This type of supply is not suited for use as a bias pack. The presence of grid (reverse) current makes a different circuit necessary. Such a regulated bias pack is described under Class C Grid Modulation in *chapter 8*.

RECTIFIER CIRCUITS

The three types of rectifier circuits for single-phase a.c. line supply consist of a half-wave rectifier, as shown in figure 14, a full-wave rectifier as shown in figure 15 and a bridge rectifier circuit as shown in figure 16.

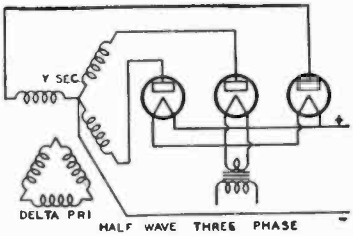
Three-phase circuits can be connected for half-wave rectification, as shown in figure 17, or for full-wave rectification as shown in figure 18.

The most popular circuits are those shown in figures 15 and 16. The maximum transformer voltage of the high-voltage secondary, d.c. output voltage for choke-input filter, and maximum direct load current are shown in the ac-



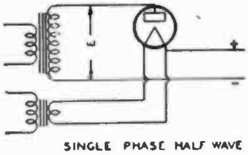
BRIDGE CIRCUIT

FIGURE 16.



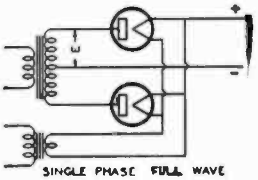
HALF WAVE THREE PHASE

FIGURE 17.



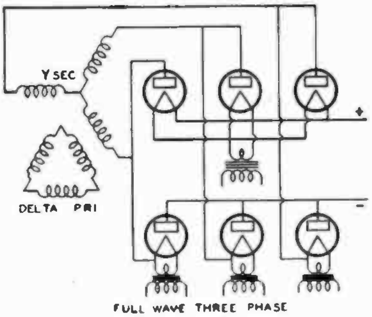
SINGLE PHASE HALF WAVE

FIGURE 14.



SINGLE PHASE FULL WAVE

FIGURE 15.



FULL WAVE THREE PHASE

FIGURE 18.

FIGURE NO.	TRANSFORMER VOLTS MAX. "E"	D.C. OUTPUT VOLTS AT INPUT TO FILTER	D.C. OUTPUT CURRENT IN AMPERES
15	.35 x Inv. Pk. Vtg.	.9 x E	.66 x Pk. Plate
16	.7 x Inv. Pk. Vtg.	.9 x E	.66 x Pk. Plate
17	.43 x Inv. Pk. Vtg.	1.12 x E	.83 x Pk. Plate
18	.43 x Inv. Pk. Vtg.	2.25 x E	1.0 x Pk. Plate

TUBE TYPE	PEAK INV. VOLTS	PEAK PLATE CURRENT (AMP.)
66 Jr.	2,500	.4
82	1,400	.20 } per
83	1,400	.40 } sect.
66	7,500	1.0
66A	10,000	1.0
249-B	10,000	2.5
72	7,500	5.0
72A	10,000	5.0
869	20,000	5.0
KY-21	11,000	3.0 grid
KY-21	11,000	controlled

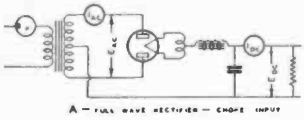


FIGURE 19.

E_{DC}-435 v.
I_{DC}-100 ma.
E_{AC}-1100 v.
I_{AC}-71 ma.
I_{PRI}-.6 a.

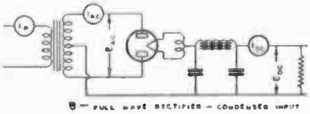


FIGURE 20.

E_{DC}-675 v.
I_{DC}-100 ma.
E_{AC}-1100 v.
I_{AC}-103 ma.
I_{PRI}-.9 a.

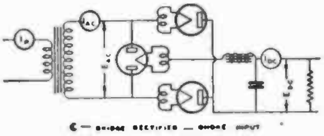


FIGURE 21.

E_{DC}-860 v.
I_{DC}-100 ma.
E_{AC}-1100 v.
I_{AC}-96 ma.
I_{PRI}-1.1 a.

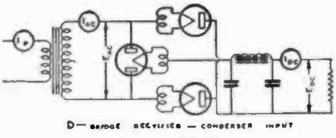


FIGURE 22.

E_{DC}-1200 v.
I_{DC}-100 ma.
E_{AC}-1100 v.
I_{AC}-148 ma.
I_{PRI}-1.65 a.

Typical voltage and current readings in various types of power supplies.

companying table in terms of rectifier tube peak ratings. These peak ratings are listed in a separate table for a few commonly used rectifier tubes.

An example for applying the figures in the table, if type 866-A rectifier tubes are used as in figure 15, is given here: The maximum transformer voltage E across each side of the center tap is 0.35 times 10,000 or 3,500 volts. The d.c. voltage at the input to the filter (choke input) is 3,500 times 0.9 or 3,150 volts. The maximum advisable d.c. output current is 0.66 times the peak plate current of 1.0 ampere or 660 millamperes.

These are the maximum voltages and curents which can be used without exceeding the ratings of the rectifier tubes. The actual d.c. voltage at the output of the filter will depend upon the d.c. resistance of the filter, and can be found by subtracting the IR drop across the filter chokes from the value of 0.9 times the transformer voltage E. This does not take into consideration the voltage drop in the power transformer and rectifier tubes. The voltage drop across a mercury vapor rectifier tube is always between 10 and 15 volts. However, the voltage drop across high-vacuum rectifier tubes can be many times greater.

The power supply circuits illustrated in figures 19 to 22 represent commonly-used connections for power transformers. The values of d.c. output voltage are indicated in each case for a load current of 100 ma. The transformer secondary potential is 1,100 volts. The interesting figures in connection with each circuit are those of the primary winding current.

The circuit in figure 22 should never be used unless the load current is very low. Manufacturers generally rate their transformers in terms of secondary r.m.s.

voltage and the maximum d.c. load current which can be taken *from a choke input filter* circuit such as shown in figure 19. In order to prevent overload of the power transformer, the load current must be reduced to less than one third of the value which can be drawn from the circuit in figure 19. The load which can be drawn from the circuit in figure 21 without overload to the power transformer is approximately 50 per cent of that for the circuit in figure 19. The permissible direct load current in figure 20 would only be two-thirds as much as for figure 19, for a given transformer size.

Mercury Vapor Rectifier Tubes

When new or long-unused high-voltage mercury-vapor rectifier tubes are first placed in service, the filaments should be operated at normal temperature for approximately 20 minutes before plate voltage is applied, in order to remove all traces of mercury from the cathode. After this preliminary operation, plate voltage can be applied within 20 to 30 seconds of the time the filaments are turned on each time the power supply is again used. If plate voltage is applied before the filament is brought to full temperature, active material may be knocked off the oxide-coated filament and the life of the tube will be greatly shortened.

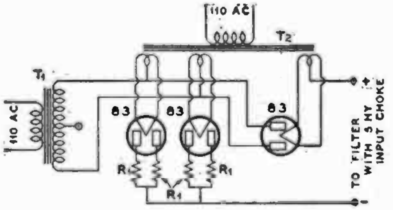


Figure 23.
Bridge rectifier suitable for 1000-volt supply. Equalizing resistors are 100 ohms each, 10 w.

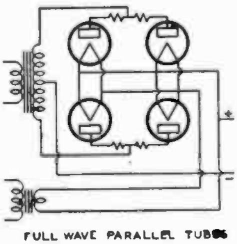


FIGURE 24.

Small r.f. chokes must sometimes be connected in series with the plate leads of mercury vapor rectifier tubes in order to prevent the generation of radio-frequency hash. These r.f. chokes must have sufficiently heavy wire to carry the load current and enough inductance to attenuate the r.f. parasitic noise current from flowing into the filter supply leads and thereby radiating into nearby radio receivers.

Small resistors or small iron-core choke coils should be connected in series with each plate lead of a mercury-vapor rectifier tube when used in circuits such as those shown in figures 23 and 24.

These resistors tend to prevent one plate from carrying the major portion of the current. *High-vacuum* type rectifiers which are connected in parallel do not require these resistors or chokes.

BIAS VOLTAGE POWER SUPPLIES

Power supplies to supply negative grid voltage for radio or audio amplifiers differ from plate supplies only in that the positive and negative connections are reversed; the positive terminal of a C-bias supply is connected to ground. The filter chokes are usually connected in series with the hot (ungrounded) lead, which in this case is the *negative lead*. A simple C-bias power supply for negative grid bias for a class-A audio amplifier is shown in figure 25.

The value of C bias depends upon the secondary voltage of the transformer and whether condenser or choke input to the filter is used.

The bias voltage supply for a linear r.f. amplifier or class-B audio amplifier must have a very low resistance bleeder. The bleeder should be chosen so that the normal bleeder current is at least 8 times the *peak* grid current of the class B modulator or linear r.f. amplifier. If this

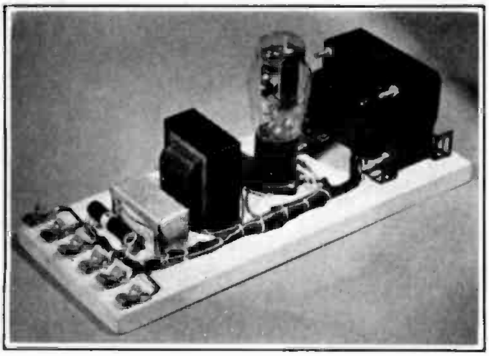


Figure 25.
TYPICAL 300-350 VOLT POWER SUPPLY.

This type of power pack ordinarily utilizes a power transformer having from 325 to 350 volts each side of c.t. with integral filament windings, and a brute force or pi type filter consisting of a single choke and dual 8 μfd. electrolytic condenser. The rectifier is usually an 80 or 5Z3. Such packs commonly deliver from 50 to 150 ma. depending upon the ratings of the transformer and choke, and are most commonly used with receivers, a.f. amplifiers and drivers, and low power exciter stages. They are also used as bias packs, in which case a very low resistance bleeder is used, adjustable taps being provided so that the bleeder can be used as a voltage divider.

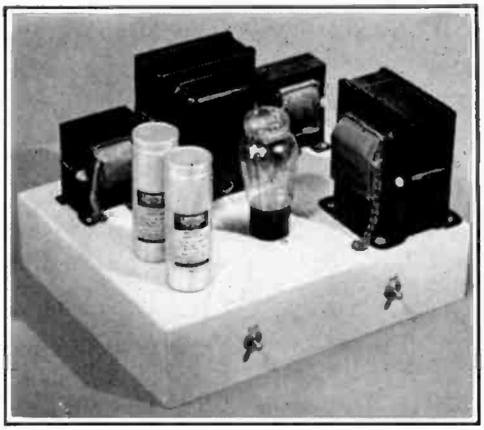


Figure 26.
TYPICAL 500-550 VOLT POWER SUPPLY.

Power supplies such as this are commonly used to feed low power r.f. stages, modulators, etc. The power transformer is generally rated at from 600 to 700 volts each side of c.t. at from 150 to 250 ma. and has no filament windings. An 83 or 5Z3 with swinging choke input filter having 600 volt oil filled paper condensers are ordinarily used. Round can condensers of this type are usually less expensive than equivalent ones in square cans.

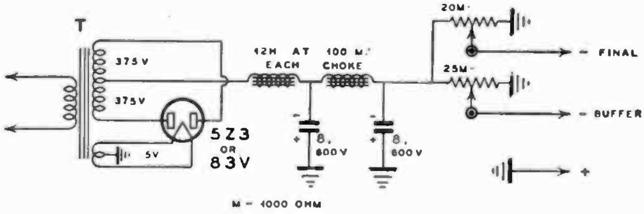
condition is not met, the bias pack will act somewhat as a grid leak and the bias on the tubes will rise excessively under modulation. High μ tubes require so little bias and draw so much grid current for class B operation (either r.f. or a.f.) that battery bias is ordinarily employed. It is inadvisable to use a bias pack for this purpose unless the required bias voltage is more than 90 volts.

When a pack having a tapped bleeder is used for this type of service, the tap on the bleeder should be by-passed for voice frequencies even though the pack already has a large filter condenser across the outside terminals of the bleeder.

High efficiency grid modulation also requires a low resistance source of bias, though the bias voltage required is usually several times as great as for a class B stage using tubes of similar power. For this reason bias for this type of amplifier is more commonly obtained from a regulated bias pack rather than from a conventional pack utilizing a very low resistance bleeder in order to comply with the requirement of low resistance in the bias supply. Such a regulated bias pack is described in *chapter 8* under High Efficiency Grid Modulation.

Bias Pack Considerations

It should be borne in mind that when a power supply is used "inverted" in order to provide bias to a stage drawing grid current, the grid current flows in the *same direction as the bleeder current.* This means that the grid current does not flow through the power pack as when a pack is used to supply plate voltage, but rather through the bleeder. The transformer and chokes in the bias pack actually have less work to do when the biased stage is drawing grid current, because the greater the grid current flowing through the bleeder the greater the voltage drop across it and the less current



ADJUST BIAS FOR ZERO PLATE CURRENT WHEN TUBE IS NOT BEING EXCITED

Figure 27.

BIAS PACK FOR C.W. OR PLATE MODULATED TRANSMITTER.

This pack will deliver up to 250 volts of protective bias to the various stages of a high power phone or c.w. transmitter. A large safety factor in the filter condensers is provided to permit using the full output of the pack for bias as would be the case with crystal keying of high power using medium μ tubes and running heavy grid current. The voltage dividers should be of at least 100 watt rating in order to handle safely the grid current of a high powered transmitter. The power transformer should be of about 75 ma. rating. This type of bias pack does not have good regulation, and should not be used with class B linear or class B audio stages; such applications require a very low resistance bleeder.

the bias pack supplies to the bleeder. In fact, if the grid current is great enough and the bleeder resistor high enough, the voltage developed across the bleeder will be greater than the maximum voltage which the power pack can deliver, and hence the power pack will be delivering no current to the bleeder. Under these conditions it is quite possible for the voltage to exceed the voltage rating of the bias pack filter condensers. Bear in mind that the bleeder always acts as a grid leak when grid current is flowing, and while the effect can be minimized by making the resistance quite low, all grid current *must flow through the bleeder*, as it cannot flow back through the bias pack.

Class C amplifiers, both c.w. and plate modulated, require high grid current and considerably more than cutoff bias, the bias sometimes being as high as 4 or 5 times cutoff. To protect the tubes against excitation failure, it is desirable that fixed bias sufficient to limit the plate current to a safe value be used. This is normally the amount of bias that would be used on the same tubes at the same plate voltage in a class B modulator. It is best practice to obtain only this amount of bias from a bias pack, the additional required amount being obtained from a variable grid leak which is adjusted for correct bias and grid current while the stage is running under normal conditions. This condition is such that the voltage divider tap on the bias pack will be delivering only a portion of the full bias pack voltage when the biased stage is inoperative. Then, when grid current flows to the biased stage, there is no danger of the voltage across the filter condensers in the bias pack rising to dangerously high values.

A bias power supply for providing "protective bias" to the r.f. stages of a medium-power radio transmitter is shown in figure 27.

Two bleeder resistors with slider adjustments provide any desired value of negative grid bias for the r.f. amplifiers. The location of the slider on the resistors should be determined experimentally with the amplifier in operation, since the direct grid current of the r.f. amplifier itself will affect the voltage across the bias supply taps. If the final r.f. amplifier or buffer-amplifier operates with high-μ tubes, the values of bleeder resistance shown in figure 27 may have to be reduced as much as 50 per cent. The total resistance in series with the grid to ground acts as a grid leak resistance. The circuit illustrated is practically free from reaction between buffer and final amplifier bias.

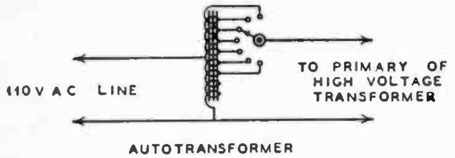


Figure 28.

AUTOTRANSFORMER VOLTAGE CONTROL.

TRANSMITTER POWER INPUT CONTROL

In the interests of interference reduction, one should run only sufficient power input to a radio transmitter to maintain satisfactory communication. The power input to the final r.f. amplifier of a c.w. transmitter can be controlled over a very wide range by means of an *autotransformer,* connected as shown in figure 28.

The a.c. voltage can be varied from a few volts up to 130 volts, by means of a relatively small autotransformer. This a.c. voltage should be applied only to the high-voltage power transformer which supplies plate power to the final r.f. amplifier.

Convenient adjustment of input to a phone transmitter other than of the plate modulated type is a more difficult problem. Input to a plate-modulated transmitter can be varied the same as for a c.w. transmitter without danger of overmodulating the reduced input if the primary voltage for the plate transformer that feeds the modulators is fed from the same tap on the autotransformer as the plate transformer for the final amplifier. If one power supply is used for both, the problem is further simplified.

Reducing the power of a grid-modulated final amplifier is more of a problem. The best method for reducing power is to reduce the r.f. excitation *and* audio gain together, wthout disturbing the bias or plate voltage or antenna coupling adjustment.

Those using linear r.f. amplifiers can either incorporate a switching arrangement for throwing the antenna over to the low-level modulated stage and thus reduce power about 10 db, or else merely reduce excitation to the linear amplifier *without* disturbing the a.f. gain control.

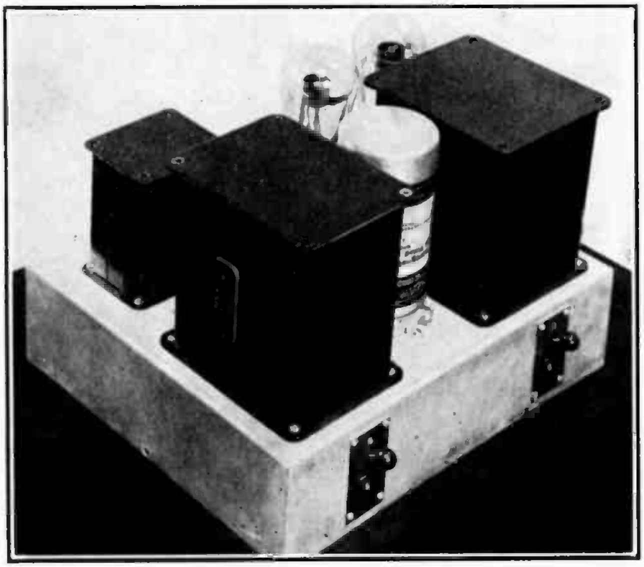


Figure 29.

This power supply was designed for supplying 850 volts with good regulation to a class B modulator using 809's, TZ20's, TZ40's, HK24's, etc. The transformer delivers 1000 volts r.m.s. each side of c.t. and both transformer and swinging choke are rated at 300 ma. 866Jr. rectifiers and a 4 µfd., 1000 volt, filter condenser complete the power pack. The single section filter is sufficient for push-pull a.f. work (such as a class B modulator) but is not recommended for supplying a modulated r.f. stage. For such service a smoothing choke and another 4µfd. condenser should be added.

TRANSFORMER DESIGN

A common problem in radio and allied work is to determine how a transformer can be built to supply certain power requirements for a particular application, or how to calculate the windings needed to fit a certain transformer core which is already on hand. These problems can be solved by a small amount of calculation.

The most important factor in determining the size of any transformer is the amount of core material available. The electrical rating, as well as the physical size, is determined almost entirely by the size of the core. The core material is also important. The present practice is to use high-grade silicon-steel sheet. It will be assumed that this type of material is to be employed in all construction herein described. Soft sheet-iron or stovepipe iron is sometimes substituted, but transformers made from such materials will have about 50 to 60 per cent of the power rating, pound for pound of core, as those made from silicon-steel.

The core size determines the performance of a transformer because the entire energy circulating in the transformer (except small amounts of energy dissipated in resistance losses in the primary) must be transformed from electrical energy in the primary winding to magnetic energy in the core, and reconverted into electrical energy in the secondary. The amount of core material determines quite definitely the power that any transformer will handle.

Transformer cores are often designed so that if the losses per cubic inch of core material are determined, these losses can be used as a basis for calculating the rating of the transformer. These losses exist in watts, and are divided between the eddy current loss and the hysteresis loss. The eddy current loss is the loss due to the lines of force moving across the core, just as if it were a conductor, and setting up currents in it. Induced currents of this type are very undesirable and they are merely wasted in heating the core, which then tends to heat the windings, increase the resistance of the coils and reduce the overall power handling ability of the transformer. To reduce such losses, transformer cores are made of thin sheets, usually about no. 29 gauge. These

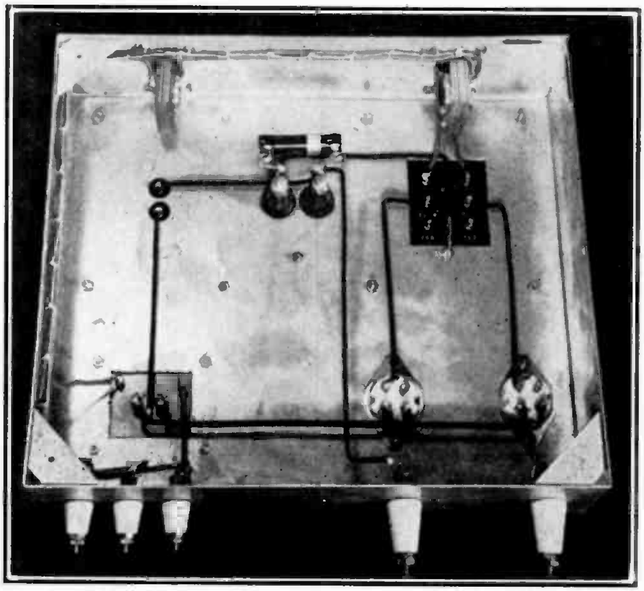


Figure 30.
This bottom view of the power supply shown in figure 29 illustrates the method of mounting the various components in an inverted position, thus keeping all wiring below the chassis. Note that ceramic sockets are used for the 866Jr's; ordinary wafer sockets do not have sufficient insulation for the high voltage applied to the rectifiers. Three 110 volt terminals are provided, the extra one to allow external switching of the plate transformer without disturbing the filaments of the rectifiers.

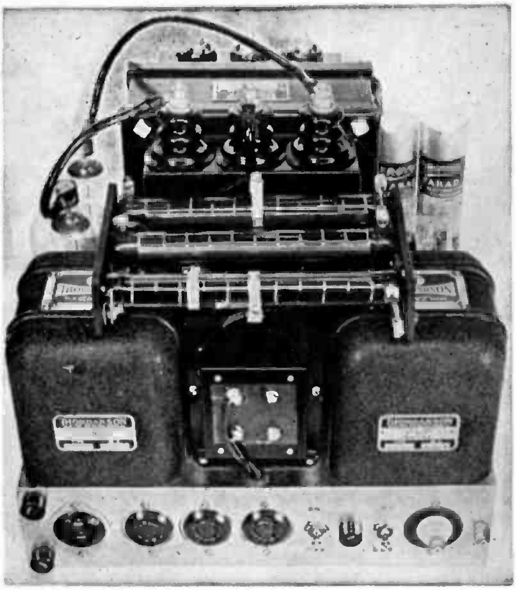


Figure 31.

This dual power supply illustrates what can be crowded on a chassis when space is at a premium. Note how the heavy bleeders, which also act as voltage dividers, are mounted so as to provide free circulation of air. A pair of 866's serve as rectifier in a conventional circuit for the high-voltage supply; an 83 rectifier is used in the low-voltage supply.

sheets are insulated from each other by a coat of thin varnish, shellac or japan, or by the iron-oxide scale which forms on the sheets during the manufacturing process and which forms a good insulator between sheets.

"Hysteresis" means "to lag," and hysteresis in an iron-core means that the magnetic flux in the core lags behind the magnetizing force that produces it, which is, of course, the primary supply. Because all transformers operate on alternating current, the core is subjected to continuous magnetizing and demagnetizing force, due to the alternating effect of the a.c. field. This force heats the iron, due to molecular friction caused by the iron molecules re-orienting themselves as the direction of the magnetizing flux changes.

The higher the field strength, the greater the heat produced. A condition can be reached where a further increase in magnetizing flux does not produce a corresponding increase in the flux density. This is called "saturation" and is a condition which would cause considerable heat in a core. In practice, it has been found that all core material must be operated with the magnetic flux well below the limit of saturation.

Core losses manifest themselves as heat and these losses are the determining factor in transformer rating. They are spoken of as "total core loss," generally used as a single figure, and for common use a core loss of from .75 watt to 2.5 watts per pound of core material can be assumed for 60 cycles. The lower figure is for the better grades of thin sheet, while the higher loss is for heavier grades.

About 1 watt per pound is a very satisfactory rating for common grades of material. This rating is also dependent on the manner in which the transformer is built and mounted and in the ease with which the heat is radiated from the core. Transformers with higher losses may be used for intermittent service.

The transformer core loss can be assumed to be from 5 to 10 per cent of the total rating for small transformers. Thus, if the core loss is known, the rating of the transformer can be easily determined. If the figure of 1 watt per pound is assumed, the problem is further simplified. To determine the rating of the transformer, weigh the core. If, for example, the core weighs 10 pounds, the transformer will handle from 100 to 200 watts. Such a transformer core can be assumed to have about 150 watts nominal rating.

If the weighing of the core is inconvenient, the weight can be calculated from the cubic content or volume. Sheet-steel core laminations weigh approximately one-fourth pound per cubic inch.

Transformer cores are generally made of two types, shell and core. The shell-type has a center leg which accommodates the windings, and this is twice the cross-sectional areas of the side legs. The core-type is made from strips built-up into a hollow-like affair of uniform

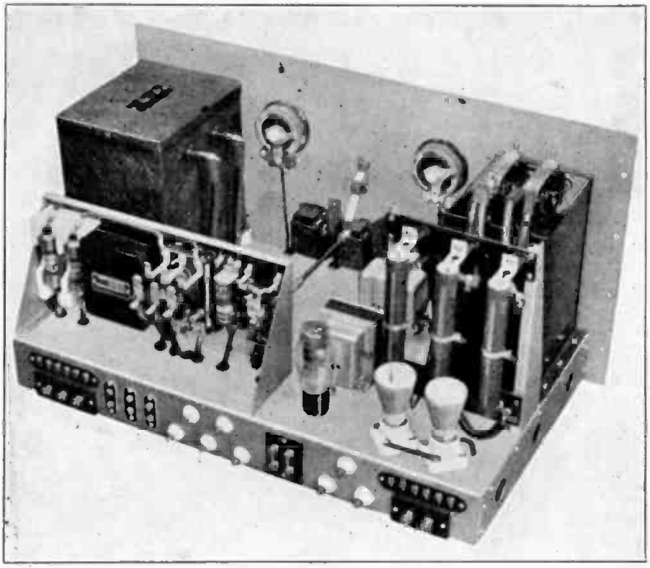


Figure 32.
Relays for push-to-talk or break-in c.w. operation can be mounted on the power supply chassis, the logical place for them, as illustrated here in this combined high-voltage and low-voltage power supply.

cross section. For the shell-type core, the area is taken as the square section of the center leg, in this case 2¼"x4½" and in the core-type, this area is taken as the section of 1 leg, and is also 2¼"x 4½", or an actual core area in both cases of 10.1 square inches, which is large enough for a comparatively large transformer.

To determine the number of turns for a given voltage, apply the following formula:

$$E = \frac{4.44\ N\ B\ A\ T}{10^8}$$

Where E equals the volts of the circuit; N, the cycles of the circuit; B, the number of magnetic lines per square inch of the magnetic circuit; A, the number of square inches of the magnetic circuit, and T, the number of turns.

The proper value for B, for small transformers and for ordinary grades of sheet-iron, such as are now being considered, is 75,000 for 25 cycles and 50,000 for 50 or 60 cycles.

Rewriting the above formula

$$T = \frac{E \times 10^8}{4.44\ N\ B\ A}$$

and since N and B are known

$$T = \frac{10^8}{4.44 \times 60 \times 50{,}000} \times \frac{E}{A}$$

from which

$$T = 7.5 \times \frac{E}{A}$$

That is, for a transformer to be used on a 60-cycle circuit, the proper number of turns for the primary coil is obtained by multiplying the line voltage by 7.5 and dividing this product by the number of square inches cross section of the magnetic circuit.

On a 25-cycle circuit, the 7.5 becomes 12, and on 50 cycles it becomes 9.

Tentative Design

Assume a transformer core that is to be used on a 115-volt, 60-cycle circuit for supplying power to two rectifier tubes, each of which takes 1,000 volts on the plate. The rectifier is of the full-wave type. The core measures 2½ inches x 4½ inches; hence,

$$T = \frac{7.5 \times 115}{2.25 \times 4.5} = 85$$ (to the nearest turn), and the volts per turn equals

Transformer Design Chart.

						SECONDARY WINDINGS (Turns for Voltages Given)																	
											HIGH-VOLTAGE WINDING												
WATTS	Section of Core (inches)	Area of Core (Square Inches)	Primary Turns	Primary Wire	Size Turns per Volt	2.5 volts	5.0 volts	6.3 volts	7.5 volts	10 volts	250 volts	300 volts	350 volts	400 volts	450 volts	500 volts	600 volts	700 volts	800 volts	900 volts	1000 volts	1250 volts	1500 volts
10	½ x ½	.25	3500	31	32	80	160	205	240	320													
10	½ x ⅝	.31	2800	31	24.2	61	122	147	182	242													
12	½ x ¾	.37	2300	30	20.0	50	100	126	150	200													
12	⅝ x ⅝	.38	2280	30	19.6	48	96	124	147	196													
15	⅝ x ¾	.46	1875	29	16.1	42	84	105	124	161													
22	⅝ x 1	.62	1400	28	12.2	31	61	77	92	122													
20	¾ x ¾	.55	1570	28	13.6	34	68	86	102	136													
25	¾ x 1	.75	1150	27	10.0	25	50	63	75	100	2620	3150	3700	4200	4750	5250							
30	¾ x 1¼	.93	930	26	8.1	21	42	52	62	81	2100	1500	3140	3400	3800	4200							
50	¾ x 1½	1.12	770	24	6.7	17	34	43	50	67	1860	2100	2500	2840	3150	3500	4200	5000					
50	1 x 1	1.0	860	24	7.5	19	38	48	57	75	1950	2400	2700	3150	3600	3900	4700	5500					
60	1 x 1¼	1.25	690	23	6.0	15	30	38	45	60	1600	1900	2200	2500	2800	3150	3800	4400					
65	1 x 1½	1.50	575	23	5.0	13	25	32	38	50	1300	1575	1850	2100	2400	2650	3150	3700					
75	1 x 1¾	1.75	490	22	4.2	11	21	27	31	42	1100	1320	1550	1750	2000	2200	2650	3150	3800	4000	4400		
110	1 x 2	2.0	430	21	3.7	9	18	23	28	37	980	1170	1370	1550	1750	1960	2300	2750	3100	3500	3900		
105	1¼ x 1¼	1.56	550	21	4.8	12	24	31	36	48	1260	1510	1770	2050	2240	2510	3050	3500	4100	4500	5020		
100	1¼ x 1½	1.87	460	21	3.8	9	19	25	29	38	1000	1200	1400	1600	1800	2000	2400	2720	3200	3560	4000		
120	1¼ x 1¾	2.18	400	20	3.5	9	18	21	26	35	920	1100	1315	1470	1650	1840	2200	2560	2940	3300	3700	4620	5500
140	1¼ x 2	2.5	350	19	3.2	8	16	20	24	32	840	1020	1180	1340	1510	1680	2050	2350	2680	3000	3380	4200	5050
125	1½ x 1½	2.25	380	20	3.3	8	16	21	25	33	870	1040	1210	1400	1560	1730	2100	2420	2800	3120	3500	4400	5250
150	1½ x 1¾	2.64	330	18	2.9	7	14	19	22	29	760	910	1130	1220	1360	1530	1840	2100	2450	2750	3050	3800	4650
200	1½ x 2	3.0	290	17	2.42	6	12	15	18	24	630	765	890	1020	1150	1265	1522	1780	2050	2380	2350	3200	3840
300	2 x 2	4.0	215	15	1.87	5	9	12	14	19	490	590	690	780	880	980	1180	1360	1570	1760	1960	2350	2940
400	2 x 2½	5.0	175	14	1.52	4	8	10	12	15	395	470	550	640	710	790	950	1110	1265	1420	1590	1980	2400
500	2 x 3	6.0	145	13	1.26	3	6	8	9	12	330	395	455	530	595	660	790	920	1060	1200	1330	1650	2000

Copper Wire Table.

Gauge No. B&S	CROSS SECTIONAL AREA			TURNS PER LINEAR INCH							TURNS PER SQUARE INCH							FT. PER POUND			RES PER 1000 FT.	CARRYING CAPACITY Copper	
	Dia. in Mils	Cir. Mils	Sq. Inches	DCC.	SCC.	DSC.	SSC.	Enam.	Enam. and SCC.	Enam. and SSC.	DCC.	SCC.	DSC.	SSC.	Enam.	Enam. and SCC.	Enam. and SSC.	DCC	SCC.	Bare	Copper	1000 CM Per Amp.	1500 CM Per Amp.
0000	460.0	211600	.1662																	1.561	.0499	211.6	140.7
000	409.6	167800	.1318																	1.968	.0629	167.8	111.3
00	364.8	133100	.1045																	2.482	.0793	133.1	88.9
0	324.9	105500	.08289																	3.130	.1000	105.5	70.3
1	289.3	83690	.06573																	3.947	.1260	83.7	55.7
2	257.6	66370	.05213																	4.977	.1592	66.4	44.1
3	229.4	52640	.04134																	6.276	.2004	52.6	35.0
4	204.3	51740	.03278																	7.914	.2334	41.7	27.7
5	181.9	33100	.02600																	9.986	.3192	33.1	22.0
6	162.0	26250	.02062	5.44	5.60															12.58	.4028	26.3	17.5
7	144.3	70820	.01635	6.08	6.23															15.87	.5080	20.8	13.8
8	128.5	16510	.01297	6.80	6.94													19.6	19.9	20.01	.6405	16.5	11.0
9	114.4	13090	.01028	7.64	7.68													24.6	25.1	25.23	.8077	13.1	8.7
10	101.9	10380	.008155	8.51	8.55													20.9	31.6	31.82	1.018	10.4	6.9
11	90.74	8234	.006467	9.58	9.60													38.9	39.6	40.12	1.284	8.2	5.5
12	80.81	6520	.005129	10.62	10.80	11.8	12.1	12.1	11.4	11.8	121	136	139	146	146	130	139	48.9	50.2	50.59	1.619	6.5	4.4
13	71.96	5170	.004067	11.88	12.06	13.2	13.5	13.5	12.8	13.2	153	171	173	103	183	162	173	61.5	63.2	63.80	2.042	5.2	3.5
14	64.09	4107	.003225	13.10	13.45	14.7	15.1	15.2	14.2	14.7	187	213	216	229	239	201	216	77.3	70.6	80.44	2.575	4.1	2.7
15	57.07	3257	.002558	14.60	14.00	16.4	16.9	17.0	15.8	16.5	229	264	268	287	290	250	271	97.3	100	101.4	3.247	3.3	2.2
16	50.82	2583	.002028	16.40	17.20	18.2	18.9	18.7	17.6	18.4	280	327	333	358	350	309	338	119	126	127.9	4.094	2.6	1.7
17	45.26	2049	.001609	18.10	18.80	20.3	21.2	21.4	19.5	20.5	340	404	412	448	458	381	421	150	155	161.3	5.163	2.0	1.3
18	40.30	1624	.001276	20.00	21.00	22.6	23.6	24.0	21.7	22.9	412	498	510	559	575	469	524	188	196	203.4	6.510	1.6	1.1
19	35.89	1288	.001012	21.83	23.60	25.4	26.8	27.2	24.2	25.8	508	629	644	715	739	587	665	237	247	256.5	8.210	1.3	.86
20	31.96	1022	.0008023	23.91	26.40	27.0	29.5	30.1	26.5	28.4	596	752	773	867	904	701	805	298	311	323.4	10.35	1.0	.68
21	28.46	810.1	.0006363	26.20	29.70	30.8	32.8	33.6	29.6	31.5	752	949	949	1078	1129	878	991	370	389	407.8	13.05	.81	.54
22	25.35	642.4	.0005046	20.58	32.00	34.1	36.6	37.7	32.7	35.0	899	1161	1161	1337	1419	1071	1727	661	491	514.8	16.46	.64	.43
22	22.57	509.5	.0004002	31.12	34.30	37.6	40.7	42.3	30.1	39.6	1070	1416	1416	1656	1785	1306	1518	564	624	648.4	20.76	.51	.34
24	20.10	401.0	.0003173	33.60	37.70	41.5	45.3	47.2	39.7	43.1	1266	1722	1722	2048	2225	1575	1858	745	778	017.7	26.17	.41	.27
25	17.90	320.4	.0002517	36.20	41.50	45.7	50.3	52.9	43.7	47.9	1491	2085	2085	2525	2800	1907	2250	903	958	1031	33.00	.32	.21
26	15.94	254.1	.0001996	39.90	45.30	50.2	55.7	59.0	47.8	52.8	1745	2515	2515	3164	3484	2281	2788	1118	1188	1300	41.62	.25	.17
27	14.20	201.5	.0001583	42.60	49.40	53.0	61.7	65.8	52.1	58.1	2029	3019	3019	3811	4329	2713	3381	1422	1533	1639	52.48	.20	.13
28	12.64	159.8	.0001255	45.50	54.60	60.1	68.3	73.9	57.0	64.4	2317	3611	3611	4666	5456	3250	4141	1759	1903	2067	66.17	.16	.11
29	11.26	126.7	.00009953	48.00	58.80	65.3	75.4	82.2	61.9	70.8	2896	4294	4294	5688	6761	3530	4968	2207	2461	2607	83.44	.13	.084
30	10.03	100.5	.00007894	51.10	64.40	71.3	83.1	92.3	67.4	77.9	3076	5081	5081	6911	8527	4347	6075	2534	2893	3287	105.20	.10	.067
31	8.928	79.70	.00006260	56.80	69.00	77.3	91.6	103.0	72.8	85.3	3449	5981	5981	8389	10580	5305	7287	2768	3483	4145	132.70	.079	.053
32	7.950	63.21	.00004964	60.20	73.00	83.7	101.0	116.0	79.1	93.9	3931	7003	7003	10101	13363	6250	8818	3137	4414	5227	167.30	.063	.042
33	7.080	50.13	.00003937	64.30	81.00	90.3	110.0	130.0	85.6	103.0	4398	8163	8163	12130	16952	7336	10672	4697	5688	6591	211.00	.050	.033
34	6.305	39.75	.00003122	68.00	87.60	97.0	120.0	145.0	91.7	112.0	4883	9487	9487	14499	20967	8403	12619	6168	6400	8310	266.00	.039	.026
35	5.615	31.52	.00002476	71.00	94.20	104.0	131.0	164.0	98.8	123.0	5391	10817	10817	17247	26845	9766	15186	6737	8393	10480	335.00	.032	.021
36	5.000	25.00	.00001964	78.50	101.00	111.0	143.0	182.0	105.0	133.0	5917	12346	12346	20480	33051	11080	17777	7877	9846	13210	423.00	.025	.017
37	4.453	19.83	.00001557	84.00	108.00	118.0	155.0	206.0	111.0	146.0	6412	13996	13996	24015	40766	12758	21293	9309	11636	16660	533.40	.020	.013
38	3.965	15.72	.00001235	89.30	115.00	126.0	168.0	233.0	120.0	157.0	6970	15763	15763	28186	54890	14291	24685	10666	13848	21010	672.60	.016	.010
39	3.531	12.47	.000009793	95.00	122.50	133.0	181.0	261.0	128.0	172.0	7524	17639	17639	32690	68120	16288	29412	11907	18286	26500	848.10	.012	.008
40	3.134	9.888	.000007766	102.50	136.00	140.0	194.0	290.0	134.0	184.0	8045	19559	19559	37779	84248	18061	43727	14222	24381	33410	1069.00	.009	.006
41	2.800	7.842	.000006160	112.00	153.00													17920	30610	42130	1323.00	.008	.005
42	2.494	6.220	.000004885	124.00	168.00													22600	38700	53100	1667.00	.006	.004
43	2.221	4.932	.000003873	140.00	192.00													28410	48600	66970	2105.00	.005	.003
44	1.978	3.910	.000003073	153.00	210.00													35950	61400	84460	2655.00	.004	.0025

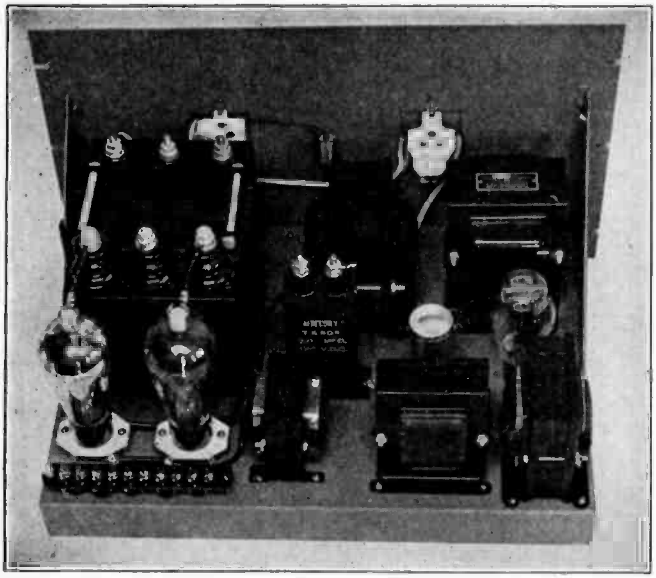


Figure 33.

In a rack-mounted power supply, which is supported from the front panel, it is advisable to place the heavy components close to the front panel to minimize the strain on the panel and chassis. Note the position of the heavy plate transformer. The chassis contains a 350-volt power supply and a 1250-volt power supply. Low-voltage power supply components are to the right.

$\frac{115}{85} = 1.353$ which is the same for all coils.

Now, the secondary coil must have two windings in series, each to give 1,000 volts, and with a middle tap. The secondary turns will be $\frac{2000}{1.353} = 1478$ with a tap taken out at the 739th turn.

Allowing 1,500 circular mils per ampere, the primary wire should be no. 12. The size of the wire on the plate coils may be no. 22 or 24 for a 400 to 300 ma. rating.

To determine the quantity of iron to pile up for a core, it is well to consider 1 to 1.5 volts per turn as a conservative range. For trial, assume 1.25 volts. Then by transforming the first equation

$A = 7.5 \times \frac{E}{T}$ or, the area required is 7.5 times the volts per turn; in this case, $7.5 \times 1.25 = 938$ sq. in.

The magnetic cross section must be measured at right angles to the laminations that are enclosed by the coil, the center leg when the core is built up around the coil and either leg where the core is built up inside the coil, that is, between the arrows in the sketches shown below.

It should be kept in mind that there is a copper or resistance loss in all transformers. This is caused by the passage of the current through the windings and is commonly spoken of as the "IR" loss. It manifests itself directly as heat and varies as the load is varied; the heavier the load, the more heat is developed.

This heat, as well as other heat losses, must be removed or the transformer will

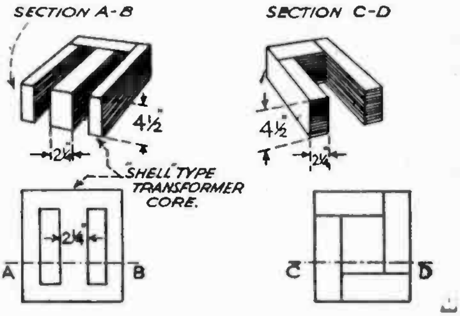


Figure 34.
TYPES OF TRANSFORMER CORES.

burn up. Most transformers are so arranged that both the core and windings can radiate heat into the surrounding air and thus cool themselves. Large transformers are mounted in oil for cooling and also for the purpose of increasing the insulation factor.

In any transformer, the voltage ratio is directly proportional to the turns ratio. This means that if the transformer is to have 110-volts input and 250 turns for the primary, and if the output is to be 1,100 volts, 2,500 turns will be needed. This may be expressed as:

$$\frac{E_p}{E_s} = \frac{T_p}{T_s}$$

It is often more convenient to take the figure obtained for the primary winding and, by dividing by the supply voltage, the number of turns per volt is calculated. This accomplished, the number of turns for any given voltage can be calculated by simple multiplication.

Radio transformers are generally of small size. The matter of power factor can therefore be disregarded, more especially because they work into an almost purely resistive load. In the design of radio transformers, the power factor can be safely assumed as unity, in which case the apparent watts and the actual watts are the same. Admittedly, this is not always a correct assumption, but it will suffice for common applications.

The size of the wire to be used in any transformer depends upon the amperage to be carried. For a current of 1 ampere as a continuous load, at least 1,000 circular mils per ampere must be allowed. For transformers which have poor ventilation, or continuous heavy load service, or where price is not the first consideration, 1,500 circular mils per ampere is a preferable figure. If, for example, a transformer is rated at 100-watts primary load on 110 volts, the current will be

$$I = \frac{W}{V} = \frac{100}{110} = 0.90 \text{ amperes}$$

and if the assumption is 1,000 circular mils per ampere, it will be found that this will require 1,000 × .90, or 900 circular mills. The wire table on page 333 shows that no. 20 wire for 1,200 mils is entirely satisfactory. If it is desired to use 1,500 circular mils, instead of 1,000, this will require 1,500 × .90 or 1350 mils, which corresponds to approximately no. 19 wire. The difference seems to be small, yet it is large enough to reduce heating and to improve overall performance. Assume, for tentative design, a 600-volt, 100-ma. high-voltage secondary; a 3-ampere 5-volt secondary, and 2.5-volt 7.5-ampere secondary. Simple calculation will show a 60-watt load on the high-voltage secondary; 15 watts on the 5-volt winding, and 16 watts on the 2.5-volt winding, a total of 91 watts. The core and copper loss is 10 watts. The wire sizes for the secondaries will be for 100-ma. current, no. 30 wire; 3 amperes at 5 volts, no. 15 wire; no. 11 wire for the 7.5-ampere secondary.

For high-voltage secondary windings, a small percentage of turns should be added to overcome the resistance of the small wire used, so that the output voltage will be as high as anticipated. The figures given in the table include this percentage which is added to the theoretical ratio and, consequently, the number of turns shown in the table can be accepted as the actual number to be wound on the core of any given transformer.

Allowance should always be made for the insulation and size of the windings. Good insulation should be provided between the core and the windings and also between each winding and between turns. Numerous materials are satisfactory for this purpose; varnished paper or cloth, called empire, is satisfactory, although costly. Good bond paper will serve well as an insulating medium for small transformer windings.

Insulation between primary and secondary and to the core must be exceptionally good, as well as the insulation between windings. Thin mica or micanite sheet is very good. Thin fibre, commonly called fish paper, is also a good insulator; bristol board, or strong, thin cardboard may also be used. In all cases, the completed coil should be impregnated with insulating varnish, and either dried in air or baked in an oven. Common varnishes or shellac are unsatisfactory on account of the moisture content of these materials. Air-drying insulating varnish is practical for all-around purposes; baking varnish may be substituted, but the fumes given off are inflammable and often explosive. Care must be exercised in the handling of this type of material. Collodion and banana oil lacquer are positively dangerous, and in the event of a short circuit or transformer burn-out, a serious fire may result.

If it is desired to wind a transformer on a given core, it is much better to calculate the actual space required for the windings, then determine whether there is enough available space on the core. If this precaution is not observed, the designer may find that only about half the turns are actually wound on the core, when the space is about three-fourths filled. Form 15 to 40 per cent more space than calculated must be allowed. The winding of transformers by hand is a space consuming process. Unless the builder is an experienced coil-winder, there is every chance that a sizable portion of the space will be used up by insulation, etc., not sufficient space remaining for the winding. Calculate the cubical space needed for the total number of turns, and allow from 15 to 40 per cent additional space in the core window. Thereby much time and labor will be saved.

FILTER CHOKE CONSIDERATIONS

A choke is a coil of high inductance. It offers an extremely high impedance to alternating current, or to current which is substantially alternating, such as pulsating d.c. delivered at the output of a rectifier.

Choke coils are used in power supplies as part of the complete filter system in order to produce an effectively-pure direct current from the pulsating current source, that is, from the rectifier. The wire size of the choke must be such that the current flowing through it does not cause an appreciable voltage drop due to the ohmic resistance of the choke; at the same time, sufficient inductance must be maintained to provide ample smoothing of the rectified current.

Smoothing Chokes

The function of a smoothing choke is to discriminate as much as possible between the a.c. ripple which is present and the desired d.c. that is to be delivered to the output. Its air gap should be large enough so that the inductance of the choke does not vary materially over the normal range of load current drawn from the power supply, but no larger than necessary to give maximum inductance at full current rating.

Swinging Chokes

In certain radio circuits the power drawn by a vacuum tube amplifier can vary widely. Class-B audio amplifiers are good examples of this type of amplifier. The plate current drawn by a class-B audio amplifier can vary 1000 per cent or more. It is desirable to keep the

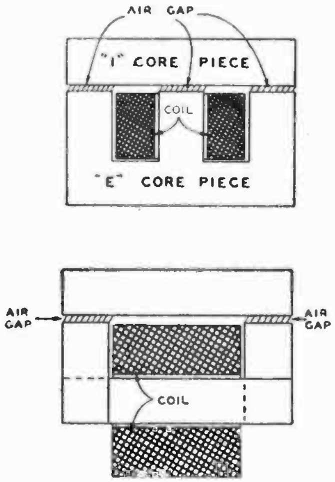


Figure 35.
Two types of choke coil construction. The air gap is approximately 1/32-inch. The gap may be filled with non-magnetic material, such as brass, bakelite, etc.

Choke Table For Transmitter Power Supply Units

CURRENT M.A.	WIRE SIZE	NO. TURNS	LBS. WIRE	APPROX. CORE (Area)	AIR GAP	WT. CORE
200	No. 27	2000	1.5	1½"x1½"	3/32"	4 lbs.
250	No. 26	2000	1.75	1½"x2"	3/32"	5 lbs.
300	No. 25	2250	2	2"x2"	⅛"	6 lbs.
400	No. 24	2250	3	2"x2½"	⅛"	7 lbs.
500	No. 23	2500	4	2½"x2½"	⅛"	10 lbs.
750	No. 21	3000	6	2½"x3"	⅛"	14 lbs.
1000	No. 20	3000	7.5	3"x3"	⅛"	18 lbs.

NOTES: These are approximately based on high-grade silicon steel cores with total air gaps as given. Air gaps indicated are total of all gaps.

The use of standard "E" and "I" laminations is recommended. If strips are used, and if an ordinary square core is used, the number of turns should be increased about 25%. Choke coils built as per the above table will have an approximate inductance of 10 to 15 henrys. Because considerable differences occur due to winding variations, allowable flux densities of cores, etc., the exact inductance cannot be stated; these chokes will, however, give satisfactory service in radio transmitter power supply systems.

The wire used is based on 1000 circular mils per ampere; this will cause some heating on long runs, and if the chokes are to be used continuously, as in a radiotelephone station in continuous service, it is good practice to use the next size larger choke shown for such loads.

d.c. output voltage applied to the plate of the amplifier as constant as possible and the voltage should be independent of the current drawn from the power supply. The output voltage from a given power supply is always higher with a condenser input filter than with a choke-type input filter. When the input choke is of the *swinging* variety, it means that the inductance of the choke varies widely with the load current drawn from the power supply, due to the fact that high initial inductance is obtained by utilizing a "butt" gap, or none at all as in a transformer core.

Choke Design and Construction

A choke is made up from a silicon-steel core which consists of a number of thin sheets of steel, similar to a transformer core, but wound with only a single winding. The size of the core and the number of turns of wire, together with the air gap which must be provided to prevent the core from saturating, are factors which determine the inductance of a choke. The relative sizes of the core and coil determine the amount of d.c. which can flow through the choke without reducing the inductance to an undesirable low value due to magnetization.

The same core material which is used in ordinary radio power transformers or from those which are burned out, is satisfactory for all general purposes.

In construction, the choke winding must be insulated from the core with a sufficient quantity of insulating material so that the highest peak voltages which are to be experienced in service will not rupture the insulation.

FIFTEEN

Transmitter Construction

A LOW power c.w. transmitter can be had simply by hooking a suitable power supply to one of the low power exciters previously described. For phone, it is only necessary to hook one of the modulators described in chapter 13 to the exciter for plate or plate-screen modulation. For medium or high power it is only necessary to connect up a suitable exciter, amplifier, speech system, modulator, and power supplies, many types of these being described in this book. They may either be placed in one rack or used separately.

To show how suitable units are combined to make a transmitter, several complete transmitters are shown in this chapter. They are shown also for the benefit of those who prefer to construct a whole transmitter from a tried-and-proven circuit which has been engineered from the standpoint of an integral unit, rather than to attempt to work out an individual design from composite units.

All of the complete transmitters shown in this chapter are radiophone transmit-

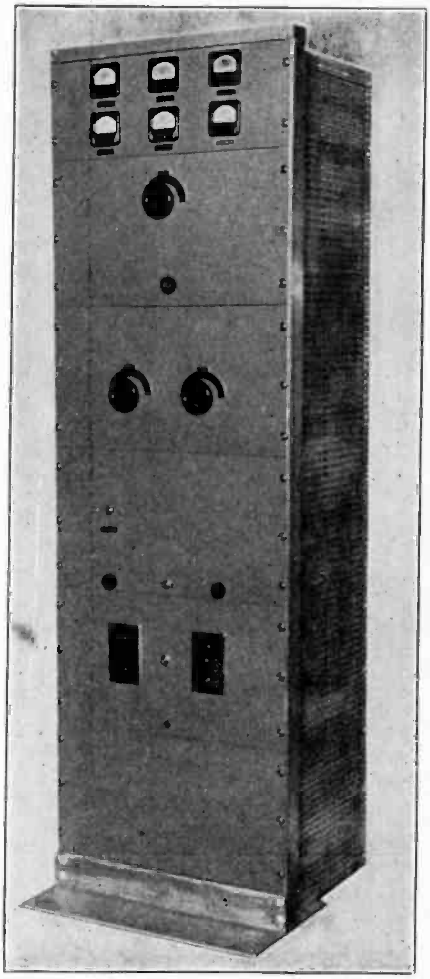


Figure 1.

TYPICAL RACK AND PANEL TRANSMITTER.

All components for a high power c.w. transmitter or medium power phone transmitter can be housed in a rack of this size. For rack and panel construction it is only necessary to build all units on standard width chassis and panels.

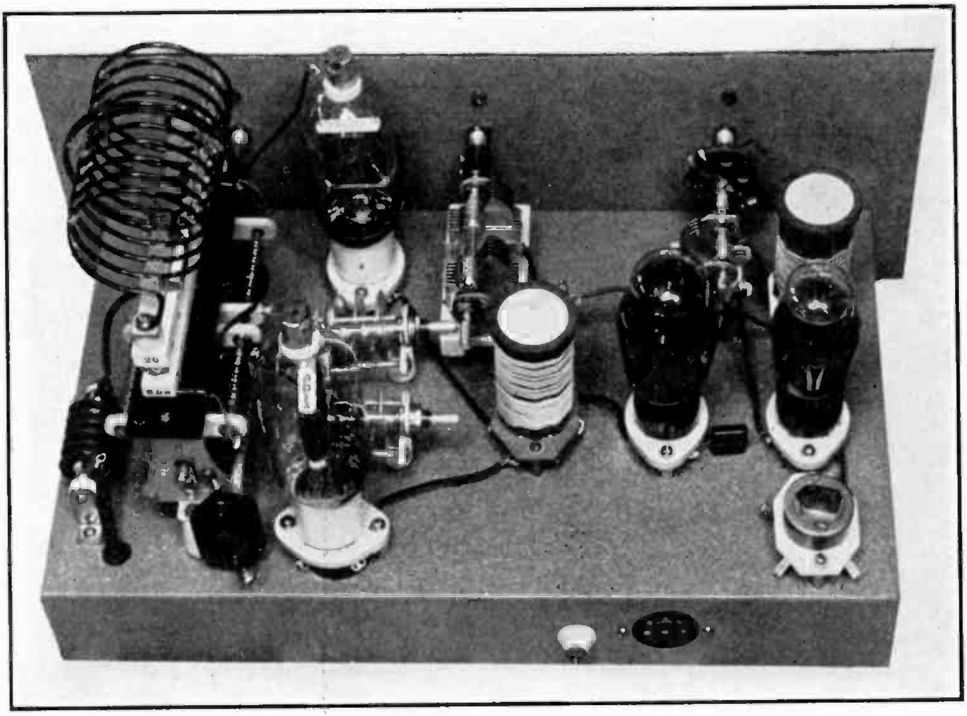


Figure 2.

250 WATT TZ40 C.W. TRANSMITTER R.F. UNIT.
This r.f. unit makes an economical c.w. transmitter for 20-, 40-, and 80-meter operation when supplied suitable plate and filament voltages.

ters, because it is a simple matter to omit the modulation equipment if phone operation is not desired. Also shown in this chapter is a 250-watt r.f. unit which requires a low-voltage and a high-voltage power supply to be considered a transmitter; it is shown in this chapter instead of in chapter 11 because it is somewhat large to be considered as an exciter for amateur work, and would always be used with suitable power supplies to feed an antenna rather than a high power amplifier. No amplifier using modern tubes running at one kilowatt input requires anywhere near 250 watts excitation even for plate modulated service.

250 WATT R.F. UNIT FOR C.W. OPERATION

Illustrated in figure 2 is a unit that will deliver up to 250 watts on 20, 40, and 80 meters, and makes an excellent c.w. transmitter when used in conjunction with a 450-volt 150-ma. power supply and a 1250-volt 300-ma. power supply. The latter supply may utilize a swinging input choke and single 4-μfd. 1500-volt oil filled condenser as the filter, working from a power transformer delivering 1400 to 1500 volts each side of c.t.

A conventional pentode oscillator using a 6F6-G drives a neutralized 6L6-G which can be used either straight through or as a doubler, with the same output. The 6L6-G output is coupled by means of an untuned grid coil to the push-pull TZ40's. The latter deliver approximately 250 watts on all three bands when loaded to a plate current of from 250 to 275 ma.

A single 100-ma. meter, M_1, is used to measure cathode current to the oscillator, cathode current to the buffer, and grid current to the final amplifier. The plate current to the latter is read by a perma-

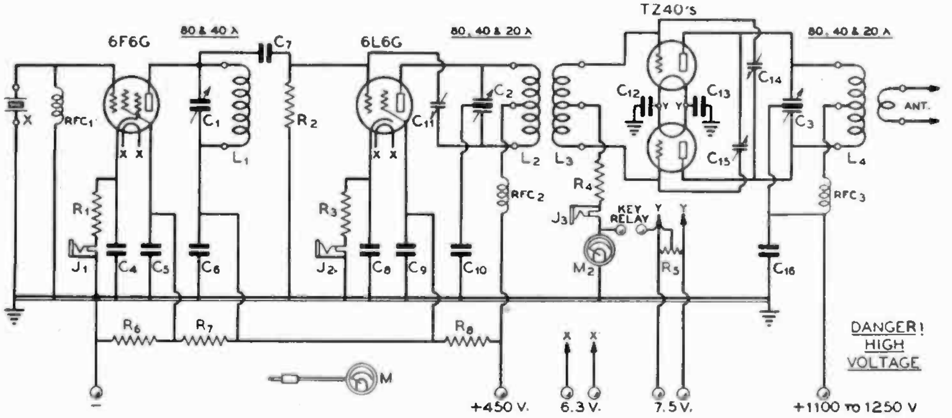


Figure 3.
WIRING DIAGRAM OF TZ40 250-WATT C.W. R.F. UNIT.

R_1 — 400 ohms, 10 watts
R_2—100,000 ohms, 2 watts
R_3 — 300 ohms, 10 watts
R_4—2000 ohms, 25 watts
R_5 — 50 ohms, 10 watts, c.t.
R_6—50,000 ohms, 2 watts
R_7—10,000 ohms, 2 watts
R_8—5,000 ohms, 10 watts
C_1—50-μμfd. midget
C_2 — 100-μμfd. per section midget
C_3 — 80-μμfd. per section, .078" air gap
C_4, C_5, C_6—.01-μfd. tubular, 600 v.
C_7—50-μμfd. mica
C_8, C_9, C_{10}—.01-μfd. tubular, 600 v.
C_{11} — 3-30-μμfd. mica trimmer with screw removed (ceramic type)
C_{12}, C_{13} — .01-μfd. tubular, 600 v.
C_{14}, C_{15} — 3-9-μμfd. neutralizing condensers, 7500 v. spacing
C_{16}—.002-μfd. mica, 2500 v. test
RFC_1, RFC_2 — 2.5 mh., 125 ma.
RFC_3—2.5 mh., 250 ma.
M—0-500 ma. d.c.
M_1—0-100 ma. d.c.

nently connected 0-500 ma. meter placed in the negative lead to remove the possibility of shock or shorting to the case. As shown in the diagram M reads plate current only; the grid current does not flow through the meter.

Because the positive high voltage appears on the rotor of C_3, it must be well insulated from the chassis, the same as C_1 and C_2.

Rather than rely upon the insulation of the tuning knob, the shaft of C_3 is driven through an insulated coupling in order to protect the operator from shock. In the

TZ-40 TRANSMITTER COIL DATA

Band	Oscillator L_1	Buffer-Doubler L_2 and L_3	Final Plate L_4
80 M.	36 turns no. 22 d.c.c. 1½" dia. spaced to 1½"	L_2—32 turns no. 22 d.c.c. 1½" dia., close wound L_3—40 turns no. 26 d.c.c., c.t., close wound	26 turns no. 14 enam. 3" dia. spaced to 4", center tapped
40 M.	18 turns no. 22 d.c.c. 1½" dia. spaced to 1½"	L_2—18 turns no. 22 d.c.c., c.t., 1½" dia., spaced to 1" L_3—28 turns no. 22 d.c.c., c.t., spaced to 1"	18 turns no. 12 enam. 2½" dia. Spaced to 3", center tapped.
20 M.	Use 40 m. coil	L_2—10 turns no. 20 d.c.c., c.t. 1½" dia, spaced to 1" L_3—12 turns no. 20 d.c.c., c.t. spaced to ½"	10 turns no. 10 enam. 2½" dia. Spaced to 3½", center tapped

L_3 is placed at ground end of L_2, spaced approximately 1/16 inch for all coils.

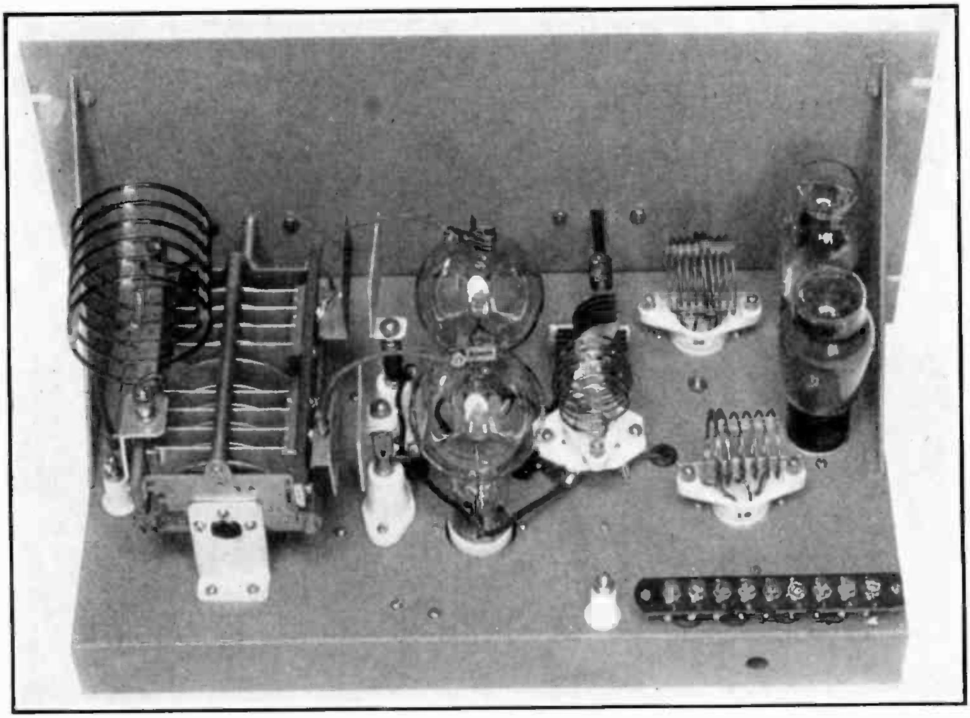


Figure 4.
R.F. PORTION OF 150-WATT HIGH EFFICIENCY GRID MODULATED TRANSMITTER FOR 10- AND 20-METER OPERATION.

The use of medium μ, high transconductance tubes makes it possible to obtain good efficiency with grid modulation at moderate plate voltage.

model illustrated, both C_1 and C_2 are also driven by means of insulated couplings, but this is not absolutely necessary if the tuning knobs for these two condensers have good insulation and protected set screw.

High voltage to the TZ40's is fed to the standoff insulator seen projecting out the rear of the chassis. All other voltages are connected by means of the socket connection.

If it is desired to use crystal keying instead of final amplifier keying the following changes should be made: Omit keying relay. Place 45-volt C battery in series with R_4 between J_3 and M_2. Substitute 1000-ohm 25-watt resistor for R_4. Connect lower end of R_2 to C minus instead of to ground. Insert key in J_1.

150-WATT GRID MODULATED PHONE TRANSMITTER

With high μ low-C tubes it is generally necessary to run very high plate voltage in order to obtain maximum efficiency with grid modulation. However, by using medium-μ high-transconductance tubes it is possible to get quite good efficiency at moderate plate voltages. The 75-T's in the transmitter illustrated deliver approximately 150 watts at an input of 300 watts, which represents an efficiency of 50 per cent.

A single 6V6-G with inverse feedback and stabilized load provides sufficient output at low distortion to effect full modulation. The output of the 6V6-G is connected to an a.g.c. circuit to reduce overmodulation and permit a higher average percentage of modulation. The

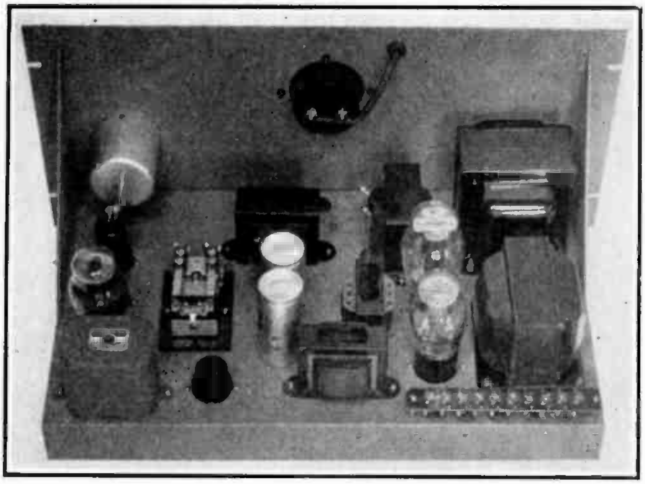


Figure 5.

SPEECH SYSTEM OF 75-T GRID MODULATED TRANSMITTER, AND ASSOCIATED POWER SUPPLY.

A 6V6-G in a special circuit providing inverse feedback and stabilized load completely modulates the 75-T's with good quality.

a.g.c. circuit is adjusted by means of the threshold control R_{22}.

The bias to the 75-T's should be adjusted by means of the slider on R_{25} to a value of 300 volts, which represents a bias of slightly greater than twice cutoff.

Excitation to the 75T's is increased by adjusting the coupling links between L_2 and L_3 until the stage will no longer modulate up properly. If the input and plate dissipation are too high or too low, it can be corrected by increasing or decreasing the antenna loading. The excitation adjustment is repeated, and if the input and dissipation are still too high or too low, the antenna coupling is again adjusted. When all adjustments have been made properly, the plate current will be

Figure 6.

CONSTANTS FOR WIRING DIAGRAM OF 75-T GRID-MODULATED TRANSMITTER.

C_1—200-600 μμfd. mica padder (adjustable trimmer)
C_2—50-μμfd. midget
C_3—50-μμfd. midget
C_4 — 50-μμfd. double spaced midget
C_5 — 50-μμfd. per section, 4500 v. spacing
C_6, C_7—.01-μfd. tubular
C_8—.002-μfd. tubular
C_9—100-μμfd. mica
C_{10}—.01-μfd. tubular
C_{11}—.003-μfd. mica
C_{12}—.003-μfd. mica
C_{13}—.003-μfd. mica
C_{14}, C_{15}—.01-μfd. tubular
C_{16}—.004-μfd. mica
C_{17} — 0.5-μfd. tubular, 400 v.
C_{18} — 10-μfd. 25 volt electrolytic
C_{19} — 0.1-μfd. tubular, 400 v.
C_{20} — 0.25-μfd. tubular, 400 v.
C_{21} — .01-μfd. tubular, 400 v.
C_{22}—0.5-μfd., 200 v.
C_{23} — .01-μfd. tubular, 400 v.
C_{24}—10-μfd. 25 v. electrolytic
C_{25}—0.5-μfd. 400 v.
C_{26}—1-μfd. 400 v. paper
C_{27}—1-μfd. 400 v. paper
C_{28} — .05-μfd. tubular, 400 v.
C_{29}, C_{30}—8-μfd. electrolytic, 450 v.
C_{31}, C_{32}—8-μfd. electrolytic, 450 v.
C_{33}, C_{34}—2-μfd. 2000 v. oil filled
R_1 — 100,000 ohms, 1 watt
R_2 — 150,000 ohms, 2 watts
R_3—300 ohms, 10 watts
R_4 — 25,000 ohms, 10 watts
R_5—3500 ohms, 20 watts
R_6 — 25,000 ohms, ½ watt
R_7, R_8—1 meg., ½ watt
R_9—1000 ohms, 1 watt
R_{10}—250,000 ohms, ½ watt
R_{11} — 50,000 ohms, ½ watt
R_{12} — 250,000 ohms, 1 watt
R_{13}—0.5 meg. pot. gain control
R_{14}—2000 ohms, 1 watt
R_{15} — 100,000 ohms, 1 watt
R_{16}—500,000 ohms, ½ watt
R_{17}—400 ohms, 10 watts
R_{18} — 15,000 ohms, 10 watts
R_{19} — 1500 ohms, 10 watts
R_{20} — 5000 ohms, 10 watts
R_{21} — 250,000 ohms, 1 watt
R_{22}—50,000 ohm potentiometer
R_{23}—250,000 ohms, ½ watt
R_{24}—500,000 ohms, ½ watt
R_{25} — 5000 ohms, 50 watts with slider
R_{26}—100,000 ohms, 150 watts
RFC_1—2.5 mh., 125 ma.
RFC_2—2.5 mh., 250 ma.
T_1—5 v. 13 amp.
T_2—450 v. each side c.t., 200 ma., and fil. windings indicated
T_3—325 v. each side c.t., 75 ma., and fil. windings indicated
T_4 — 1800 to 1900 v. each side c.t. at 300 ma.
T_5—2.5 v. at 10 amp., 5000 v. insulation
T_6—Any small class B input transformer
CH_1, CH_2—10 hy., 200 ma., low d.c. resistance
CH_3—10 hy., 75 ma.
CH_4—15 hy. 250 ma.
CH_5—5-25 hy. 250 ma.

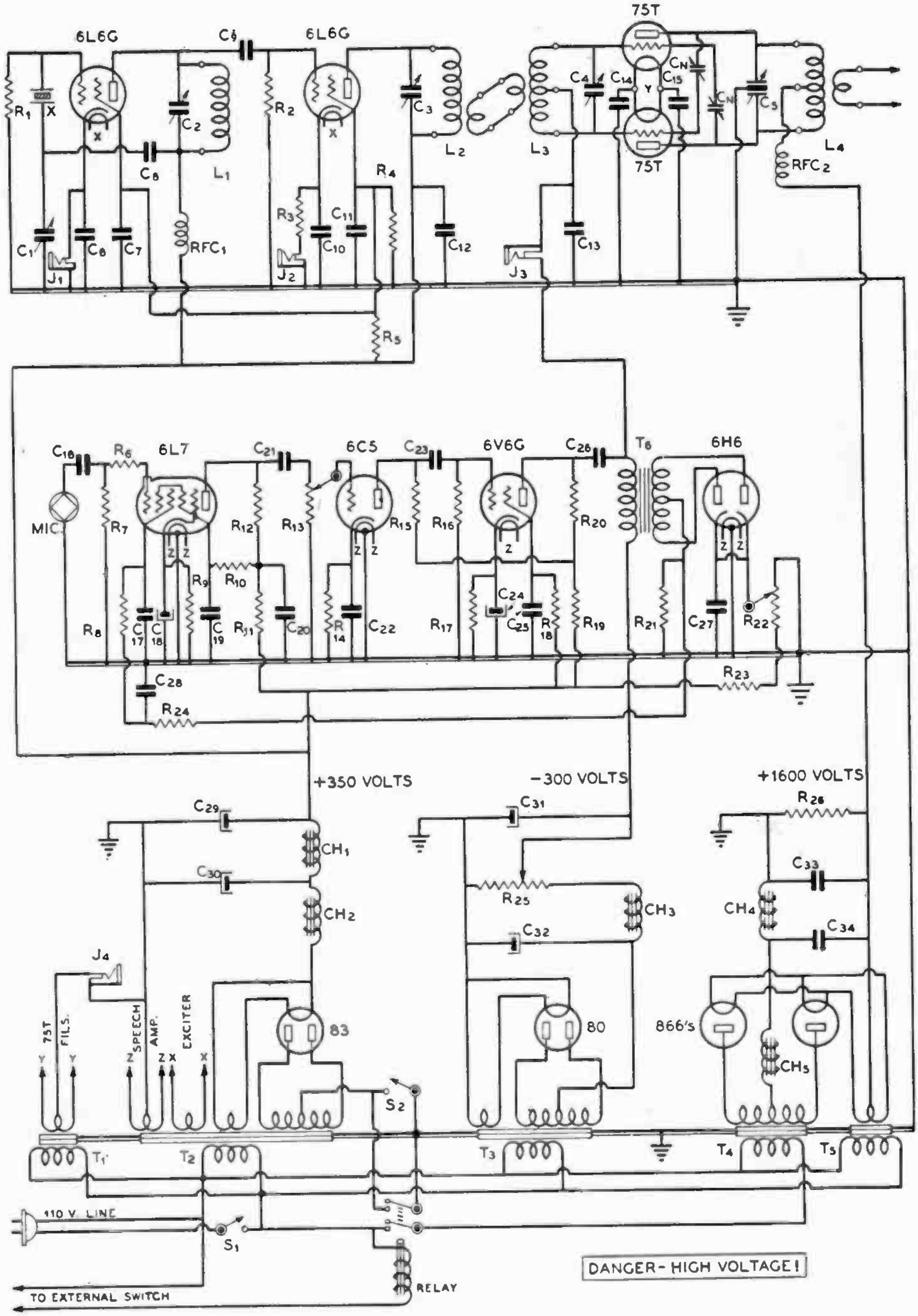


Figure 6.
GENERAL WIRING DIAGRAM OF 75-T GRID MODULATED TRANSMITTER.

COIL DATA FOR 75-T GRID MODULATED 10-20 METER PHONE

Band	6L6 Coils	Final Grid	Final Plate
10	5 turns no. 18, 1½ in. dia., spaced to 1 in.	5 turns no. 18, c.t., 1½ in. dia., spaced to 1 in.	6 turns no. 10 enam., 2½ in dia., spaced to 3 in., c.t.
20	8 turns no. 20, 1½" in. dia., spaced to 1¼ in.	10 turns no. 18 c.t., 1½ in. dia., spaced to 1½ in.	10 turns no. 10 enam., 2½ in. dia., spaced to 3 in., c.t.
40	18 turns no. 22 d.c.c., 1½ in. dia., spaced to 1½ in.		
80	35 turns no. 22 d.c.c., 1½ in. dia., close wound		

between 190 and 200 ma., and the modulation capability will be about 95 per cent, the output running close to 150 watts.

Because it is desirable in the interest of greatest output to run the 75-T's at their maximum safe dissipation, they should be placed so as to allow free circulation of air around them. Connectors having a large radiating surface will aid in keeping the elements cool by aiding in the radiation of heat conducted to them by the grid and plate leads out of the envelope.

The plate voltage may be higher than 1600 volts if desired, anything up to 2000 volts being permissible, so long as the plate current is reduced accordingly in order to limit the input to approximately 300 watts. The efficiency will fall off if less than 1600 volts is used.

100-WATT 10-160 METER 35-T CATHODE MODULATED PHONE

While it is necessary to use at least 2000 volts on tubes such as the 35-T in order to get good efficiency with ordinary grid modulation, it is possible to get the same efficiency at 1500 volts when cathode modulation is used, and the adjustments are not quite so critical. With cathode modulation the modulation of the grid bias is augmented by a small amount of plate modulation, the cathode being common to both grid and plate circuits. Somewhat more audio power is required for cathode modulation, but it is still low enough that a simple, inexpensive modulator can be used for carrier powers of 100 to 150 watts. The required r.f. grid drive is also slightly greater.

The 35-T cathode modulated transmitter illustrated will deliver slightly over 100 watts of carrier with 200 watts input. This means that the 35-T's must each dissipate about 45 watts, but they will do this safely in grid or cathode modulated service *provided they have good ventilation.*

A 6L6-G harmonic oscillator delivers output on either 1, 2, or 4 times crystal frequency. A neutralized 35-T delivers output on either 1 or 2 times excitation frequency. This means that the transmitter may be operated at 1, 2, 4, or 8 times crystal frequency.

The 35-T buffer-doubler is supplied with a high value of grid leak bias in order to limit the plate current and permit high efficiency when doubling. Because of the reserve of excitation supplied by the 35-T, it is possible to use capacity coupling to the final stage even though the transmitter is designed to include 10-meter operation. This minimizes the total number of coils required.

To provide low C on 10 meters yet allow sufficient Q for good 75- and 160-meter operation, a 50-$\mu\mu$fd. per section condenser is used for the final plate tank and fixed air padding condensers plugged in on 75 and 160 meters to provide the necessary capacity for proper operation on these two bands.

Automatic gain control is provided to minimize overmodulation and permit a higher average percentage of modulation. The initial adjustment of R_{31} should be made with the assistance of a c.r. oscil-

Figure 7.
100 WATT 35-T CATHODE MODULATED PHONE FOR 10-160 METERS.
Providing high overall efficiency with low cost, this transmitter has many of the advantages of both plate modulation and grid modulation.

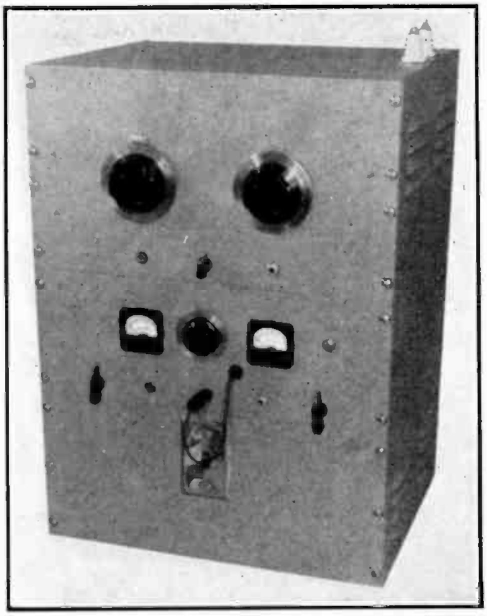
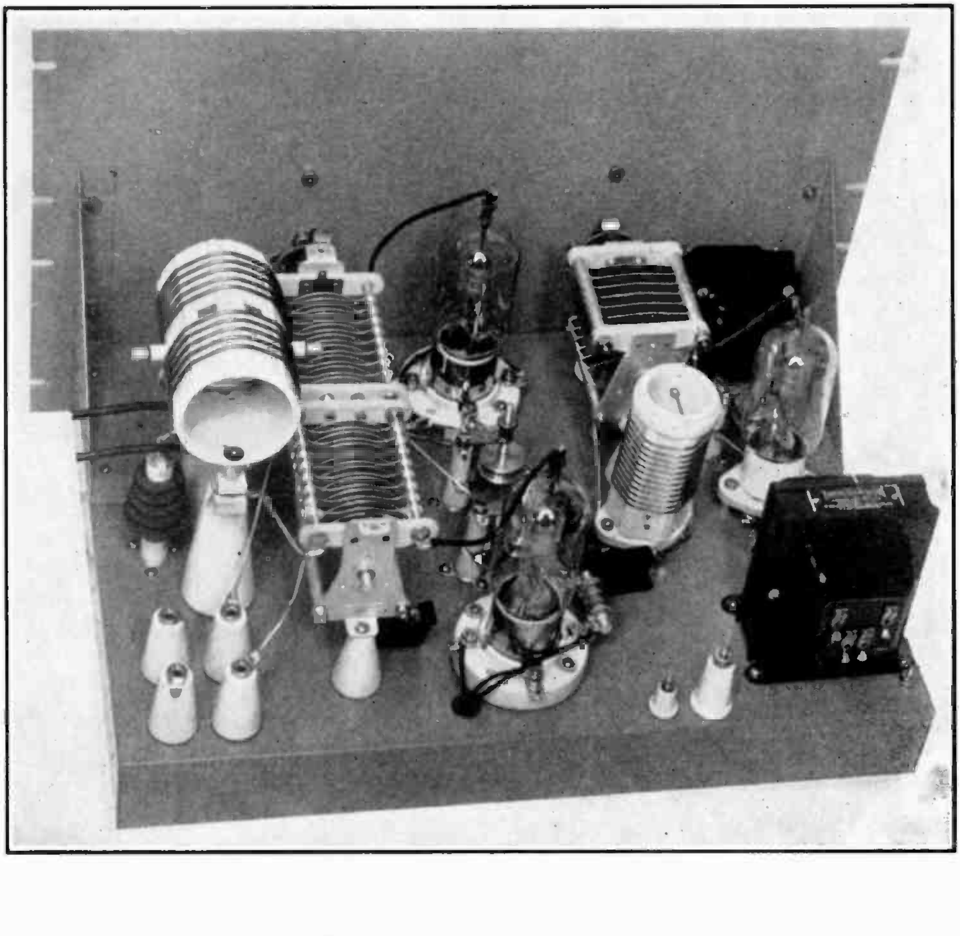


Figure 8.
BUFFER AND FINAL AMPLIFIER STAGES.
To minimize the required number of coils, the 35-T buffer-doubler is capacitively coupled to the final amplifier. The 35-T filament transformer and the cathode modulation transformer are mounted on the chassis with the r.f. components. Note the jacks for the plug in fixed air condenser for 75- and 160-meter operation.



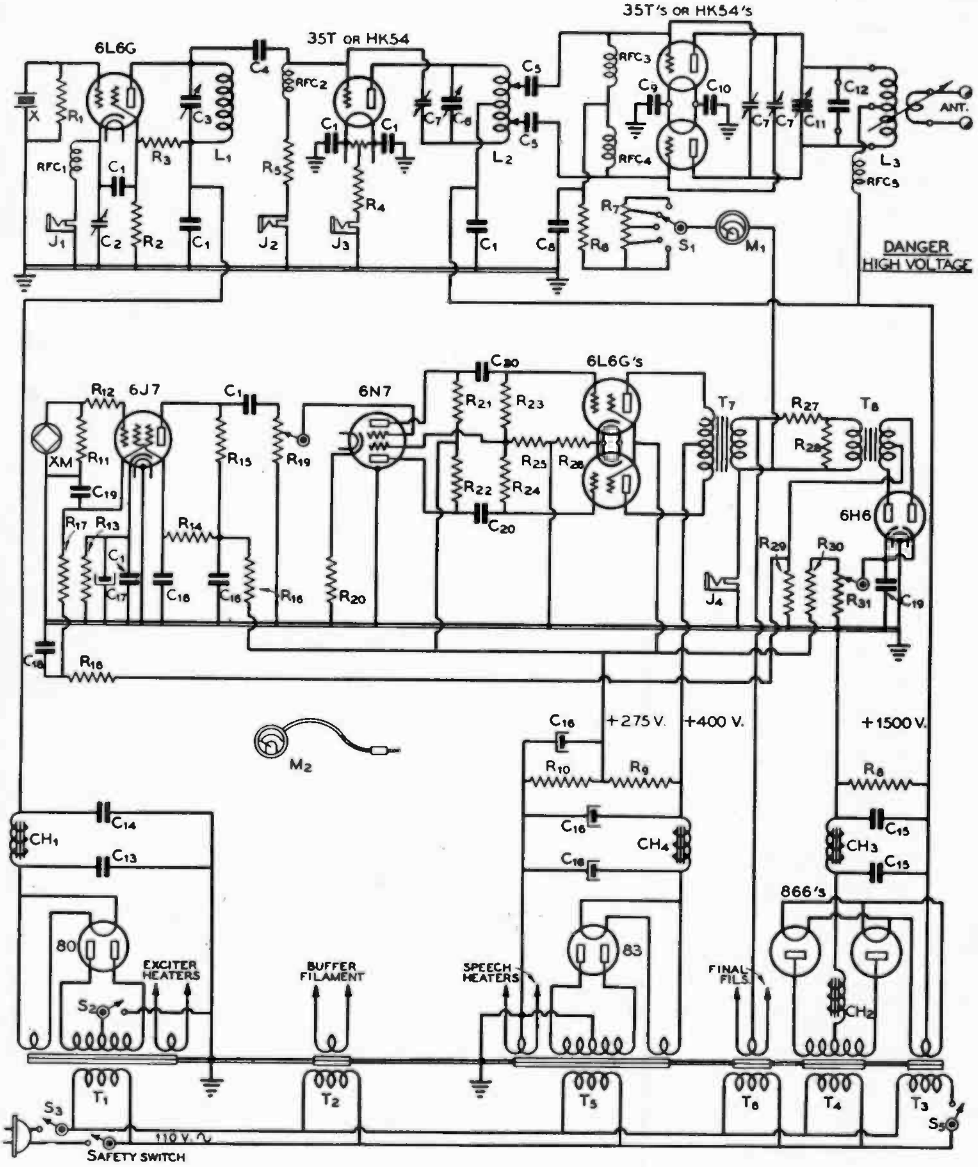


Figure 9.

GENERAL DIAGRAM OF 35-T CATHODE-MODULATED PHONE.

R_1 — 100,000 ohms, 1 watt
R_2 — 50,000 ohms, 2 watts
R_3 — 10,000 ohms, 10 watts
R_4—500 ohms, 25 watts
R_5 — 15,000 ohms, 10 watts
R_6 — 4000 ohms, 25 watts
R_7 — 15,000 ohms, 50 watts, with 3 slider taps
R_8 — 75,000 ohms, 100 watts
R_9—4000 ohms, 25 watts
R_{10} — 25,000 ohms, 10 watts
R_{11}—1 meg., ½ watt
R_{12} — 25,000 ohms, ½ watt
R_{13}—3500 ohms, ½ watt
R_{14}—2 meg., 1 watt
R_{15} — 250,000 ohms, 1 watt
R_{16} — 50,000 ohms, ½ watt
R_{17}—250,000 ohms, ½ watt
R_{18}—500,000 ohms, ½ watt

R_{19}—1 meg. pot. gain control
R_{20}—1000 ohms, ½ watt
R_{21} — 100,000 ohms, 1 watt
R_{22} — 100,000 ohms, 1 watt
R_{23}, R_{24}—250,000 ohms, ½ watt
R_{25}—100,000 ohms, ½ watt
R_{26}—200 ohms, 10 watts
R_{27} — 10,000 ohms, 1 watt
R_{28} — 20,000 ohms, 1 watt
R_{29}—200,000 ohms, ½ watt
R_{30} — 50,000 ohms, 1 watt
R_{31}—100,000 ohm pot. a.g.c. control
M_1—0-50 ma. d.c.
M_2—0-300 ma. d.c.
RFC_1, RFC_2, RFC_3, RFC_4—2.5 mh., 125 ma.
RFC_5—2.5 mh., 500 ma.
C_1—.01-μfd. 600 v. tubular
C_2 — 200-600-μμfd. adjustable mica trimmer (padder)
C_3—50-μμfd. midget
C_4 — 50-μμfd. mica, 1200 v.
C_5—50-μμfd. mica, 5000 v.
C_6 — 55-μμfd., 4500 v. spacing
C_7—2-μμfd. micrometer neutralizing condensers
C_8 — 0.5-μfd., 600 v. paper
C_9, C_{10}—.002-μfd. mica, 600 v.
C_{11}—50-μμfd. per section, 3000 v. spacing
C_{12} — Fixed air padder, 0.144" air gap, 50 μμfd. for 75 m., 100 μμfd. for 160 m.
C_{13}, C_{14}—4-μfd., 600 v. oil filled
C_{15}—2-μfd. 1500 v. oil filled
C_{16}—8-μfd. electrolytic, 450 v.
C_{17}—10-μfd. 25 v. electrolytic
C_{18} — 0.1-μfd. 600 v. paper tubular
C_{19} — 0.5-μfd. 400 v paper
C_{20} — .02-μfd. 600 v. tubular
T_1—680 volts c.t., 65 ma., and indicated fil.
T_2—5 v. 4 amp.
T_3—2.5 v. 10 amp., 5000 v. insulation
T_4 — 3650 volts c.t., 300 ma.
T_5—700 volts c.t., 145 ma., and indicated fil.
T_6—5.25 v., 10 amps.
T_7—3300 to 250 or 500 ohms, 40 to 60 watts, P.P. parallel 6L6 output to 250 or 500 ohm line
CH_1—15 hy., 85 ma.
CH_2, CH_3—10 to 15 hy., 250 ma.
CH_4—10 to 15 hy., 150 ma.

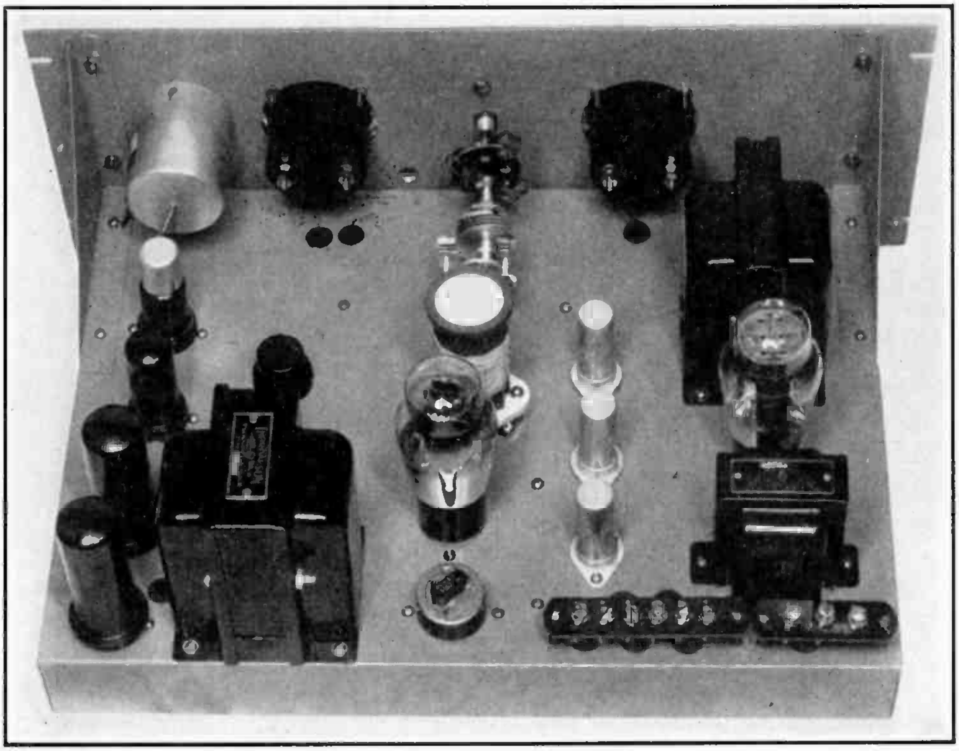


Figure 10.

SPEECH, OSCILLATOR, AND OSCILLATOR POWER SUPPLY.

Located on the second deck are the speech channel, a.g.c. components, crystal oscillator, and small power pack for the crystal oscillator. A relay in the center tap lead of the high voltage transformer turns the oscillator plate voltage on and off in unison with the plate voltage to the 35-T's, which have a plate transformer with no filament windings and can therefore be switched in the primary.

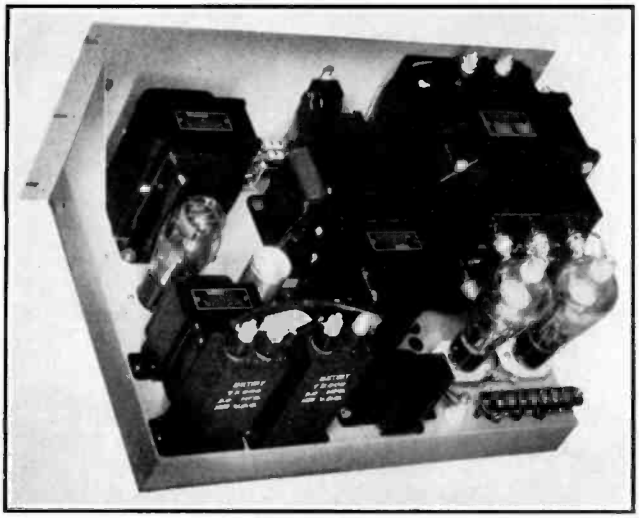


Figure 11.

POWER SUPPLIES FOR MODULATOR AND 35-T STAGES.

The 1500-volt power supply for the buffer and final amplifier and the 400-volt supply for the speech system are mounted on the lower deck. Note that the heaviest components are mounted towards the front of the chassis. A 110-volt a.c. relay permits turning the transmitter on and off with one switch, in the 110-volt line.

loscope. The operation of a.g.c. circuits is discussed in chapter 8.

The particular phase inverter used is very stable and not critical with respect to tubes. It need not be initially adjusted by means of a meter or c.r. oscilloscope if the resistors used have a reasonable degree of accuracy.

The 6L6's have more than the necessary output capability for full modulation, but the reserve power results in excellent quality, as the modulator is run at about half output. For coupling to the cathodes of the r.f. tubes, a transformer designed for coupling four 6L6's in p.p. parallel to a 250- or 500-ohm line is used. The impedance match is not critical for cathode modulation and this transformer gives equally good results when either the 250-ohm or 500-ohm winding is used. The winding must carry about 150 ma., which it seems to do without bad effects in spite of the fact that it was not designed to carry d.c. Evidently the wire is heavy enough and the impedance of the winding low enough that there is neither

COIL DATA FOR 35-T CATHODE-MODULATED TRANSMITTER.

Band	Oscillator (Bakelite Coil Forms	Buffer Plate (Ceramic Coil Forms)	Final Plate (Ceramic or Air Wound)
160	76 turns no. 22 enam. close wound, 1½ in. dia.	82 turns no. 24 d.c.c. close wound c.t., tapped also 15 turns each side c.t., 1¾ in. dia.	40 turns no. 16 enam., c.t., 2½ in. diam., spaced to 3 in., shunted with 100 μμfd. fixed air padder
80	36 turns no. 20 d.c.c. 1½ in. dia., spaced to 2 in.	38 turns no. 18 enam., c.t., 1¾ in. dia., spaced to 2 in., also tapped 7 turns each side c.t.	24 turns no. 14 enam., c.t., 2½ in. dia., spaced to 3 in., shunted with 50 μμfd. fixed air padder
40	18 turns no. 20 d.c.c. 1½ in. dia., spaced to 1½ in.	18 turns no. 18 enam., c.t., 1¾ in. dia., spaced to 1½ in., also tapped 4 turns each side c.t.	18 turns no. 14 enam., c.t., 2½ in. dia., spaced to 3 in.
20	9 turns no. 18 enam. 1½ in. dia., spaced to 1 in.	12 turns no. 18 enam., c.t., 1¾ in. dia., spaced to 2 in., also tapped 3 turns each side c.t.	12 turns no. 12 enam., c.t. 2½ in. dia., spaced to 3 in.
10	Use 20 m. coil	6 turns no. 16 enam., c.t., 1¾ in. dia., spaced to 2½ in., also tapped 2 turns each side c.t.	6 turns no. 10 enam., c.t., 2½ in. dia., spaced to 3 in.

Figure 12.

COMPLETED TRANSMITTER HOUSED IN CABINET, REAR VIEW WITH DOOR OPEN.

To provide adequate ventilation several additional holes are drilled in the rear door of the cabinet at both top and bottom. Note the safety interlock switch on the door latch.

heating of the wire nor core saturation. Special transformers designed expressly for cathode modulation are being released by some manufacturers.

The excitation and loading adjustments are not critical. Simply increase the bias on the 35-T's by means of the selector switch connected to R_7 until 10 to 20 ma. of grid current flows and the stage modulates up properly. If the plate current and tube dissipation are excessive, reduce the antenna coupling and repeat the bias adjustment. If the dissipation and plate current are low, increase the antenna coupling and repeat the bias adjustment. Under correct operating conditions both grid current and plate current to the 75-T's will be substantially constant during modulation.

Typical meter readings for correct operation are as follows:

Osc. cathode—35 to 60 ma.
35-T buffer cathode—45 to 65 ma.
35-T doubler cathode—65 to 80 ma.
Final grid current—10 to 20 ma.
Final plate current—140 to 150 ma.

These readings hold for a 35-T plate voltage of 1500 volts and modulator and exciter voltage of 400 volts.

HK-54's may be substituted for the 35-T's if desired. No changes in circuit constants will be necessary.

400-WATT 10-160 M. PLATE-MODULATED PHONE

While the amateur to whom price is no item will naturally want to run a full kilowatt input plate-modulated phone when interested in high power, the amateur who is interested in economy will do better to content himself with a transmitter running in the neighborhood of 600-watts input to the plate-modulated stage. Tubes and modulation transformers for this power are widely available and quite reasonably priced, but when one goes to a full kilowatt

400-WATT PHONE TRANSMITTER COIL DATA

BAND	6L6G PLATE	BUFFER & FINAL GRIDS	FINAL PLATE
160	66 turns #22 d.c.c. 1½" diam. closewound	80 turns #18 d.c.c. 2⅝" diam. closewound center tap	Use 80-λ coil shunted by fixed tank condenser (see text)
80	30 turns #20 d.c.c. 1½" diam. 1½" long	36 turns #14 enam. 2¾" diam. 8 turns/in. center tap	28 turns #10 enam. 4½" diam. 4½ turns per in. center tap
40	15½ turns #18 d.c.c. 1½" diam. 1½" long	20 turns #14 enam. 2⅝" diam. 5 turns/in. center tap	20 turns #10 enam. 3½" diam. 3 turns/in. center tap
20	7½ turns #16 enam. 1½" diam. 1¼" long	10 turns #14 enam. 2½" diam. 2½ turns per in. center tap	10 turns #10 enam. 3¼" diam. 1½ turns per in. center tap
10		6 turns #12 enam. 1¾" diam. 1½ turns per in. center tap	6 turns #10 enam. 2¼" diam. 1 turn/in. center tap

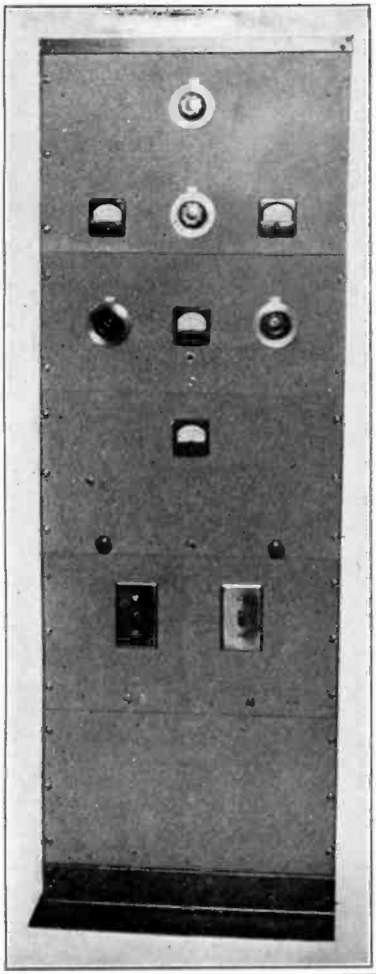


Figure 13.

FRONT VIEW OF THE TRANSMITTER.

This five-foot relay rack contains the complete 400-watt (carrier) radiotelephone transmitter. A pair of class B 203Z's plate-modulate a pair of push-pull 100TH's.

the price of these components goes up distressingly. As there is less than 3 db difference (just barely discernible) between a kilowatt and 600 watts input, the cost of the additional power will not be justified in the case of the majority of amateurs.

Hence, for a high-power phone transmitter, one delivering about 400 watts of carrier is shown—a very economical size. If one insists upon running a full kilowatt input, it is possible to do so with substantially the same circuit by replacing the 1250-volt power supply with a 1500-volt 400-ma. supply and the 1900-volt supply with a 2500-volt 400-ma. supply. This will permit the use of an HK254 or 100TH buffer and 250TH's or HK354D's in the modulated amplifier. Slightly greater spacing will be required for the plate tank condenser C_{18}. The 203Z's can be replaced with 822's to deliver sufficient audio at 1500 volts to modulate fully a kilowatt input on speech waveforms.

Construction of the 400-watt transmitter illustrated obviously is not for the

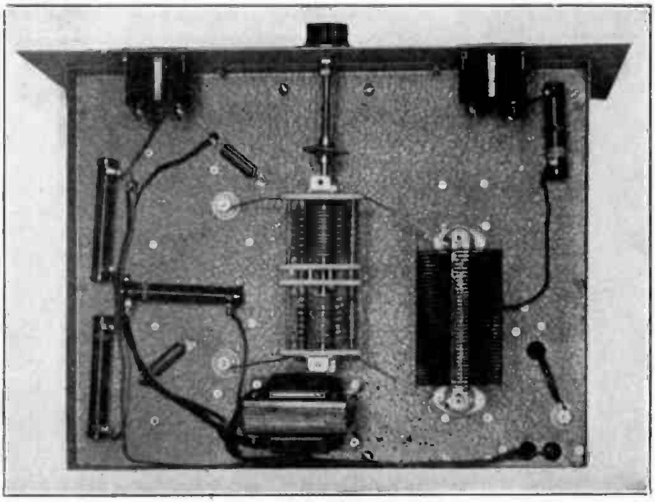


Figure 14.

UNDER - CHASSIS VIEW OF FINAL AMPLIFIER.

The grid coil is effectively shielded from the plate coil by the chassis.

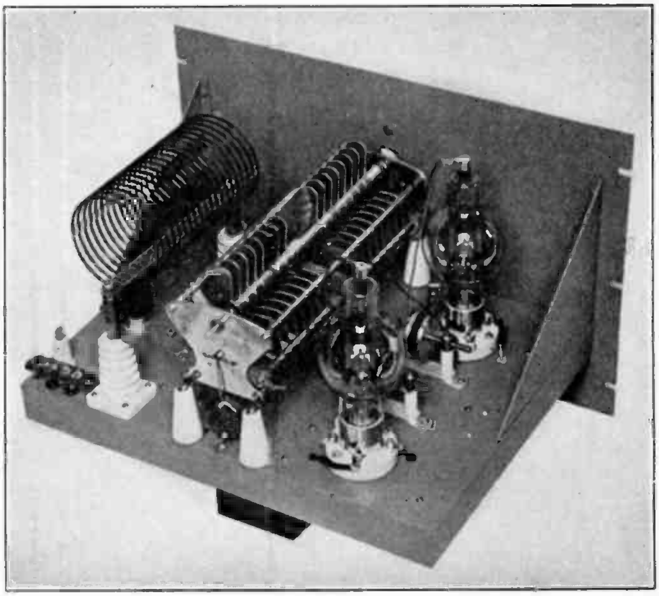


Figure 15.

THE FINAL AMPLIFIER DECK.

The tubes illustrated are 100TH's.

newcomer. And the amateur who has had sufficient construction experience to warrant an attempt at the building of the transmitter will find the illustrations and wiring diagram largely self-explanatory.

The R. F. Exciter

A 6L6G harmonic oscillator, of the type previously discussed in connection with various other transmitters described, drives a 35-T or HK54 neutralized amplifier or doubler. This stage is link-coupled to the grid circuit of the modulated amplifier. The HK54 is first neutralized when working as a straight amplifier on 20 meters. The neutralization will then hold close enough and be sufficiently accurate for operation on all

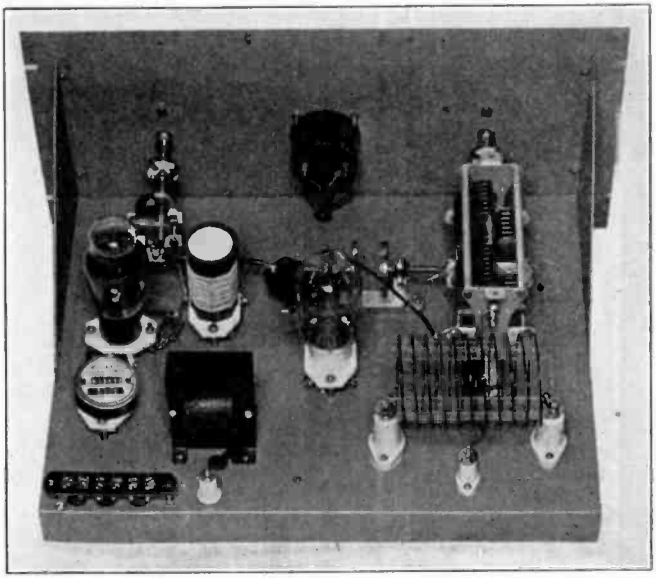


Figure 16.

THE EXCITER DECK.

Layout of the exciter components is clearly indicated in this view.

Figure 17.

THE SPEECH AND MODULATOR SYSTEM.

The entire speech channel is contained in one rack unit. The shield on the back of the panel encloses the input jack, bias cell, grid resistor, etc. and prevents hum pickup.

bands. The neutralizing condenser is not disturbed when the stage is used as a doubler.

The Modulated Amplifier

The tubes in the final amplifier "loaf" at between 550- and 600-watts input. While a pair of HK54's or 35-T's could be run at a half kilowatt input at the plate voltage specified, such input with plate modulation is rather severe and larger tubes will give longer life. HK254's or 100TH's can be run considerably under their rated maximum plate current rating and very long life can be expected.

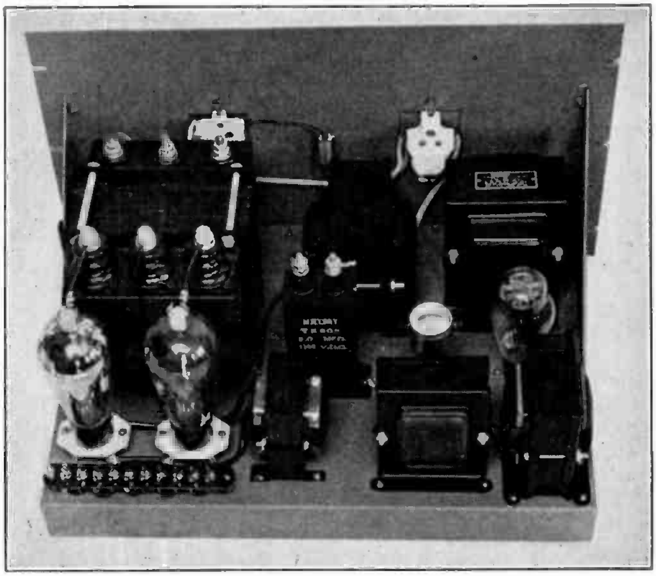


Figure 18.

350 AND 1250 VOLT POWER SUPPLIES.

Low voltage power supply components are to the right.

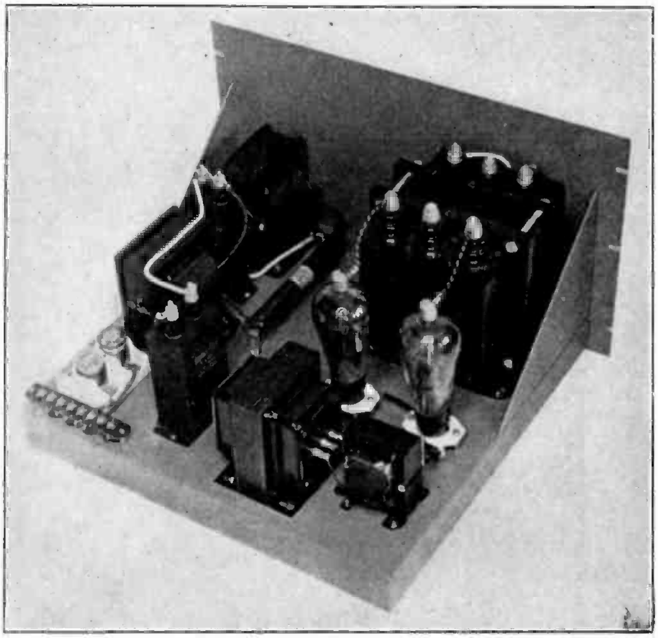


Figure 19.
1900-VOLT POWER SUPPLY.
This power supply, which feeds the modulated amplifier, has a two section filter in order to remove all carrier hum.

Sufficient coupling between the buffer and modulated amplifier can usually be obtained with a single turn link around the center of buffer plate and final grid coils. If the grid current to the modulated amplifier runs over 80 ma., the grid tank condenser can be detuned slightly. If it is impossible to obtain 80-ma. grid current on the lower-frequency bands, two-turn links will be required for those coils.

To eliminate the need for a more bulky, higher capacity plate tank condenser for 160-meter operation, which

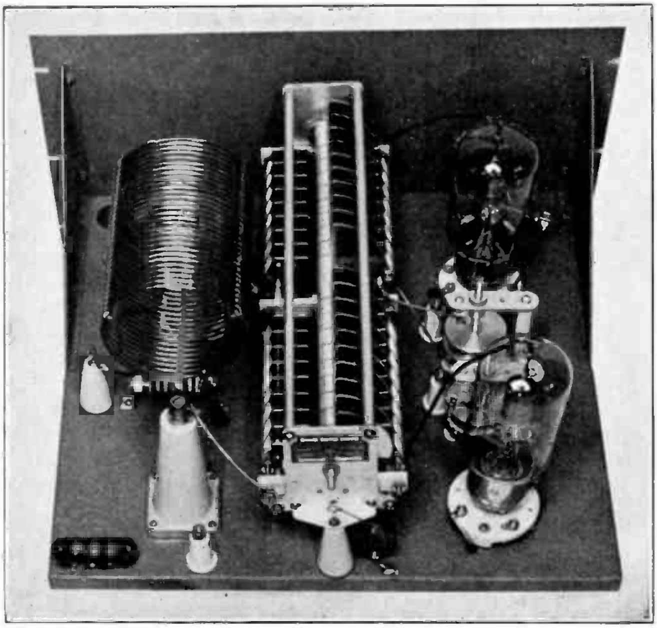


Figure 20.
HK254 AMPLIFIER FOR 400-WATT PHONE TRANSMITTER
This final amplifier is identical electrically to the one illustrated in figure 15 but uses components by different manufacturers.

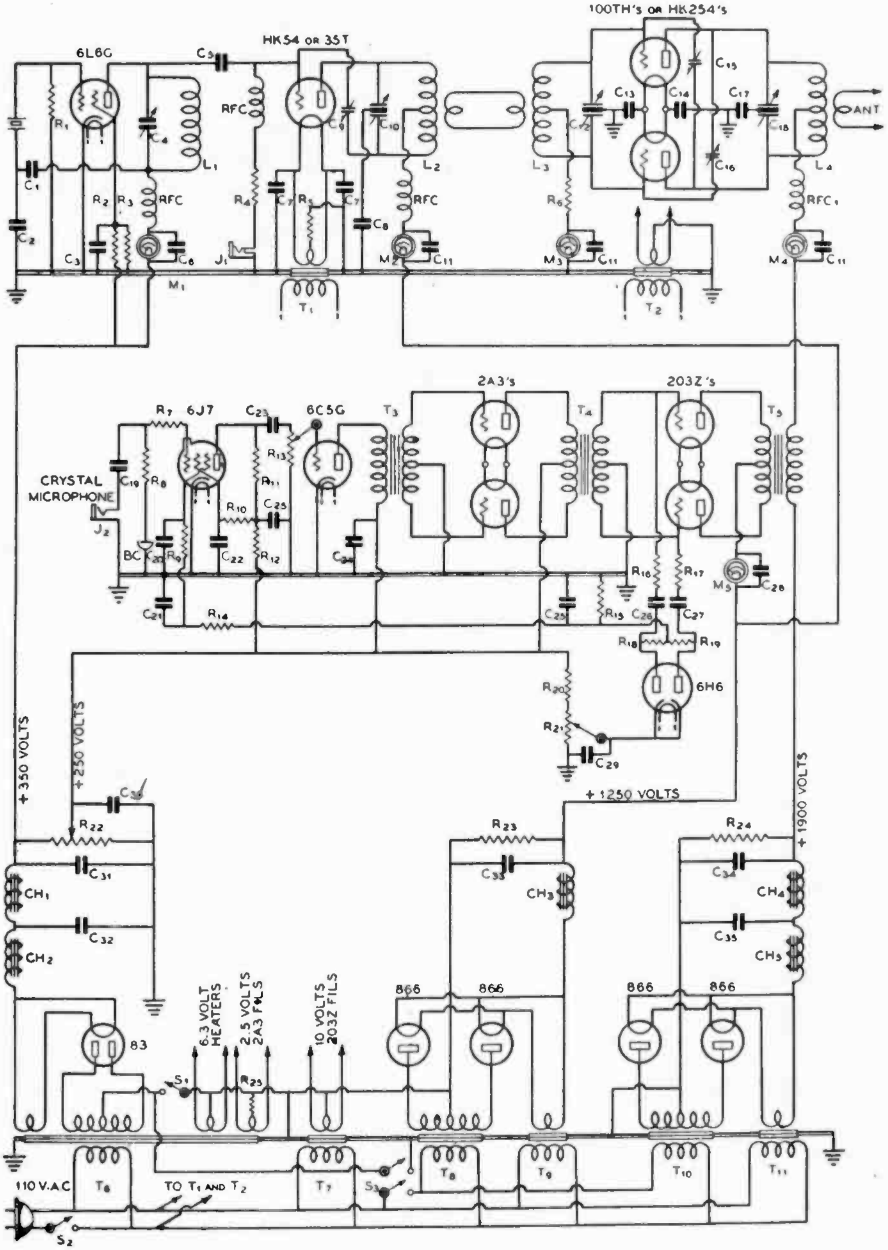


Figure 21.

GENERAL WIRING DIAGRAM OF THE 400-WATT PHONE TRANSMITTER.

Figure 21.

CONSTANTS USED IN GENERAL WIRING DIAGRAM OF 400-WATT PHONE TRANSMITTER.

C_1—.0004-μfd. mica
C_2—.002-μfd. mica
C_3—.01-μfd. tubular
C_4—50-μμfd. midget
C_5—.0005-μfd. mica
C_6—.002-μfd. mica
C_7—.01-μfd. tubular
C_8 — .002-μfd. mica, 2500 volts
C_9—Disc type neutralizing condenser
C_{10}—80-μμfd. per section, 3000-v. spacing
C_{11}—.002-μfd. mica
C_{12}—80-μμfd. per section, 3000-v. spacing
C_{13}, C_{14}—.01-μfd. tubular
C_{15}, C_{16}—Disc type neutralizing condensers
C_{17} — .0001-μfd. mica, 5000 v.
C_{18}—75 μμfd. per section, ¼" air gap
C_{19}—.01-μfd. tubular
C_{20}, C_{21}, C_{22}—0.1-μfd. tubular
C_{23}—.01-μfd. tubular
C_{24}—0.1-μfd. tubular
C_{25}—0.5-μfd. tubular
C_{26}, C_{27}—0.1-μfd, tubular
C_{28}—.002-μfd. mica
C_{29}—1-μfd. paper, 400 volts
C_{30}, C_{31}, C_{32} — 8-μfd. electrolytics, 450 volts
C_{33}—2-μfd., 1500 w. v.
C_{34}, C_{35} — 2-μfd. 2000 w.v.
R_1 — 100,000 ohms, 1 watt
R_2 — 10,000 ohms, 10 watts
R_3 — 50,000 ohms, 2 watts
R_4 — 15,000 ohms, 10 watts
R_5—300 ohms, 10 watts
R_6 — 2000 ohms, 50 watts
R_7 — 50,000 ohms, ½ watt
R_8—1 meg., ½ watt
R_9—250,000 ohms, ½ watt
R_{10} — 1 meg., ½ watt
R_{11} — 250,000 ohms, 1 watt
R_{12} — 50,000 ohms, ½ watt
R_{13} — 1-meg. tapered pot.
R_{14}—250,000 ohms, ½ watt
R_{15} — 100,000 ohms, 1 watt
R_{16}, R_{17} — 2 meg., ½ watt
R_{18}, R_{19}, R_{20} — 100,000 ohms, 1 watt
R_{21}—50,000-ohms pot.
R_{22}—25,000 ohms, 50 watts
R_{23}—75,000 ohms, 100 watts
R_{24}—100,000 ohms, 100 watts
R_{25}—750 ohms, 10 watts
RFC—2.5 mh., 125 ma.
RFC_1—2.5 mh., 500 ma.
M_1—0-100 ma. d.c. or meter jack
M_2—0-200 ma. d.c.
M_3—0-100 ma. d.c. or meter jack
M_4—0-500 ma. d.c.
M_5—0-500 ma. d.c.
T_1—5 v. 6 amp.
T_2—5 v. 15 amp.
T_3 — Push-pull input trans.
T_4—Class-B input for 203Z
T_5 — 300-watt variable ratio modulation transformer
T_6—440 v. each side c.t., 250 ma., and indicated fil. windings
T_7—10 v. 7.5 amp.
T_8—1500 v. each side c.t., 300 ma.
T_9—2.5 v. 10 amp., h.v. insulation
T_{10}—2200 v. each side c.t., 300 ma.
T_{11}—2.5 v. 10 amp., h.v. insulation
CH_1, CH_2—12 hy., 200 ma.
CH_3—5-20 hy. 300 ma.
CH_4—12 hy. 300 ma.
CH_5—5-20 hy., 300 ma.

would not be advisable for 10-meter operation due to the high minimum capacity, the following expedient is resorted to: the 75-meter amplifier plate coil is made slightly lower Q than optimum. The same coil is then used on 160 meters by shunting a fixed vacuum padding condenser of 50-μμfd. capacity across the tank tuning condenser. This results in a Q slightly higher than optimum for 160-meter operation, but the compromise design of the coil results in operation substantially as satisfactory as would be obtained with separate 75-meter and 160-meter coils.

The Speech System

The speech amplifier-driver and 300-watt modulator are conventional except for the incorporation of automatic peak compression to allow a higher average percentage of modulation without the danger of overmodulation on occasional loud voice peaks. The delay action (percentage modulation at which compression starts) can be adjusted by means of the potentiometer R_{21}. The modulators are fed from the same 1250-volt supply that furnishes plate voltage to the buffer amplifier.

All leads and components in the 6J7 first speech stage should be shielded to prevent grid hum and possible feedback. TZ40's can be substituted for the 203Z's by utilizing 9 volts of fixed battery bias. The tubes will supply sufficient output for complete modulation of 600 watts input when voice is used, though their life will not be as long as that of 203Z's.

The Power Supplies

The 350-volt and the 1250-volt power supplies are built on one chassis; the

1900-volt supply has a chassis all its own. To keep the carrier hum at a very low level, a two-section filter is used in the 1900-volt supply feeding the modulated amplifier. As the push-pull modulators and the r.f. driver stage are relatively insensitive to a moderate amount of plate supply ripple, a single-section filter suffices for the 1250-volt supply.

While it is desirable to have six meters to facilitate reading of all important grid and plate current values simultaneously, it is possible to get by with fewer meters by incorporating metering jacks. Such jacks should be placed in filament return leads rather than in plate leads when the plate potential is over 500 volts. Meters in filament return jacks read combined grid and plate current, and the grid current should be subtracted from the meter reading to determine the actual value of plate current.

Construction

The mechanical construction and layout of components can be observed in the various illustrations. All chassis measure 13″x17″x1½″ and have end brackets to strengthen them. All panels are of standard 19″ width, with heights as follows: final amplifier 12¼″, exciter 8¾″ all others 10½″.

Operation

Initial tuning of as elaborate and expensive a transmitter as this should preferably be done by an experienced amateur familiar with tuning and adjustment of high-power phone transmitters. General considerations regarding transmitter tuning and adjustments are covered in the transmitter theory chapter. The following meter readings are typical of normal operation:

6L6G cathode current: 35 to 60 ma.
Buffer grid current: 10 to 15 ma.
Buffer plate current: 50 to 75 ma. as buffer; 80 to 100 ma. as doubler.
Final plate current: 300 to 325 ma.
203Z plate current: 75 to 100 ma. static, swinging up to approximately 200 ma. on voice peaks.

SIXTEEN

U. H. F. and Mobile Communication

THE very-high frequency or *ultra-high frequency* range may be said to extend from 30 megacycles (10 meters) to infinity. Frequencies higher than 300 Mc. (1 meter in wavelength) are usually classed as *microwaves*, though they are still part of the u.h.f. range. The microwaves extend into the region of heat wavelengths, thence into the wavelengths of light.

The 10 meter amateur band, 28,000 to 30,000 kc., is neither "fish nor fowl"; it isn't strictly a u.h.f. band, yet in some respects can be considered as such. Throughout a good portion of the year the band is "open" some time during the day and sky-wave communication can be carried on with fair reliability at these times. Also, it is possible to get most any transmitter using modern tubes to work after a fashion on 10 meters if reasonable care is exercised to keep the leads short in the final amplifier.

On the other hand, the ground wave of a 10-meter signal acts very much as does the ground wave of a signal on the 5-meter band. In fact, when used for mobile work, 10 meters is primarily a "local" band, even though with mobile equipment dx contacts are possible under favorable conditions. Also, because of restrictions in the regulations, mobile gear is never used on the amateur bands below 28 Mc. Due to this, 10-meter mobile equipment is designed much as it would be for 5 meters: very short leads, small tuning condensers, self-supporting coils, etc. This results in maximum efficiency on 10 meters.

For these reasons the 10 meter band will be considered in this chapter as a "u.h.f. band" when used for mobile work, but is regarded as being outside the u.h.f. category when fixed station equipment is concerned.

U.H.F. CONSIDERATIONS

Very short radio waves (5 meters and below) behave very much like light waves and are not often reflected or refracted by the Heaviside layer. These radio waves are most useful over quasi-optical paths, i.e., between points which are nearly in visual range with one another. The wavelength used for radio communication in the u.h.f. range, however, is thousands of times greater than that of light; there is a greater curvature of the paths of the radio waves. For this reason the range is somewhat greater than can be obtained by means of light rays, and signals can, therefore, be received from points beyond the horizon.

The range of transmission is governed by the height of the transmitting and receiving antennas. Objects that lie in the path of the transmitted wave introduce a *shadow effect*, which often prevents reception of the transmitted signal. This shadow effect can be overcome to some extent by using higher power in the transmitter.

Occasionally, the radio waves in the range of 56 to 60 Mc. are reflected back to earth by the Heaviside layer with the result that these signals can be heard over distances of a few hundred, or even a few thousand, miles. This type of long-distance communication is extremely erratic, and the practical service of the ultra-high frequencies lies in the short-distance visual range.

The occasional reflection of 5-meter signals from the Heaviside layer seems to depend upon sun spot activity and the season of the year, as well as the time of day. At distances somewhat beyond the horizon, reception is often erratic because the atmosphere changes its temperature in layers close to the earth which, in turn, may change the amount of refraction of the 5-meter signals. Refraction bends the radio waves into a curve along the earth's circumference and, therefore, increases the range of the radio wave beyond the optical distance.

Very little transmitter power is required for communication in the u.h.f. range over optical distances. The following formula can be used for calculating the optical range of transmission and reception:

$$X = \frac{2\,d^2}{3},$$

where

X = height of the u.h.f. antenna in feet,

d = distance in miles.

This empirical formula can be used to calculate the height of an antenna in order to obtain any given distance of transmission to the optical horizon (in level country). If the receiving antenna is also located at some height above ground, the range will be increased and the same formula can again be used. For example, if the transmitting antenna is located at a height of 75 feet above ground, the transmission range will be found as follows:

$$75 = 2/3 \times d^2,$$

thus $d = 10.5$ miles.

If the receiving antenna is 30 feet high, the optical range can be found from the same formula, i.e., $30 = 2/3 \times d^2$ or $d = 6.7$ miles. The receiving station could, therefore, be located 6.7 + 10.5 or 17.2 miles from the transmitter and still be within the optical range. In this case, the radio wave will just graze the surface of the earth in reaching the receiving location and would tend to be cancelled at the earth so that the signal at the receiving station would be considerably attenuated. The tendency of u.h.f. waves to be curved along the surface of the earth by refraction compensates for their tendency to be reflected upward from the surface of the earth; so this range can be maintained, provided that no large objects lie between the transmitter and receiver locations.

Amateur operation is permissible for both voice and c.w. communication in the ranges 56 to 60 Mc., 112 to 116 Mc., 224 to 230 Mc., 400 to 401 Mc. and 401 Mc. and beyond.

The regulations stipulate that a high degree of stability must characterize 56 Mc. signals. This calls for crystal control or else a m.o.p.a. having a stabilized oscillator (high Q tank). On 112 Mc. the requirements are not so stringent, and simple, modulated oscillators and transceivers can be used.

Transmitters for battery portable operation can operate successfully with power outputs of one watt or less. Those for mobile operation usually have an output of from 5 to 10 watts; fixed amateur stations commonly use power outputs varying from 5 to 30 watts. Experimental and commercial stations require higher outputs; values of several kilowatts are desirable for reliable general coverage over a radius of 25 or 30 miles.

U.H.F. RECEIVERS

Radio and television receivers for the u.h.f. region vary in design from simple one-tube radio receivers up to as many as 25 or 30 tubes in a television receiver. In the more complex types of u.h.f. radio receivers, the superheterodyne circuits are quite similar to those used in the short-wave and broadcast ranges. The design of tuning coils and inductances is somewhat different if they are to function successfully in the u.h.f.

range. U.h.f. receivers of several types are described in *Chapter 6* and later in this chapter.

Superregeneration

Regeneration carried beyond the point of oscillation, called *superregeneration,* is used extensively for reception of radio waves in the range of from 10 down to ½-meter. Superregeneration is accomplished by allowing the detector to oscillate, then damping out the oscillations a great many times per second (at a rate above audibility). This increases the sensitivity of the detector to an enormous degree for weak signal reception. Superregeneration becomes more effective at higher frequencies, and since the selectivity of a superregenerative receiver is very poor in comparison with ordinary regeneration, this type of receiver can be used successfully to receive the simple modulated oscillator transmitter signals which are so common on 2½ meters.

Superregeneration can be obtained with a simple, regenerative "autodyne" circuit simply by increasing the value of the grid leak to a sufficiently high value and providing an abundance of feedback. This is known as a blocking grid-leak type of superregenerative circuit, and the u.h.f. oscillation is started and stopped at a rate above audibility, determined by the grid leak and grid condenser values. The oscillator may be said to be *self-quenching.*

This type of circuit functions as an ordinary oscillator in which the resistance of the grid leak is too high to permit the electrons on the grid to leak off at a rate that will give constant value of grid-bias voltage. Such blocking action causes a change in the average grid bias and stops the u.h.f. oscillation because the plate current is decreased and the mutual conductance of the tube also decreases during the blocking action. If the circuit constants are correct, this blocking action takes place at an inaudible high-frequency rate and superregeneration is accomplished. Quite often best results are obtained when the grid leak is returned (through the coil) to the positive side of the power supply.

Damping or Quenching Action

Damping or quenching action can be obtained by means of a separate oscillator which functions at some inaudible frequency, such as 100,000 cycles per second, as shown in figure 1. The interruption-frequency circuit consists of an oscillator tuned to about 100,000 cycles per second, connected so that this oscillation modulates the d.c. plate supply to the u.h.f. detector. To do so, R.F.C. must be no larger than 0.1 mh. and C_4 should be about .006 μfd. The latter is an ordinary oscillator which is made superregenerative by means of the interruption-frequency oscillator. The interruption-frequency voltage varies the detector plate voltage to such an extent that the detector goes in and out of oscillation at a rate determined by the interruption-frequency oscillator circuit constants.

Fairly heavy antenna loading or coupling is required in either circuit in

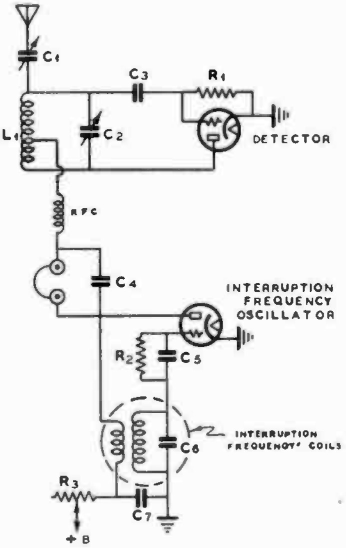


Figure 1.
SUPERREGENERATOR WITH SEPARATE QUENCH OSCILLATOR.
This superregenerative u.h.f. receiver circuit uses a separate oscillator to generate the interruption frequency.

order to obtain good audio quality and sensitivity. Too much antenna coupling will pull the detector out of superregeneration. The antenna system can be either inductively or capacitively coupled to the detector tuned circuit or to an r.f. amplifier preceding the detector. Superregenerative detectors connected directly to an antenna radiate a signal fully modulated by the quenching frequency and thereby cause bad interference in other receivers for a radius of several miles. The blocking-grid-leak detector is more troublesome in this respect. In either case, a radio-frequency amplifier should be connected ahead of the superregenerative detector in order to eliminate or minimize receiver radiation into the antenna system.

A. V. C. Effect

A superregenerative detector has an automatic volume control effect, in that it has high sensitivity to weak signals and low sensitivity to strong signals. This action greatly reduces automobile ignition interference, since the latter is usually of very strong intensity, but fortunately of short time amplitude. The detector sensitivity automatically drops down during the small fraction of a second in which this noise impulse is present, and, although the desired signal is also reduced, the human ear will not respond to changes of such short duration. The ignition interference, therefore, does not cause an excessively loud signal in the audio output as compared with the strength of the desired phone signal. The high sensitivity of a superregenerative detector, when no carrier signal is present, results in a loud audible hiss or rushing sound in the output circuit and is due to thermal and contact noise in the detector circuit and to the quenching effect. A fairly strong carrier signal automatically reduces the sensitivity of the detector and, consequently, reduces the background noise or hiss; a strong signal will completely eliminate the background noise. The hiss present when receiving weak signals usually is not objectionable after one becomes accustomed to it.

WAVELENGTH OR FREQUENCY DETERMINATION

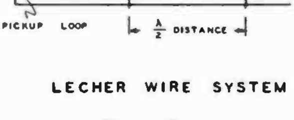
Transmitter and receiver frequency or wavelength checking can be accomplished by means of parallel-wire measurements (Lecher wire system), by wavemeters or by means of harmonics from a crystal or calibrated low-frequency oscillator. The parallel wire or Lecher wire system is very easily applied to wavelength measurements in the microwave region.

Lecher Wire Systems

A Lecher wire measuring system consists of a pair of parallel wires, short-circuited at one end in order to provide a pickup loop which can be coupled to the tuned circuit of the transmitter or receiver. The energy induced into the parallel wires establishes standing waves of voltage and current along the wire, and these standing waves can be located with a sliding bar or copper wire, as shown in figure 2.

A single sliding bar can be moved along the parallel wires until two successive points are located which produce a change in the oscillator plate or grid current, or in the receiver noise level when the pickup loop of the parallel wire system is inductively coupled to the circuit under test. The distance between these two points is a half wavelength, and this value can be converted from feet or inches into the wavelength in meters by multiplying the number of feet by 0.656 or the number of inches by 0.0547.

For microwave measurements, the distance between half-wave points is usually measured in inches and converted to



LECHER WIRE SYSTEM

Figure 2.

wavelength in centimeters by multiplying the number of inches by 5.47. This conversion factor takes into consideration the conversion into the metric system and the fact that the distances are a half-wave apart. The result is the actual wavelength of the oscillator. An accuracy of approximately 1 per cent can be expected; for more accurate frequency or wavelength determination, the harmonic method should supplement these measurements.

A Lecher wire system suitable for measurement of wavelengths below one meter can be made by stretching two no. 12 bare copper wires approximately 1-inch apart. Each wire has a length of about 50 inches; this length will depend upon the wavelength being measured. Lengths of 35 to 40 feet will be necessary for 10-meter measurements. The spacing between wires can be as much as 3 or 4 inches for wavelength measurements above 10 meters.

A Lecher wire system can consist of a long wooden framework and some means of clamping or stretching the two parallel wires to prevent sag or change in wire spacing. No supports or insulators should be connected to the parallel wires in the actual measuring range between the two half-wave points over which the sliding bar is moved.

U. H. F. Wavemeters

Absorption-type wavemeters are easily constructed and considerable time can be saved in making oscillator wavelength measurements by this means rather than by Lecher wires. These wavemeters can be calibrated by means of a superregenerative receiver and harmonics from a calibrated low-frequency oscillator or by means of Lecher wire comparative measurements. A simple absorption-type wavemeter which has a range of about 4.5 to 7 meters can be constructed by connecting a 5-turn coil of wire across a 25-$\mu\mu$fd. midget variable condenser which is in parallel with a 20-$\mu\mu$fd. midget fixed condenser as shown in figure 3.

The turns can be squeezed in and out to spot the 5-meter band on the center of the condenser dial and the device then calibrated from known frequencies or Lecher wires. The coil can be wound with no. 10 wire in a winding length of 1-inch and with a diameter of about ½-inch.

A similar type of wavemeter with a range of from 4 to 14 meters can be made with a 150-$\mu\mu$fd. variable condenser connected across a 2-turn coil, 2 inches in diameter. Hand-capacity effects can be eliminated by turning the condenser with a bakelite extension shaft. A two-turn coil, approximately ⅝-inch diameter, tuned with a 15-$\mu\mu$fd. condenser, will cover the range of 2 to 3 meters. These absorption-type wavemeters are inductively coupled to the tuned circuit in the transmitter or receiver under measurement. When the wavemeter is tuned to the same frequency or wavelength as that of the oscillator under measurement, a change in plate or grid current will be noted.

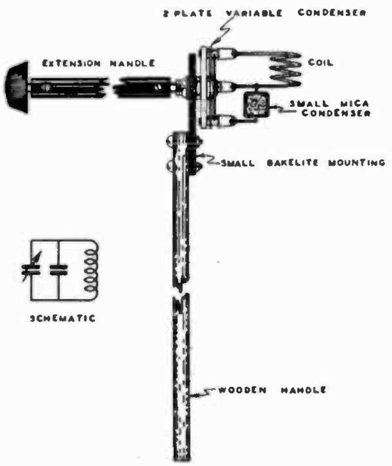


Figure 3.
ABSORPTION TYPE U.H.F. WAVEMETER.

Harmonic Frequency Determination

A calibrated low-frequency oscillator, such as a quartz crystal, will provide an accurate means of frequency determination in the range of from 2 to 10 meters. An oscillating quartz crystal in the 160- or 80-meter amateur bands will produce strong harmonics in the u.h.f. region between 2 and 10 meters. A superregenerative receiver, when tuned to this region (while very loosely coupled to the oscillator), will indicate the harmonics by sharp reductions in hiss level in the receiver output. An absorption wavemeter can be coupled to this receiver and calibrated by this means. More accurate measurements can be made by using an oscillating regenerative receiver or a superheterodyne receiver equipped with a beat-frequency oscillator. Such receivers can be tuned to zero-beat with the harmonics, and then to the u.h.f. oscillator or transmitter for accurate frequency determination.

ANTENNA SYSTEMS

Many types of antenna systems can be used for u.h.f. communication. Simple, non-directive half-wave vertical antennas are desirable for general transmission and reception in all directions. Point-to-point communication is most economically accomplished by means of directional antennas which confine the energy to a narrow beam in the desired direction. If the power is concentrated into a narrow beam, the *apparent* power of the transmitter is increased a great many times.

The useful portion of a signal in the u.h.f. region for short-range communication is that which is radiated in a direction parallel to the surface of the earth. A vertical antenna transmits a wave of low-angle radiation which is vertically polarized. For best results, vertical receiving antennas should be used to receive signals from a vertical transmitting antenna.

Vertically-polarized radio waves are not easily reflected upward by the surface of the earth as are horizontally-polarized waves. Horizontal antennas can be used to advantage during the occasional periods in which the 5-meter signals are reflected from the Heaviside layer.

The antenna system for either transmitting or receiving should be as high above earth as possible and clear of nearby objects. Transmission lines, consisting of concentric-line or spaced two-wire lines, can be used to couple the antenna system to the transmitter or receiver. Nonresonant transmission lines are more efficient at these frequencies than those of the resonant type.

Antenna design data, charts, tables and graphs for simple and complex antennas and arrays are covered in the chapter on *Antennas*.

U. H. F. TRANSMITTERS

The primary activity on the u.h.f. bands is telephony, though some i.c.w. and occasionally some c.w. is heard. On 28 and 56 Mc., radiophone transmitters are either crystal controlled or else m.o. p.a. with a very high Q self-excited oscillator and preferably at least one buffer stage. Modulated oscillators are not suitable for use on this band, as the stability requirement as set forth in the F.C.C. regulations automatically rules them out.

On 2½, 1¼ and ¾ meters the F.C.C. is more lenient, and modulated oscillators are permitted in the interest of simplicity. However, some attempt at stabilizing the oscillator usually is made. This is commonly done by the use of high Q circuits, particularly in the grid circuit. High Q is obtained by the use of linear tanks (parallel rods) or by concentric pipes. The Q is often increased still further in the grid circuit by tapping down on the quarter-wave section for the grid connection.

2½ meter portable and mobile communication with a minimum of equipment is made possible through the use of *transceivers*. As the name implies, a transceiver is a combined transmitter and receiver. One tube (usually a triode) serves as the modulated oscillator when transmitting and as a superregenerative detector when receiving. Another tube (usually a power pentode or beam tetrode) serves as a modulator when transmitting and as an audio amplifier when receiving. The various circuits are switched by means of a multiple-pole double-throw switch.

10 WATT 2½-METER RADIOPHONE

The newcomer interested in working u.h.f. telephony can get on the air with the least amount of equipment by choosing the 2½-meter band. Illustrated in figure 4 is a 10 watt 2½-meter oscillator which shows good stability and efficiency. The modulator and power supply are built on another board.

The range of this transmitter will depend almost entirely upon the location, particularly the height of the antenna above the surrounding countryside. With a vertical dipole antenna atop a 40-foot pole it is possible to work 25 miles consistently in level country.

The oscillator is built on a baseboard measuring 5 x 23 x ¾ inches. The two rods are each 15½ inches long, of either copper or aluminum ⅜ inch o.d. tubing. They are supported on 1½-inch standoff insulators, placed as shown.

The "stock" supporting the tubes is made from a block of wood measuring 4¼ x 2½ x ¾ inches. The grain should run the long way of the block. Holes are drilled just large enough to take the bases of the tubes, their centers 1⅝" apart and ⅞" from one of the 4¼" edges. Now with a rip saw, cut the length of the block parallel to the long edges, through the centers of the two socket holes. The tubes will be held firmly, with a viselike grip, when two screws are run down through the assembly and into the baseboard 5 inches from one end of the latter.

This method of mounting the tubes, and soldering direct to the tube prongs, permits shorter leads than could be obtained with any type socket, as even socket terminals represent objectionable lead length at this frequency.

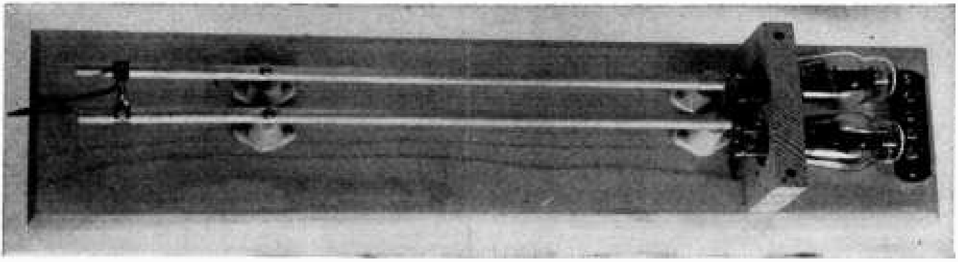


Figure 4.
2½-METER BREADBOARD OSCILLATOR USING PUSH PULL 76'S.

The oscillator is built breadboard fashion, with connections made directly to the tube prongs. The linear tank circuit permits high efficiency and an output of about 10 watts. A suitable modulator and power supply are shown in the diagram.

Bakelite tube bases show rather high losses at 2½ meters, but it is possible to reduce these losses by putting two hacksaw slots in each base, as shown in the insert in the upper right corner of figure 5. Be sure to saw all the way through the base (about 1/16"), but don't go any farther or you may saw into the glass tip that seals the stem of the tube.

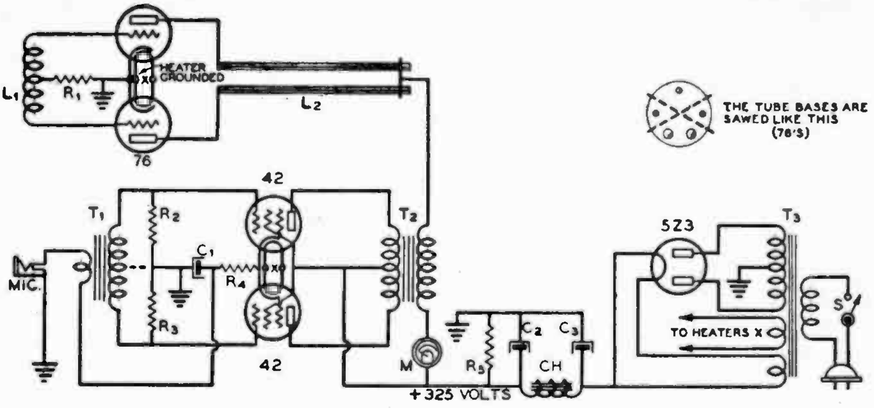


Figure 5.
GENERAL WIRING DIAGRAM OF THE COMPLETE TRANSMITTER.

L_1—5 turns no. 14 enameled, ½" dia., spaced to approx. ⅝" (see text)

L_2—Copper or aluminum tubing "linear tank," each element ⅜" dia., 15½" long, spaced 1¼" center to center (see text)

C_1—25-µfd. 25-volt electrolytic

C_2, C_3—Single "dual 8-µfd." electrolytic, 450 w.v.

R_1—7500 ohms, 1 watt

R_2 R_3—200,000 ohms, 1 watt

R_4—400 ohms, 10 watts

R_5—50,000 ohms, 2 watts

T_1—High ratio sing. button mike trans. (see text)

T_2—Class-B output transformer for 6N7, 6A6, 53, etc. to class-C load

T_3—350 v. each side c.t. at 110 ma.; 5 v. at 3 amp.; 6.3 v. at 2 amp.

CH—10 to 30 hy., 110-ma. filter choke

M—0-100-ma. milliammeter

MIC—Closed circuit jack for microphone

The grid coil is soldered directly to the grid prongs of the tubes, which should be mounted with the grid prong (the isolated prong) upward. The coil consists of 5 turns of no. 14 enameled, spaced to approximately ⅝". The exact spacing constitutes tuning of the grid circuit. The carbon resistor which serves as a grid leak is mounted vertically between the grid coil and the wood "stock." The top of the resistor is soldered to the center turn of the grid coil (top of the coil) and the other resistor lead is soldered to the jumper which connects the two 76 cathodes.

The sliding jumper for the plate tank is constructed by soldering together two of the older type grid clips which just slip over a ⅜" diameter. These make firm contact to the rods, and can be slid along by pressing upon the two "tongues" while attempting to slide them. The lead from this jumper runs underneath the baseboard *midway between the two tank rods* to prevent unbalancing of the circuit.

Tuning

The oscillator is tuned by placing the shorting bar 14½ inches from the plate end of the plate tank rods. With the antenna disconnected, squeeze the grid coil in and out until the oscillator draws 50 ma. It should be possible to draw small sparks from the plate end of the rods with the tip of a lead pencil, indicating oscillation. The antenna is now coupled to the plate tank by means of hairpin link, the coupling being adjusted until the oscillator draws 60 ma. Tighter coupling should not be used, as the life of the 76's will be greatly shortened if they are allowed to draw over 60 ma. for any length of time. The output under these conditions will be very close to 10 watts.

The microphone jack, MIC, must be of the closed circuit (shorting) type. Otherwise the low voltage by-pass condenser C_1 will be blown when the microphone plug is removed.

30 WATT 1¼ AND 2½-METER LINEAR TANK OSCILLATOR

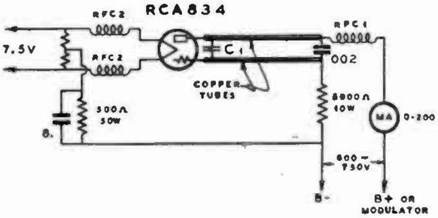
The Western Electric 304-B, Eimac UH-50, and RCA 834 are equally suitable for use in the transmitter shown in figures 6 and 7. The characteristics of these three tubes are similar.

The circuit in figure 6 is suitable for oscillation between 1 and 3 meters, depending upon the length of the parallel rods or pipes. This oscillator delivers about three times as much output on 2½ meters as the push-pull 76 oscillator just described, or about 30 watts. On 1¼ meters the output is about 20 watts.

A slight variation of frequency is possible if two condenser plates each ¾-in. square are connected across the pipes near the tube leads. This type of circuit works more efficiently than a conventional coil and condenser oscillator circuit. The tube leads fit into the ends of copper pipes, and small set screws provide good electrical contact between pipe and tube leads. This type of mounting must be used with care in order to avoid breakage of the tube envelope. The tube socket mounting strip should have slotted holes in order to make correct alignment with the copper pipes.

Figure 6.

SINGLE ENDED LINEAR TANK OSCILLATOR.



C_1—Aluminum plates, ¾-in. square
Copper tubes—3 in. long for 1¼ meters
Copper tubes—9 in. long for 2½ meters

RFC$_1$—40 turns no. 28 d.s.c., ¼-in. diam.

RFC$_2$—25 turns no. 14 enam., ½-in. diam.

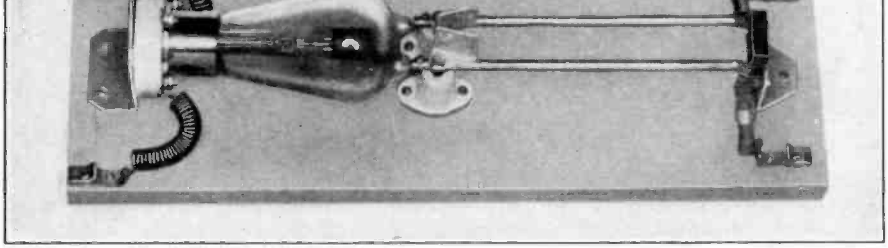
Filament r.f. chokes are necessary below 3 meters in order to secure oscillation. At 1¼ meters, the metal shell of the tube socket, and the metal support that holds the socket, introduce excessive capacity to the filament circuit of the tube, resulting in nonoscillation if either of these metal surfaces is grounded. A nonmetallic socket and socket support would be preferable if operation in the neighborhood of 1 meter is wanted. A tuned filament circuit, somewhat similar to the type used with filament tubes in a *tritet*, will work more effectively than r.f. chokes for wavelengths below 1½ meters.

The antenna feeder is coupled to the parallel pipes or tubes by means of a

Figure 7.

THE LINEAR TANK OSCILLATOR OF FIGURE 6 WITH 2½-METER RODS IN PLACE.

Either an RCA-834, WE-304B, or Eimac UH-50 may be used. The oscillator is tuned over the band by varying the spacing of the two small movable plates on the standoff insulators.



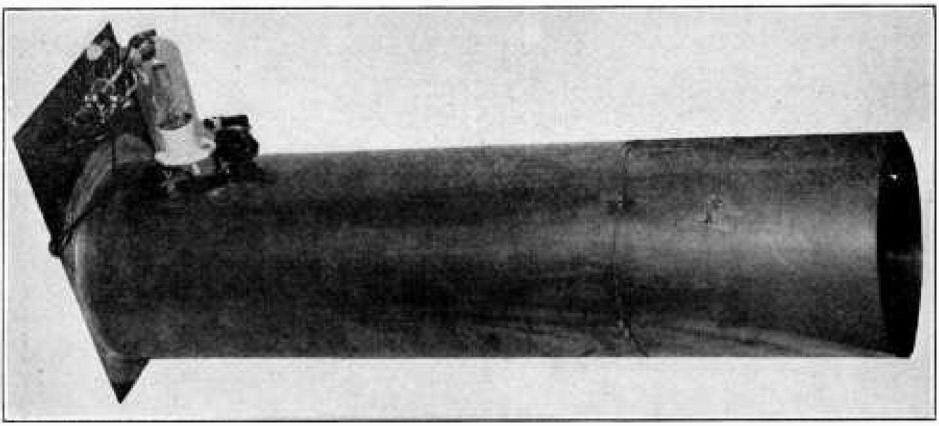


Figure 8.

2½ METER CONCENTRIC PIPE OSCILLATOR.

The concentric pipe grid tank has very high Q, resulting in excellent frequency stability.

coupling loop. A half- or quarter-wave antenna can be capacitively coupled through a very small variable condenser to the plate rod at a point approximately one to two inches from the plate blocking condenser.

On 2½ meters 750 volts may be applied to the oscillator, but on 1¼ meters it is advisable to reduce the plate voltage slightly. The oscillator may be modulated by any modulator delivering 25 or more sine wave watts to a 6000 ohm load.

30 WATT 2½ METER CONCENTRIC PIPE OSCILLATOR

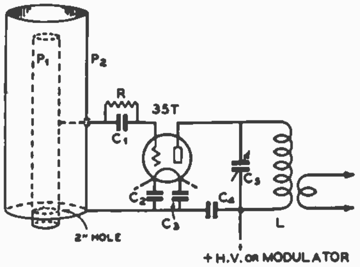
A concentric-pipe oscillator suitable for the amateur 2.5-meter band can be made as shown in the illustrations, figures 8 and 9.

The output and efficiency are approximately the same as for the single ended linear tank oscillator just described, but the frequency stability is much better, due to the very high Q obtained in the grid circuit.

The grid of a 35-T tube is connected to the inner pipe at a point about 6 inches from the short-circuited end. The outer pipe is 30 inches long and is soldered to a copper sheet through which the inner pipe slides; this inner pipe is 27 inches long and from 24 to 25 inches of the pipe extend into the larger pipe. Waxed linen cords are wrapped around the inner pipe in order to center its position with respect to the outer pipe. The quarter-wave pipe tuned circuit controls

Figure 9.

WIRING DIAGRAM OF 35-T CONCENTRIC PIPE OSCILLATOR.



C_1—.0001-μfd. midget mica

C_2, C_3—.001-μfd. mica, 600 v.

C_4 — .001-μfd. mica, 2500 v.

C_5—4-μμfd. double-spaced midget (neutralizing condenser)

R—10,000 ohms, 10 watts

P_1—2"-dia. copper pipe 27" long slides inside P_2 through 2" hole in copper end plate

P_2—30" x 24" piece 16-oz. copper sheet formed into a pipe 30" long by 7¼" dia.

L—3 t. ⅝" dia. no. 14 soldered directly to C_5.

the frequency of operation and results in a highly stable self-excited oscillator.

The entire transmitter should be suspended by a shock absorbing system in order to prevent vibration, which would impair the frequency stability.

At 800 volts on the plate, the plate current will run around 70 ma. with the oscillator fully loaded. It is not advisable to apply over 900 volts, especially if the oscillator is modulated.

The oscillator can be plate modulated with very little frequency modulation, or it can be used to drive a high power class C amplifier.

HIGH POWER 2½ METER LINEAR TANK OSCILLATOR

A parallel rod oscillator utilizing two sets of quarter-wave parallel rod tuned circuits is shown in figures 10 and 11. The parallel grid rods act as a high-Q circuit, giving a high degree of frequency stability. These rods are approximately 2¼ feet long for the 2.5-meter band. The lower ends of the grid rods are connected to a short-circuiting copper plate, and the two grid leads are tapped to the rods a few inches above the copper plate.

The plate tuning rods are nearly as long as the grid rods, and a sliding shorting-bar, or connection, tunes this circuit to resonance as indicated by minimum plate current. The oscillator is a tuned-grid-tuned-plate circuit in which the grid circuit controls the frequency of operation.

Plate modulation can be used without excessive frequency modulation, though such use should be confined to 1¼ and 2½ meters. The antenna can be inductively coupled to the plate rods or directly coupled to the rods through fixed mica condensers which are connected to the rods near the shorting bar. The coupling can be adjusted so that normal plate current is drawn.

Figure 10.
HIGH POWER 2½ METER LINEAR TANK OSCILLATOR USING HK-354-C GAMMATRONS.

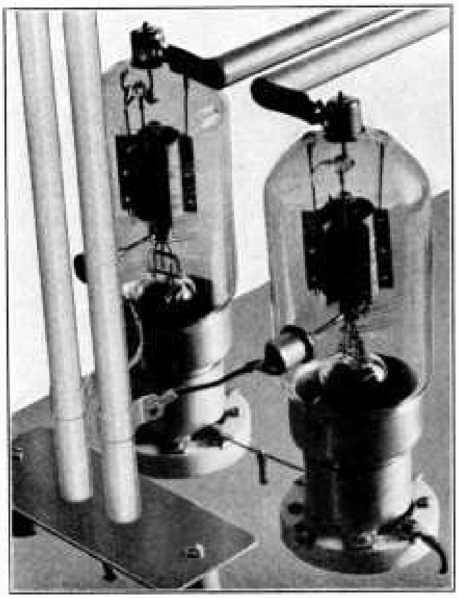
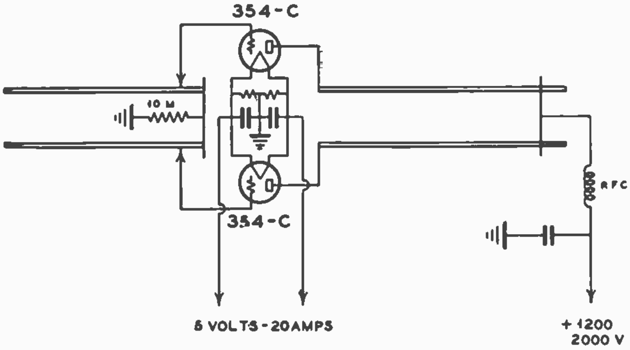


Figure 11.
WIRING DIAGRAM OF HIGH POWER LINEAR-TANK OSCILLATOR.

This oscillator will deliver over 300 watts on 2½ meters, and has good frequency stability. RCA-806's or Eimac 250-TL's may also be used.



CRYSTAL CONTROLLED AND M. O. P. A. TRANSMITTERS

SIMPLE CRYSTAL-CONTROLLED 5-M. EXCITER OR TRANSMITTER

The use of a 10-meter crystal makes it possible to construct a very simple, but highly effective, 5-meter crystal-controlled transmitter using only two stages. The r.f. unit illustrated in figures 12 and 13 delivers between 3 and 5 watts output when fed from a 300-volt supply. A regenerative 10-meter triode crystal oscillator drives a triode doubler, which may be plate-modulated for phone by a single 6V6 or 6L6 (or glass equivalent).

An RK34 dual triode permits a physical layout resulting in very short r.f. leads. This and the high output of the regenerative oscillator largely contribute to the high overall efficiency. The regenerative oscillator is of the type described and discussed in detail in the exciter chapter. It gives very good output

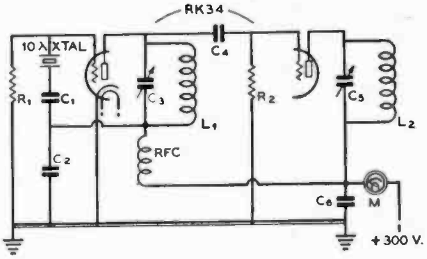


Figure 12.

WIRING DIAGRAM OF THE 5-METER TWO-STAGE CRYSTAL-CONTROLLED TRANSMITTER.

C_1—.001-μfd. midget mica
C_2—.0001-μfd. midget mica
C_3—25-μμfd. midget variable
C_4—.0005-μfd. midget mica
C_5—15-μμfd. midget variable, preferably ceramic insulation
C_6—.005-μfd. mica
R_1—25,000 ohms, 1 watt
R_2—50,000 ohms, 2 watts
RFC — Midget 2.5-m.h. r.f. choke
M—0-100 ma. d.c.
L_1, L_2—Refer to text

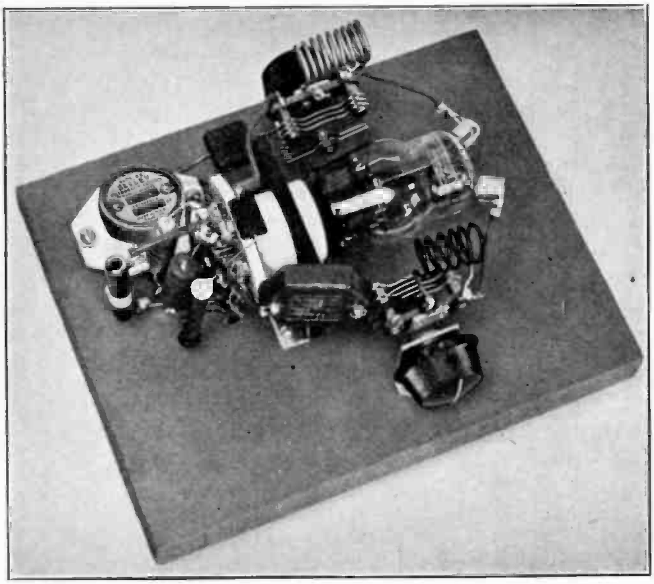


Figure 13.

SIMPLE 5-METER 5 WATT R.F. UNIT USING 10 METER CRYSTAL.

This r.f. unit delivers from 3 to 5 watts on 5 meters when fed from a 300-volt supply. It may be modulated by a single 6V6 or 6L6 for either mobile use or operation at the home station.

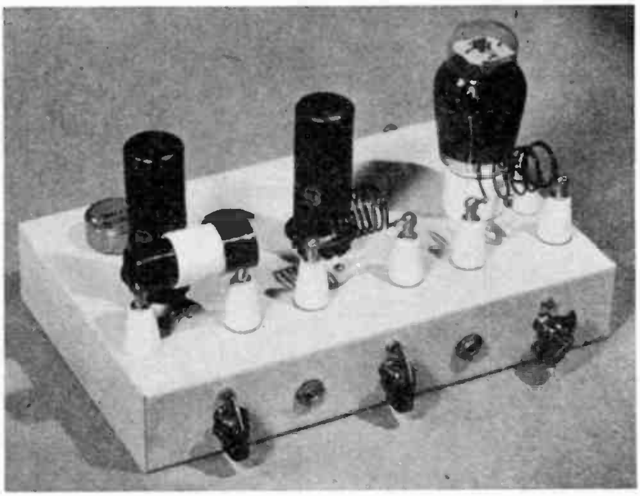


Figure 14.
THREE STAGE 20 WATT CRYSTAL CONTROLLED 56 MC. UNIT.
A 6L6 oscillator on 7 Mc. drives a 6L6G quadrupler, which in turn drives a T21 doubler on 56 Mc.

with less than 100-ma. r.f. crystal current which is well within the maximum allowable value for 10-meter crystals.

This unit can be used in conjunction with a modulator for either mobile or stationary operation, or it can be used as an exciter to drive a higher-powered 5-meter amplifier, such as a pair of push-pull 807's.

Both tank circuits are tuned for maximum output. If the total plate current to both sections exceeds 75 ma., the loading on the doubler section is too heavy and should be reduced by using looser coupling.

The oscillator coil L_1 consists of 9 turns of no. 14 enamelled, ¾″ in diameter and spaced 1¼″ long. The doubler amplifier coil L_2 consists of 6 turns of the same wire-wound the same diameter, spaced ¾″ long.

20 WATT CRYSTAL CONTROLLED 14, 28, 56 Mc. TRANSMITTER OR EXCITER

The crystal controlled 56 Mc. r.f. unit illustrated in figures 14 and 15 and diagrammed in figure 16 uses conventional circuits and low cost parts. With but three stages and a 7-Mc. crystal, it supplies 20 husky watts of crystal controlled, 56-Mc. or 28 Mc. r.f. For phone operation the output stage may be modulated by a 25-watt modulator. As an exciter it has sufficient output to drive a 56-Mc. final stage to 200 watts input.

The chassis measures 12 x 7 x 2 inches. As can be seen from the photographs, the tubes are evenly spaced along the center of the chassis. Each plate coil is directly in front of the tube with which it operates. The tank condensers are mounted on the front lip of the chassis directly below their respective coils. Small jack type feed-through insulators are used to support the plug in coils and at the same time to provide connections to the condensers. Banana plugs on the coils allow quick and easy band change.

Inasmuch as each tuned circuit is on a different frequency, placing the coils in line along the front of the chassis does not have any adverse effect on the operation of the unit.

Underneath the chassis, parts are placed where convenience dictates. The T21 stage has all its ground return connections made to the feed-through insulator which is at the cold end of the plate tank. While this does not enhance the appearance of the unit, it aids in eliminating coupling in the various ground return circuits.

Two feed-through insulators at the rear of the chassis are provided for the connections from the modulator. If the

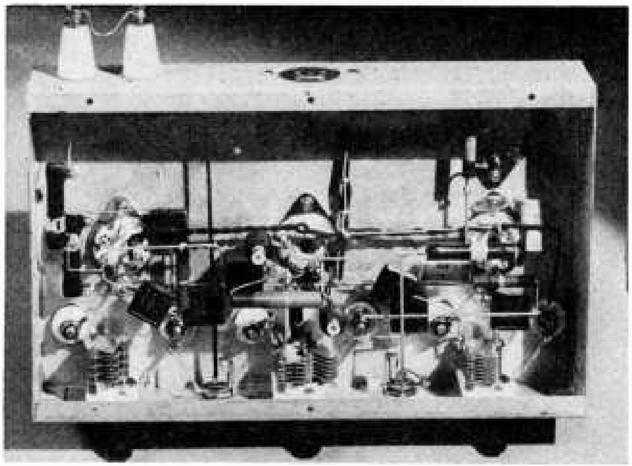


Figure 15.
UNDERNEATH THE CHASSIS OF THE 56-Mc. R.F. UNIT.

Note how relatively few components are used for the three stages.

unit is used as an exciter or c.w. transmitter, these terminals are simply shorted together.

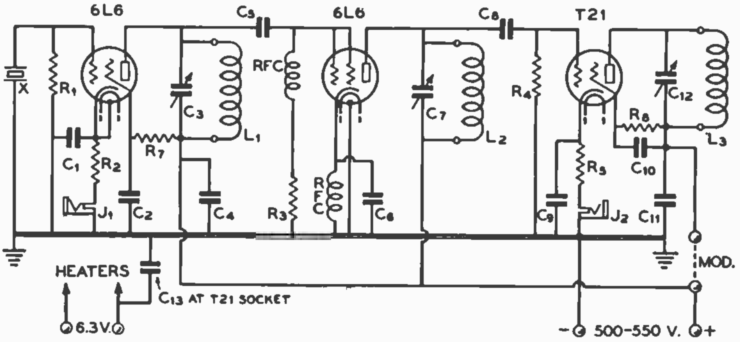
The second 6L6 acts either as a doubler or quadrupler, depending upon the crystal frequency and desired T21 output frequency. Thus with a 40 meter crystal, 10 or 5 meter output is obtainable from the T21. With an 80 meter crystal, either 20 or 10 meter output is obtainable from the T21.

With the meter plugged in the cathode circuit of the T21 the total plate, screen and grid current is shown. This gives a false indication as to the plate current "dip" of the stage, which is to about 15 milliamperes lower than the cathode current would indicate.

For optimum performance, the T21 stage should be loaded to approximately 90 milliamperes. At this input, the output is approximately 20 watts.

No antenna coupling circuit has been provided as the type of coupling circuit will depend upon the antenna used. Any of the usual capacitive, inductive or link-

Figure 16.
GENERAL WIRING DIAGRAM OF THE 14-28-56 MC. R.F. UNIT.



C_1, C_2—.01-μfd. paper
C_3—75-μμfd. midget
C_4—.005-μfd. mica
C_5—100-μμfd. mica
C_6—50-μμfd. mica
C_7—50-μμfd. midget
C_8—.001-μfd. mica
C_9—.002-μfd. mica
C_{10}, C_{11}—.001-μfd. mica
C_{12}—15-μμfd. midget, double spaced
C_{13}—.001-μfd. mica
R_1—25,000 ohms, ½ watt
R_2—400 ohms, 10 watt
R_3—25,000 ohms, 10 watt
R_4—150,000 ohms, 2 watt
R_5—600 ohms, 10 watt
R_6—30,000 ohms, 10 watt
R_7—100,000 ohms, 1 watt
RFC—2.5-mh. r.f. chokes
J_1, J_2—Closed-circuit jack

coupling circuits will be suitable, however. When used as an exciter, the unit should be link coupled to the next stage.

COIL TABLE

All coils have small, banana type plugs spaced 2½ in. 80 and 40 m. coils are wound on bakelite tubing; 20, 10 and 5 m. coils are self-supporting.

---

80 osc.
37 turns no. 22 d.c.c. on 1 inch form.

40 osc. or doubler
22 turns no. 22 d.c.c on 1 inch form

20 doubler
13 turns no. 14 enam. 1 in. dia. spaced to 1½ in.

20 final
17 turns no. 14 enam. 1¼ in. dia. spaced to 1½ in.

10 quadrupler
6 turns no. 14 enam. 1 in. dia. spaced to 1 in.

10 final
8 turns no. 14 enam. 1 in. dia. spaced to 1¼ in.

5 final
4 turns no. 14 enam. ⅞ in. dia. spaced to 1¼ in.

Note: 40 meter coil serves either as osc. coil or doubler coil.

MEDIUM POWER 56-Mc. AMPLIFIER

By using tubes having close element spacing, yet low interelectrode capacities, and a plate tank condenser especially designed for u.h.f. service, it is possible to construct a medium power 56-Mc. amplifier that will exhibit good efficiency without resorting to the use of parallel rods in the plate circuit.

Such an amplifier is illustrated in figure 17. It utilizes a pair of HK24's in push pull, and the efficiency is as good as that obtained with commonly used equipment on the 14-Mc. band. With proper coils, the amplifier could also be used on 28 and 14 Mc., but as it was expressly designed for 56 Mc. work, the coils are not of the plug in type. By fastening the plate coil directly to the condenser stator lugs, losses are minimized.

About 20 watts excitation are required, this amount of excitation permitting approximately 175 watts input on phone or 225 watts input on c.w. The T21 exciter of figure 16 is ideally suited for use with this amplifier, the excitation being sufficient so long as the coupling link between exciter plate coil and amplifier grid coil is not too long. The losses are high at 56 Mc. in a twisted pair line; even in a good line. EO-1 cable makes the best coupling line, and it should be not more than 18 inches long unless reserve excitation is available to compensate for the losses in the line.

A conventional, resistor-biased circuit is used with circuit balance provided by a grounded-rotor grid condenser. Plate voltage is fed to the center of the plate coil through a u.h.f. choke. Since the circuit is balanced by grounding the rotor of the grid condenser, it is possible to let the rotor of the plate condenser "float," thus increasing the allowable plate voltage for a given condenser spacing. No filament by-pass condensers are used, as they were found to be unnecessary. Mechanically, the amplifier differs somewhat from the usual push-pull stage and the mechanical layout will therefore be discussed in greater detail.

Construction Details

An 11 x 7 x 2-inch chassis allows ample room for all the components except the filament transformer, which is mounted externally.

The plate condenser is one designed for u.h.f. use. The stator terminals are arranged so as to allow an extremely compact neutralizing condenser assembly. This condenser is mounted on its side with the stator terminals toward the tubes. Two angle brackets and small standoff insulators serve to hold the condenser above the chassis. Mounting the condenser in this manner permits short plate leads to the upper stator terminals. The plate coil, 6 turns of no. 14 wire 1¼ inches in diameter, is spaced so as to mount directly on these upper terminals.

Two small discs of aluminum, 1 inch in diameter and 1/16 inch thick, are used for the movable plates of the neutralizing condensers. Each of these plates has

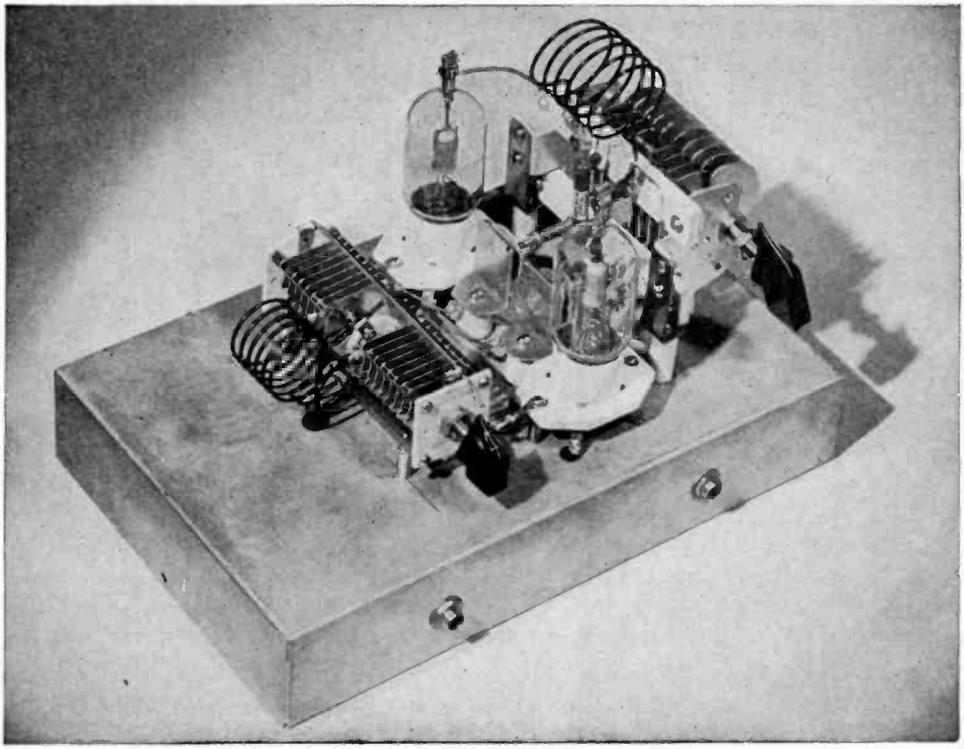


Figure 17.

125 WATT 56-MC. AMPLIFIER.

Extreme simplicity characterizes the amplifier. The neutralizing condensers may be seen between the tubes. All components with the exception of the grid resistor are above the chassis.

a flat-headed 6-32 screw through its center. The screws are held in place by nuts on the back of the discs. The heads are filed smooth with the surface of the discs. The edges of the discs are rounded with a fine-tooth file to prevent corona losses.

Two pieces of hollow rod, threaded with a 6-32 tap are mounted on the lower stator terminals of the plate condenser. The screws through the discs are screwed into these rods and neutralizing adjustments are made by running the screws in or out of the threaded rods, thus changing the spacing between the circular plates and the stationary plates, which are simply small rectangular pieces of aluminum mounted on standoff insulators.

The grid coil is 6 turns of no. 14 enameled wire 1⅛ inches in diameter and 1⅛ inches long. This condenser tunes with its plates about one-third meshed. Both ends of the rotor are grounded for the sake of symmetry.

The amplifier should not be operated for any length of time with the load removed, as the heavy r.f. field within the plate coil will heat and melt the soldered connection at its center. With the tank circuit loaded however, no trouble of this kind will be experienced.

By slightly exceeding the plate voltage rating and operating the two tubes at 1750 volts, an output of slightly over 200 watts is obtained from the amplifier at the normal plate current of 150 ma. for the two tubes. For modulated operation,

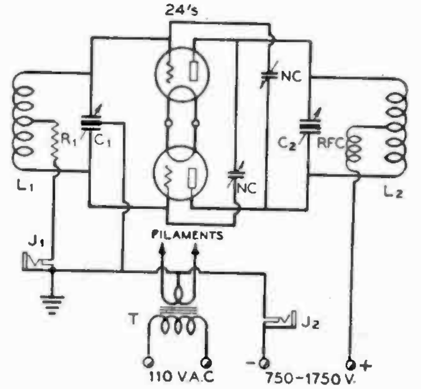


Figure 18.

125 WATT U.H.F. HK24 AMPLIFIER.

C_1—30-μμfd. per section midget
C_2—35-μμfd. per section, 4500-volt spacing
R_1—3000 ohms, 10 watts
J_1, J_2—Single closed circuit jacks
T—Filament transformer, 6.3 v., 6 a.
NC—See text
L_1, L_2—See text
RFC—U.h.f. choke

the plate voltage should be lowered to 1250 volts, however. Two jacks, J_1 and J_2, are provided for reading the grid and plate current. A one-turn link is used between the amplifier and the exciter and the grid current is adjusted to 50 milliamperes under load by varying the coupling.

250-WATT LINEAR TANK AMPLIFIER

By cross neutralizing a push-pull linear tank u.h.f. oscillator, a highly efficient u.h.f. amplifier results. Linear tanks are advantageous in power amplifiers not for reasons of frequency stability, but to provide an inexpensive, highly efficient tank circuit having high impedance and low losses. For this reason a linear tank is ordinarily used only in the plate circuit of an amplifier, a grid coil being satisfactory for the grid tank when very high Q is not required for the sake of stability.

The 56-Mc. amplifier of figures 19 and 20 will deliver over 250 watts with good efficiency, and requires approximately 35 watts excitation. The excitation may be furnished either by a stabilized push-pull HK54 linear tank oscillator using parallel rods in the grid circuit with grid connections made one quarter of the way up from the voltage node, or by an HK54 crystal-controlled doubler using a low C tank circuit and high bias. The oscillator should be run at about 750 volts, the HK54 doubler at about 1000 volts. Crystal control is to be preferred, but the frequency modulation will be within tolerable limits when the push-pull final amplifier is excited directly from a lightly-loaded, stabilized oscillator.

It will be noticed that the rods not only are bent back upon themselves, but that the spacing between the two rods is not uniform. This has no detrimental

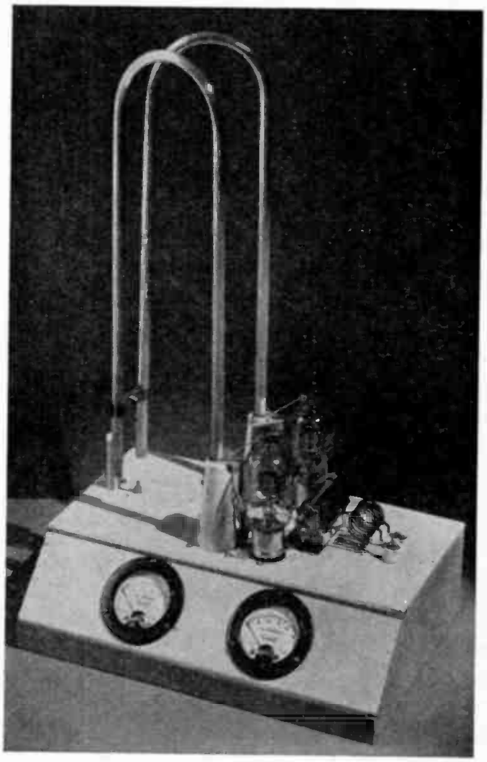


Figure 19.

FOLDED LINEAR TANK 56 MC. 250-WATT AMPLIFIER.

An inexpensive yet compact and highly efficient tank circuit for this HK54 amplifier is had by folding back on itself a quarter-wave stub made of half-inch aluminum tubing.

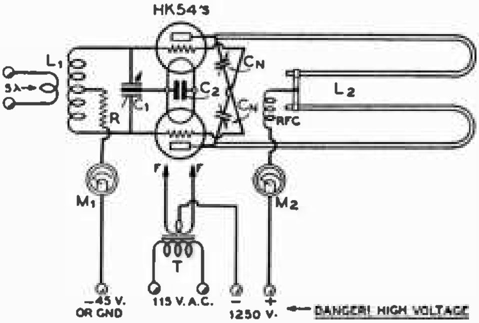


Figure 20.
HK54 FOLDED LINEAR TANK AMPLIFIER.

C_1—30-μμfd. per section, double-spaced midget
C_2—.002-μfd. mica
L_1, L_2—See text
R—3000 ohms, 25 watts if no fixed bias; 2000 ohms if 45 v. fixed bias.
M_1—0-100 ma. d.c.
M_2—0-500 ma. d.c.
T—5 v. 10 amp. fil. trans.

effect upon the efficiency of the tank, and permits a compact arrangement. The rods are of half-inch aluminum tubing, each slightly over three feet long, and bent and mounted as shown in figure 19. The position of the shorting bar is adjustable, and the tank is resonated by sliding the bar along the rods with a piece of dry wood until minimum plate current is obtained. The shorting bar is then clamped firmly by tightening the screw.

The husky, four-inch ceramic pillars which support the rods also support two of the small aluminum plates used for neutralizing.

The grid coil consists of 6 turns of no. 14 wire, 1 inch in diameter and spaced to 1¼ inch. The coil is soldered directly to the stator terminals of the grid condenser.

The plate choke consists of 50 turns of no. 20 d.c.c. close wound on a ceramic pillar insulator ½ inch in diameter. Very little r.f. voltage appears at the shorting bar, and the choke has little work to do; however it is advisable to incorporate it in order to insure proper circuit balance.

About 350 watts output may be obtained by raising the plate voltage to 1750 volts. The value of grid resistor should be increased about 50 per cent and greater excitation power will be required. At this plate voltage it is necessary to keep the tubes loaded evenly and the tank circuit in exact resonance. If the higher value of plate voltage is used, it is advisable first to tune up at reduced voltage.

MOBILE TRANSMITTERS

Amateurs are permitted to engage in mobile operation only on amateur frequencies above 28 Mc. On 28 Mc., most amateurs working mobile make use of a two stage crystal-controlled transmitter and a one-, two-, or three-tube converter (see chapter 6) which works in conjunction with a regular auto set. On 56 Mc. some amateurs use crystal control, usually with a 28-Mc. crystal, and some use m.o.p.a. with stabilized oscillator. Both converters and superregenerative receivers, the latter with an r.f. stage to prevent receiver radiation, are popular for 56-Mc. mobile work. On 112 Mc. the simplest type of equipment is ordinarily used: superregenerative receivers (without r.f. stage) and modulated oscillators. Most often these are combined in the form of a "transceiver."

Because the regulations are less strict on the matter of stability and character of signal on 112 Mc., it is possible to get by with a minimum of equipment. For this reason this band is becoming quite popular for local mobile work.

Most any low powered transmitter for use on any of the aforementioned bands can be used for mobile work. though it is advisable that there be a minimum number of stages, and it is preferable that all tubes have 6.3-volt heaters.

112-Mc. TRANSCEIVER

In the 112-Mc. transceiver to be described, a simple ultra-audion oscillator circuit is used, which is made superregenerative for receiving by insertion of a high value of grid leak. A type 6F6 pentode is used as an audio amplifier to drive the phones when receiving or as a modulator for the 76 oscillator when transmitting. A study of what changes take place when the send-receive switch is thrown will result in a better understanding of how both tubes do double duty.

The r.f. portion should be arranged exactly as shown. This includes the 76 socket, the tuning condenser, grid coupling condenser, r.f. chokes, and tank coil. The oscillator circuit is quite simple, but unless constructed exactly as shown there is a possibility that difficulty will be encountered.

The 76 socket, which must have either ceramic or other h.f. type low loss insulation, should be of the type that has the terminals extending straight out the base as an extension of the jaws that hold the tube prongs. This results in shorter leads to the coil, as the length of the socket terminals has to be taken into consideration at this high frequency, and it is important to provide as short a path as possible from the grid and plate prongs of the tube to the tuning condenser and coil.

The 76 (5-prong) socket is mounted vertically, raised up off the chassis a half inch or so by means of angle brackets, so that shorter connections may be made to the tuning condenser. The socket is oriented so that the grid (isolated) pin is at the top.

The tuning condenser, a ceramic insulated midget having but three plates, is mounted on the chassis by means of a mounting bracket designed for use with this type midget condenser and available as an accessory. The bracket is fastened to the ceramic portion of the condenser, thus permitting both rotor and stator to "float." This is necessary because in this circuit not only are both sides of the condenser "hot," but if there is too much capacity from either side of the condenser to ground there will be an improper ratio of grid-cathode to plate-cathode capacity and the feedback will not be of the right value for best operation. In other words, there should be no more metal making connection to either side of the condenser than absolutely necessary. This explains the insulated coupling connecting to the tuning condenser shaft. It should preferably have ceramic insulation.

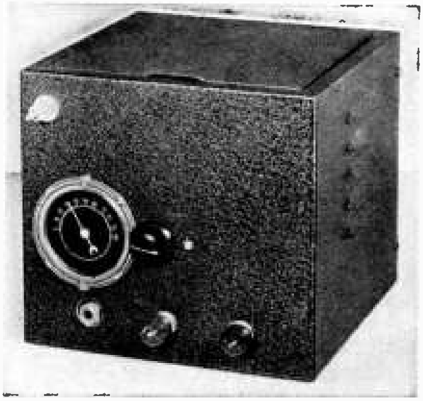


Figure 21.

112-MC. TRANSCEIVER.

This compact transceiver provides the least expensive form of mobile operation.

The coil consists of three turns of no. 14 enameled wire, ½ inch in diameter and spaced to approximately 1 inch. This coil is mounted directly on the condenser, with as short leads as possible. Because a small difference in the coil dimensions or length of grid and plate leads has such an effect upon the frequency, it may be necessary to "prune" the coil a bit to hit the 112-Mc. band.

The grid condenser should be of the midget mica type, the smallest available (in physical size). This should connect from the grid terminal on the socket to the *rotor* terminal on the tuning condenser. The grid condenser may be seen just under the coil. The plate terminal on the socket should go directly to the closest stator lug on the tuning condenser.

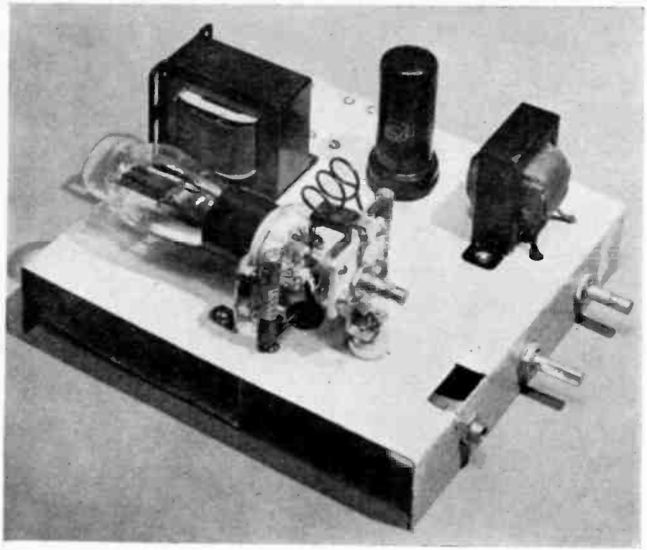


Figure 22.

INTERIOR VIEW SHOWING CONSTRUCTION OF 112-MC. TRANSCEIVER.

The parts in the foreground should be placed and wired exactly as explained in the text. This includes tube socket, r.f. chokes, tuning condenser, grid condenser, and coil. The tuning condenser should be driven by a ceramic insulated shaft coupling.

Probably the most practical and least expensive source of high voltage is a 200-volt 100-ma. self-rectifying "vibrapack," such as designated in the diagram. On the highest voltage tap these packs will deliver approximately 225 volts at 65 ma. (transmitting condition) and nearly 250 volts at 42 ma. (receiving condition). A single section "brute force" filter of the type used for regular 60-cycle a.c. power supplies will provide sufficiently pure d.c.

As the vibrapack is used both when transmitting and receiving, a single husky switch can be used to apply battery voltage to both the pack and tube heaters. Wire at least as heavy as no. 12 should be used between the vibrapack and the "A hot," as it will draw between 4 and 5 amperes and even a slight drop in voltage will result in considerable reduction in the maximum plate voltage available for the transceiver.

Most of the vibrator power supplies used in the newer auto radios, especially those having six or more tubes, will deliver around 225 volts under load. This voltage may be robbed for use on the transceiver by running a lead from the B plus side of the speaker output transformer to the transceiver.

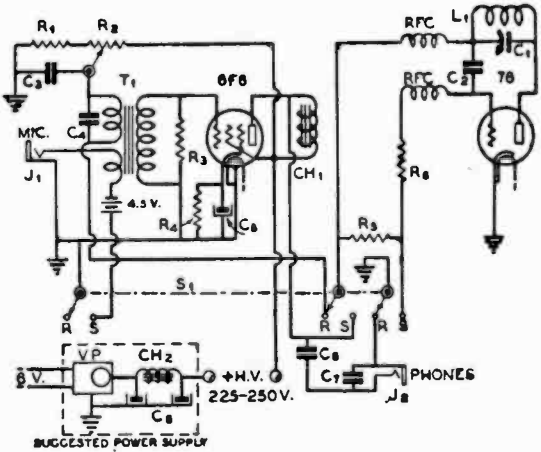
A switch inserted in the heater lead to the tubes in the auto set will prevent these tubes from drawing heater current when the power pack is turned on (regular switch on auto set), and at the same time permit the full output of the high-voltage pack to be used on the transceiver, as the tubes in the auto set cannot draw plate current when their heaters are not lit. If your auto set is of the type that has a filamentary rectifier (84, 6Z4, 6X5, etc.) instead of a gaseous cold-cathode or synchronous vibrating rectifier, the heater to this tube must not be opened or there will be no high voltage delivered by the pack. The heater switch should be connected so that it opens all heaters *except* the heater of the rectifier tube.

Because the voltage of the power pack will go up considerably at no load and there is a possibility of blowing filter or by-pass condensers in the auto set if they are not conservatively rated, the heater of the 6F6 in the transceiver should be allowed to reach operating temperature before the regular switch (not the heater switch) in the auto set is turned on. Also, be sure not to apply high voltage to the transceiver unless the heaters in the auto set are opened, because otherwise both auto set and the transceiver will draw plate current, and the combined plate current may be high enough to damage the power pack.

Figure 23.

GENERAL WIRING DIAGRAM OF THE 122-MC. TRANSCEIVER.

C_1—10-μμfd. midget, ceramic insulation
C_2—100-μμfd. midget mica (smallest physical size)
C_3—0.25-μfd. tubular, 400 volt
C_4—.002-μfd. tubular, 400 volt
C_5—10-μfd. electrolytic, 25 volt
C_6—0.25-μfd. tubular, 400 volt
C_7—.01-μfd. tubular, 400 volt
C_8—Dual 8-μfd. electrolytic, 450 volt
L_1—See text
R_1—100,000 ohms, 1 watt
R_2—100,000-ohm pot.
R_3—250,000 ohms, ½ watt
R_4—500 ohms, 2 watts
R_5—1 meg., 1 watt
R_6—15,000 ohms, 1 watt
RFC—U.h.f. radio frequency chokes
S_1—3-pole 2-throw rotary switch, shorting type
CH_1, CH_2—10 hy. or more, 75 ma.
VP—200-volt 100-ma. "vibrapack," synchronous rectifier
T_1—Midget "transceiver" transformer, plate and s.b. mike to grid
J_1, J_2—Open circuit jacks



The "hot" end of each r.f. choke should be connected with as short a lead as possible, one to each side of the grid coupling condenser. These r.f. chokes should be the special u.h.f. type, as regular r.f. chokes, even the high-frequency type, have too much distributed capacity for effective operation at 112 Mc.

The cathode of the 76 is grounded to a lug under the closest of the two screws which fasten the socket to the two brackets. The heater wires and the wires to the bottom of the r.f. chokes come up through a hole in the chassis midway between the tuning condenser and socket. The balance of the wiring is all below deck, and as it carries only d.c. and high level a.f. no care need be taken to obtain short leads. Cabling the wire with waxed cord as shown in the bottom view of the chassis is not necessary but makes a workmanlike job.

The material ordinarily used for tube bases has a rather poor power factor at 112 Mc.; hence the base of the 76 is slotted by means of a fine tooth hack saw. Be careful or you will crack the base; and don't go too far or you may crack the stem of the tube. The base should be held in a vise with just enough "squeeze" to keep it steady during the sawing process.

The size of the cabinet is not important just so long as it is sufficiently large to hold all the components without crowding, the one illustrated being approximately 7 inches on a side.

Power Supply

The transceiver power supply should deliver between 225 and 250 volts under load. If the voltage is greater than 250, the 76 will run too hot and draw more than the maximum advisable plate current when transmitting. If the voltage is less than about 225 volts, the tube cannot be made to superregenerate in the "receive" position when normal antenna loading is used. The drain on the power pack at 225-250 volts is around 42 ma. when receiving and approximately 65 ma. when transmitting.

The correct procedure is as follows: Turn on heaters to transceiver (assuming high-voltage lead is connected from auto set to transceiver). Open heater switch on auto set. After a half minute turn on regular switch on auto set. When all through working the transceiver, turn off regular switch on auto set. Turn off heaters in transceiver. Close heater switch on auto set. The auto set is then ready for b.c.l. operation; just turn on the regular switch on the auto set.

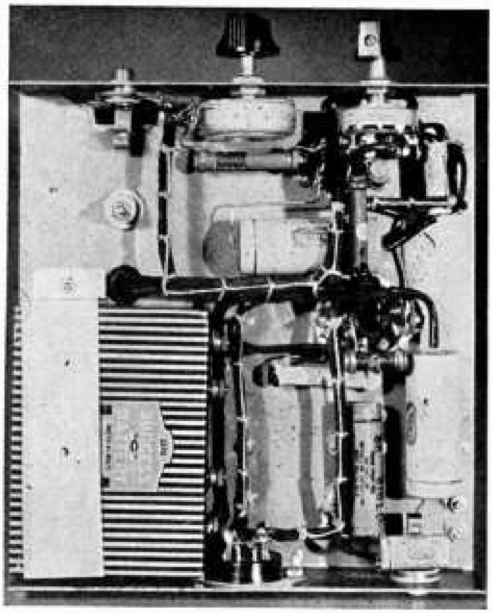


Figure 24.
UNDER-CHASSIS VIEW OF THE 112-MC. TRANSCEIVER.

Exact placement of these parts and length of leads between them is not important. All grounds are made to the nearest convenient point on the chassis.

Antenna

The best antenna for general coverage, either for fixed station or mobile use, is a vertical half-wave doublet, placed as high and in the clear as possible. An excellent mobile antenna is a "fishpole" exactly 4 feet long and well insulated at the base.

A two-wire line of no. 16 wire, spaced from 1½ to 2 inches with ceramic spreaders, makes a very efficient line if kept at least 3 or 4 inches away from large pieces of body metal where the line parallels such metal. The line is delta matched to the radiator by fanning it out and attaching it at points 6 inches each side of center. The line should leave the antenna at a right angle for at least 8 inches, and the feeder wires should be exactly the same length. The feed line can be supported away from the car body and kept from swinging by means of waxed cord tied to the spreaders.

The most logical place in the car for the transceiver is in the glove compartment. If you look around you can find an antenna of the type that bolts to the door hinge that telescopes out to four feet. Most door hinge antennas are not quite four feet extended, but if you look around you can find one that extends to four feet. Unfortunately the insulation at the base probably will not be good enough for u.h.f. (there is a voltage loop at the bottom of a half-wave antenna; hence insulation is important). However, with a little ingenuity you can substitute a piece of micalex, victron, Lucite, or ceramic material for the mud or other composition the manufacturer intended for insulation. Just remember in so doing that there is considerable torque at the base of the antenna as a result of the whipping it does while the car is being driven, and the support should be made sufficiently strong from a mechanical standpoint.

With such an antenna on the same side of the car as the transceiver, only a short length of line will be required to connect the antenna to the transceiver. Small feedthrough insulators can be used to take the wires through the side of the car body.

The antenna feed line is coupled to the transceiver coil by means of two turns of insulated solid hookup wire shoved down straddling the center turn of the three-turn coil. It should be shoved down until the transceiver will no longer superregenerate over the whole band when the regeneration control is full on, superregeneration being indicated by a fairly loud hiss or rushing noise in the phones when the send-receive switch is on "receive." Back off the coupling just enough to permit superregeneration over the whole band and then leave the coupling alone until such time as you make any changes in the antenna or feed line.

The gain of the modulator is such that with an ordinary telephone microphone of the "F" type one should talk directly into the microphone in a normal tone of voice. Talking too loudly will result in overmodulation and consequent distortion, while talking too far from the microphone will reduce the transmitting range.

When not using the transceiver be sure either to throw the send-receive switch to "receive" or pull the microphone plug. Otherwise the microphone will be drawing current and running down the microphone battery needlessly.

The drain of the microphone is low enough that many hours of transmission can be had from one battery, but there is no point in leaving it on when the transceiver is not in use.

10-WATT 28-Mc. MOBILE TRANSMITTER

One advantage of 28 Mc. over 56 Mc. and 112 Mc. for mobile operation is that dx contacts are possible under favorable conditions. For reliable sky wave communications, however, the transmitter should preferably have an output of at least 10 watts. A simple crystal-controlled 28-Mc. mobile transmitter which will deliver this output is illustrated in figures 25, 26 and 27.

The crystal oscillator uses a 6F8G in a conventional twin triode oscillator-doubler circuit. Note that in this tube each cathode is brought out to the tube base. When using a 6A6 in this type of circuit the cathode is common and will not allow separate cathode bias and metering for the respective sections.

The first tuned circuit is tuned to the fundamental frequency of the crystal, which in this case is on 7 Mc. For police use a crystal somewhere in the neighborhood of 9 Mc. will be used. The cathode of the oscillator circuit is grounded and all bias comes from the grid leak. Thus the plate current will dip upon hitting resonance. The current drawn by this circuit will be about 15 ma.

The second section of the tube is used as a triode doubler with the plate circuit tuned to the 20-meter band. The two sections are coupled through a .00005-μfd. condenser, which affords the proper amount of excitation. Bias for this section is supplied by a 150-ohm resistor placed in the cathode and a 50,000-ohm grid leak.

The T21 final amplifier operates as a doubler. Fewer parts are required, and any inexpensive pentode or tetrode may be used, as neutralization is not made necessary by lack of perfect screening within the tube.

In the unit described the T21 cathode current dips to 15 ma. with no load. For ten-meter operation this is considered

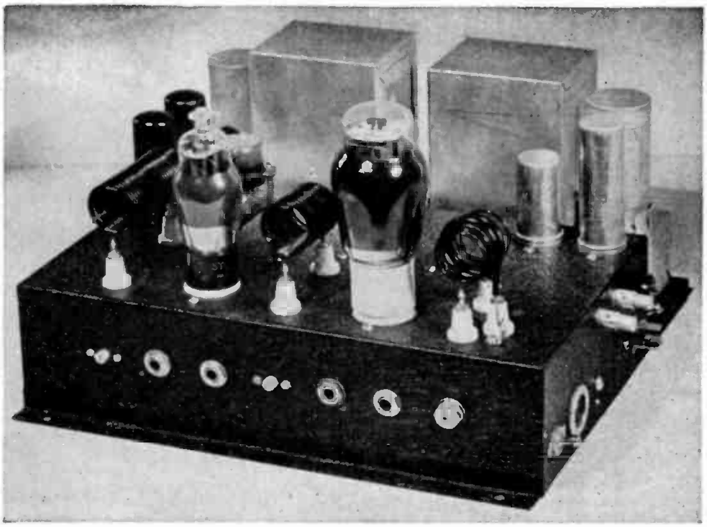


Figure 25.
10-WATT 28-MC. MOBILE TRANSMITTER.

The unit is entirely self-contained, requiring connections only to antenna, microphone, and 6.3-volt lead. A 6F8G in a twin triode oscillator-doubler drives a T21 power doubler. A pair of 6V6's in class AB serve as modulators.

very good even for a "straight through" final amplifier. Out of resonance the cathode current is around 60 or 70 ma. The current measured is cathode current, which includes control grid, screen, and plate current. When the stage is connected to an antenna the cathode current should read around 60 to 70 ma. At this loading the output will be around 10 watts.

Plate modulation of the T21 is provided by a pair of 6V6's in push-pull. They will operate very well right out of a carbon microphone if a high ratio microphone transformer is used. Thus no speech amplification is required ahead of the modulators, eliminating extra tubes, battery drain, etc. The input transformer used has a 50-ohm primary and a 200,000-ohm center-tapped secondary.

The resting plate current on the modulators is about 50 ma. This makes a total of around 85 to 90 ma. being drawn by the exciter and modulators, which are supplied voltage from one vibrator pack.

Relays

The relays used are of the six-volt type, drawing about 700 ma. each. One is a single-pole single-throw; the other is a double-pole double-throw. The first relay is used just to turn on the filaments to the transmitter. At this point we cannot stress too strongly the necessity of having the highest battery voltage possible at the transmitter. It is for this reason that the relay was used in the A lead.

Another advantage of having the relay in this part of the circuit is that only one wire is required from the front part of the car to turn on the filament voltage. All relays are operated by means of switches to ground; thus the relays are connected to the "hot" A voltage at all times.

The second relay switches the A voltage to the vibrators, keeping the voltage drop here at a minimum, too. The other part of the relay throws the antenna back and forth between the receiver and transmitter, permitting use of one antenna for both the receiver and transmitter.

Power Supplies and Battery Drain

The transmitter unit is designed to operate with a full 300 volts, and in order to obtain the proper voltage and have sufficient current carrying capacity, it is necessary to use two vibrator supplies.

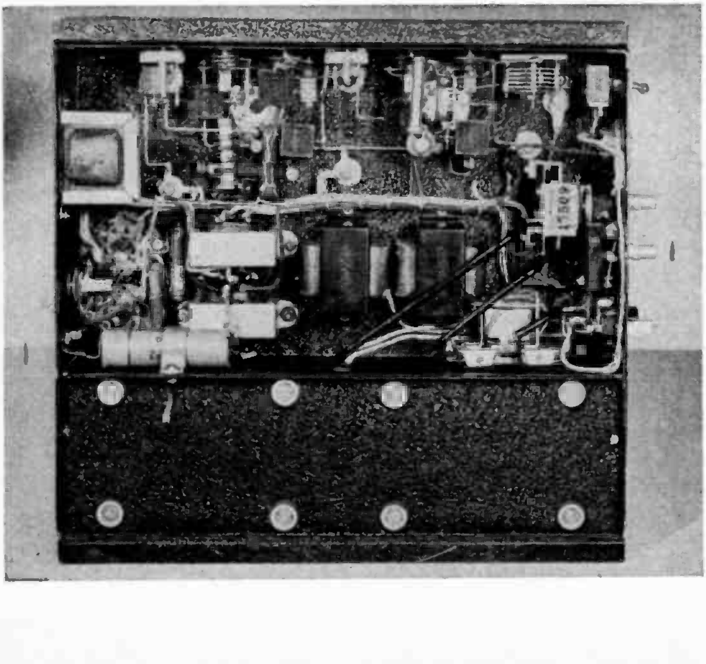


Figure 26.
UNDER-CHASSIS VIEW OF THE 10-WATT 10-METER MOBILE TRANSMITTER.

The midget tuning condensers are of the type permitting mounting on a metal chassis by support studs connected to the insulation rather than to the condenser rotors. They are tuned by means of a screwdriver.

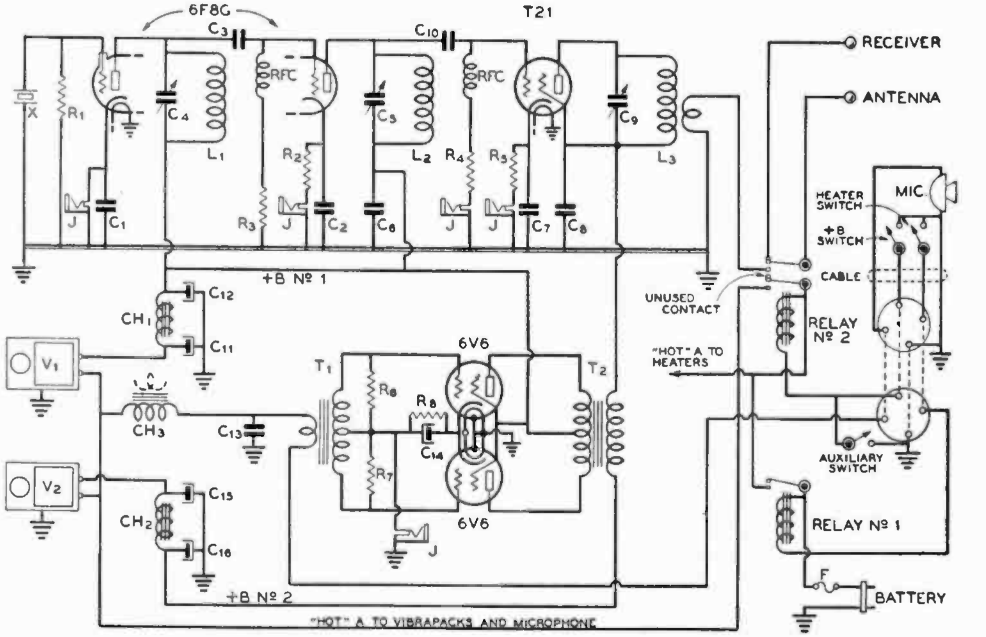


Figure 27.

GENERAL WIRING DIAGRAM OF THE 28-MC. MOBILE TRANSMITTER.

C_1—.001-μfd. midget mica
C_2—.001-μfd. midget mica
C_3—.00005-μfd. midget mica
C_4—75-μμfd. air trimmer
C_5—25-μμfd. air trimmer
C_6—.001-μfd. midget mica
C_7—.001-μfd. midget mica
C_8—.001-μfd. mica
C_9—25-μμfd. double spaced
C_{10}—.0001-μfd. midget mica
C_{11}—10-μfd. 450 v.
C_{12}—10-μfd. 450 v.
C_{13}—25-μfd. 25 v.
C_{14}—25-μfd. 25 v.
C_{15}—10-μfd. 450 v.
C_{16}—10-μfd. 450 v.
R_1—50,000 ohms, 1 watt
R_2—150 ohms, 1 watt
R_3—50,000 ohms, 1 watt
R_4—40,000 ohms, 1 watt
R_5—100 ohms, 5 watts
R_6—50,000 ohms, 1 watt
R_7—50,000 ohms, 1 watt
R_8—300 ohms, 5 watts
CH_1—10 hy., 125 ma.
CH_2—10 hy., 125 ma.
CH_3—Primary of midget 2½ v. fil. trans.
V_1, V_2—Vibrator pack, 100 ma. 300 v.
T_1—High gain microphone trans. 50-ohm primary, 200,000-ohm c.t. secondary
T_2—Output trans. 10-000-ohm primary, 5000-ohm secondary
Relay 1—Single-pole single-throw 6 v. d.c.
Relay 2—Double-pole double-throw
RFC—2.5 mh., 125 ma.
Fuse—30-amp. cartridge

The vibrators have individual filter networks, as may be seen in the diagram. A single 300-volt 150-ma. dynamotor could be substituted for the two vibrator supplies if desired.

The total drain on the car battery with the transmitter in operation is about 18-20 amperes. Many of the newer cars come equipped with heavy duty generators capable of handling easily the load offered by the transmitter, and auxiliary charging of the battery will seldom be required.

The microphone voltage is obtained from the main battery through a small

COIL TABLE

(29 Mc.)

L_1—26 turns no. 14 enameled wound on 1¼" dia. and strengthened with ribs of Duco cement

L_2—15 turns no. 14 enameled wound on 1¼" dia.

L_3—7 turns no. 14 enameled wound on 1¼" dia.

Antenna link—2 turns 1¼" dia., insulated wire decoupling choke, which is the primary of a small 2½-volt filament transformer. The choke, in conjunction with the 25-μfd. condenser C_{13}, removes every last trace of vibrator hash.

Antenna

Several antenna systems were tried, but after careful tests a simple quarter wave against the car body was chosen. The antenna is mounted on the rear bumper and is fed with a concentric line, which may be either ordinary shielded wire or the "bead line" type which may be obtained from any large supply house. The direction of the car affects the signal strength somewhat. The signal strength is highest with the car pointed towards the station being worked.

MICROWAVE TRANSMITTERS, RECEIVERS

Microwaves, as previously related, are those whose length is less than one meter. Microwaves are generated by means of *magnetrons, electron-orbit oscillators* and *regenerative oscillators.* Microwaves are used by broadcast stations for remote pickup, by amateurs and experimenters and for occasional telegraph and telephone communication such as the British channel-spanning system. The technical problems encountered in this field are numerous, yet new tubes designed for microwaves have simplified many of these problems and have been instrumental in increasing the usefulness of the band.

The Magnetron Oscillator

The magnetron is a specially designed tube for very-short-wave operation. It consists of a filament or cathode between a split plate, as shown in figure 28.

A magnetic field is produced at the filament by means of a large external field coil which is energized by several hundred watts of d.c. power. Ultra-high-frequency oscillations are produced in the split plate circuit when this magnetic field is in the correct direction and of the proper intensity. A parallel-wire tuned circuit should be used for wavelengths below one meter. The frequency stability is not very good and it is difficult to obtain satisfactory voice modulation from magnetron oscillators.

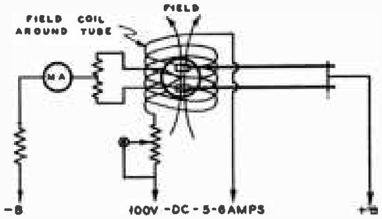


Figure 28.

SPLIT MAGNETRON MICROWAVE OSCILLATOR.

Special magnetron tubes delivering several watts output at very short wavelengths are available for experimental purposes.

Electron Orbit Oscillator

The range of oscillation in ordinary circuits is limited by time required for electrons to travel from cathode to anode. This transit time is negligible at low frequencies, but becomes an important factor below 5 meters. With ordinary tubes, oscillation cannot be secured below 1 meter, but by means of *electron orbit oscillators,* in which the grid is made positive and the plate is kept at zero or slightly negative potential, oscillation can be obtained on wavelengths very much below 1 meter.

Parallel-wire tuning circuits can be connected to these tube oscillators in

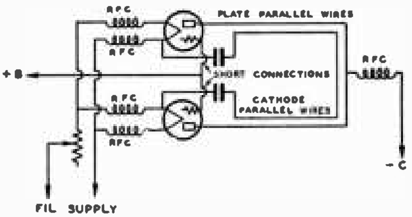


Figure 29.

KOZANOWSKI OSCILLATOR.

This type of u.h.f. oscillator requires the use of tubes having cylindrical elements, such as the 35T, HK54, 852, etc.

order to increase the power output and efficiency. The tubes most suitable for this type of operation have cylindrical plates and grids, and their output is limited by the amount of power which can be dissipated by the grids. For transmitting, tubes such as the 35T, HK54, 852, etc., can be used in the circuit shown in figure 29, which is a modification of the circuit of figure 30. More output is obtained by using a tuned-cathode circuit instead of tuned-grid circuit. Modulation can be applied to either the plate or grid. The frequency stability is very poor.

Regenerative Oscillators

The introduction of RCA "Acorn" tubes made low power ½-meter regenerative oscillators practical. These tubes are more efficient than ordinary types for ultra-high-frequency work, and are available in several types in both 6.3 v. and 1.4 v. series. They are satisfactory for low-power transmitters and super-regenerative receivers. The regenerative circuits are quite similar to those for longer wavelengths, except for the physical size of condensers and coils. The tube element spacing in these acorn tubes is made so small that electron transit time becomes a negligible factor for wavelengths above 0.6 meter.

Acorn tubes are also made in r.f. pentode amplifier types, both sharp cutoff and remote cutoff. However, these require concentric tank circuits below 2½ meters because at such high frequencies it is impossible, due to high losses, to obtain appreciable gain (high Q) with conventional tanks.

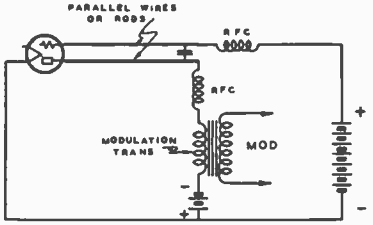


Figure 30.

BARKHAUSEN - KURTZ OR GILL-MORRELL OSCILLATOR.

As with all oscillators of the electron orbit type, the grid dissipation will be very high and the oscillator tube should have cylindrical elements.

For higher power oscillators, special transmitting tubes designed for microwave work are offered by several manufacturers, notably Western Electric and Eimac. The HK24 also makes an excellent microwave tube when two are used in push-pull.

For maximum output at 2½ meters and shorter wavelengths, filament chokes are sometimes required. One way to avoid the necessity for filament chokes and at the same time increase the efficiency is to substitute a tuned filament circuit for the usual tuned grid circuit, by-passing the grids to ground.

Microwave regenerative oscillators are most efficient when linear tank circuits are used in place of coils, and when two tubes are used in push-pull. Maximum output and efficiency cannot be obtained with single-ended circuits.

3/4-Meter Parallel Rod WE-316A Transmitter

A large variety of circuits could be suggested for micro-wave operation, but the most simple of these is the one shown in figure 32. It consists of two parallel half-wave rods, spaced about ¼-inch apart, to provide a ¾-meter tuned circuit of fairly-high Q. The grid and plate of the tube are connected to the copper rods; this capacity causes the physical length to be less than a

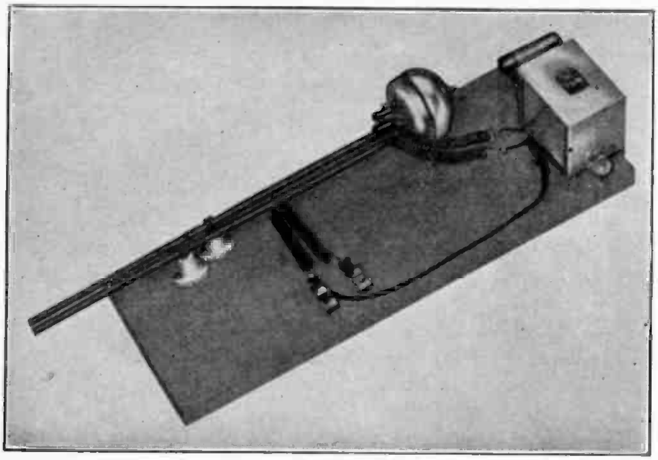


Figure 31.
WE-316A PARALLEL ROD ¾ - METER MICROWAVE OSCILLATOR.

half wavelength. As can be seen from the photograph, the plate r.f. choke and the grid leak do not connect to the center of the rods, but rather across the voltage node. The distance between this point and the free ends of the rods is a quarter wavelength.

Filament r.f. chokes, or tuned filament leads, are desirable for operation below one meter because the filament is not strictly at a point of ground potential in the oscillating circuit. These filament chokes consist of 30 turns of no. 16 enameled wire, wound on a ¼-inch rod, then removed from the rod and air-supported, as the picture shows. The length of these chokes is approximately 3 inches. A 200-ohm resistor is placed in series with the 110-volt a.c. line to the filament transformer in order to reduce the transformer secondary voltage from 2½ to 2 volts, because the filament of the tube operates on 2 volts at 3.65 amperes. This particular oscillator gave outputs in excess of 5 watts on ¾ meter, even when no filament r.f. chokes were used.

This oscillator, when loaded by an antenna, draws from 70 to 80 milliamperes at 400 volts plate supply. The oscillator should be tested at reduced plate voltage, preferably by means of a 1000- to 2000-

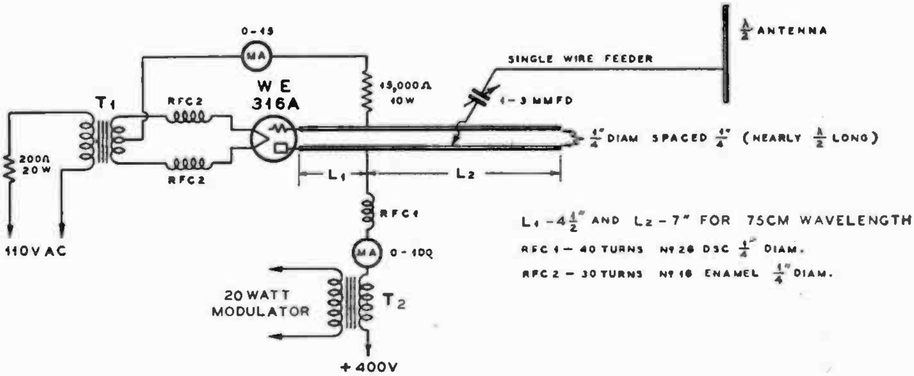


Figure 32.
WE-316A ¾-METER OSCILLATOR CIRCUIT.

ohm resistor in series with the positive B lead, until oscillation has been checked. A flashlight globe and loop of wire can be coupled to the parallel rods at a point near the voltage node, in order to indicate oscillation. A thermo-galvanometer coupled to a loop of wire makes a more sensitive indicator, but the high cost of this meter prohibits its use in most cases.

A 15-inch antenna rod or wire can be fed by a one- or two-wire feeder of the nonresonant type. A single-wire feeder can be capacitively coupled to the plate rod, either side of the voltage node, through a small blocking condenser. If a two-wire feeder is employed, a small coupling loop, placed parallel to the oscillator rods with the closed end of the loop near the voltage node of the oscillator, will provide a satisfactory means of coupling to the antenna.

3/4 METER RECEIVER

Lack of stability and difficulty of tuning a microwave receiver have been the two principal obstacles in the past. Stable operation is obtained by using a parallel-wire oscillator, as shown in figures 33 and 34.

In this receiver, the quarter-wave parallel-wire tuning section can be tuned over a range of nearly 10 centimeters by means of a relatively large series tuning condenser. This condenser, when set to maximum capacity, acts as a short-circuit across the parallel wires. Settings of lower capacity tend to decrease the effective length of the parallel wires by means of series tuning. This is more satisfactory than the use of parallel tuning across the grid and plate terminals of the type 955 acorn tube.

The acorn tube and tuning condenser are mounted on a small panel above the aluminum chassis. Small r.f. chokes are placed in series with the heater and cathode leads of the 955 tube. These r.f. chokes consist of 25 turns of no. 24 d.c.c. wire, in the form of a self-supported winding, ¼ inch in diameter. The plate choke is similar in construction, and with the same number of turns as the other chokes.

A quarter-wave tuned circuit of two parallel wires, terminated with a small fixed mica condenser, can be used in place of the heater and cathode chokes for wavelengths of less than ¾ meter. One side of the heater connects to the cathode at the acorn tube socket. The

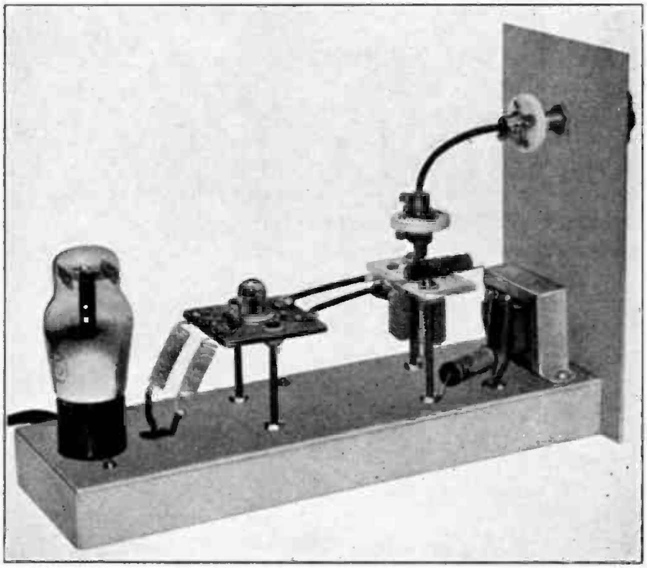
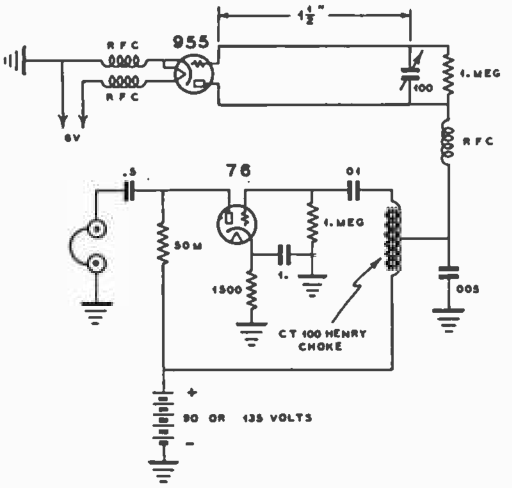


Figure 33.
¾ - METER SUPER-REGENERATIVE RECEIVER USING ACORN TRIODE.

For good results, the design shown must be rigidly adhered to and specifications closely followed.



RFC — ALL 25 TURNS Nº 24 D.S.C. ¼" IN DIAMETER

Figure 34.
WIRING DIAGRAM OF THE 955 MICROWAVE SUPERREGENERATIVE RECEIVER.

plate and grid terminals to the 955 tube connect to two parallel wires, each approximately 1½-in. long for ¾-meter operation. These two wires are soldered directly to the leads of the submidget 100-$\mu\mu$fd. tuning condenser, which is designed for u.h.f. operation.

The rotor of this condenser is connected through an insulated flexible coupling for front-panel dial tuning; a cable drive connects the tuning dial to the condenser coupling. The tuning range is approximately 70 to 80 centimeters. Superregeneration can be obtained with a 90-volt plate supply over a range of approximately 75 to 80 centimeters. The higher plate potential of 135 volts will allow superregeneration at lower capacity settings of the series tuning condenser, and thus permit higher frequency operation.

Superregeneration is obtained by means of a blocking grid action, with a 1-megohm grid leak connected across the parallel wire circuit. The output of the detector can be amplified by means of an audio transformer coupled stage or by impedance coupling; the latter is used in the circuit shown.

The chassis for this receiver measures 3"x10"x1"; the panel is 4"x8". The ¾-meter tuned circuit is mounted high enough above the chassis so that there will be no effect from the metal chassis. Three resistors and the two larger fixed condensers are mounted under the chassis. A condenser and resistor in the plate circuit of the audio amplifier prevents d.c. from flowing through the headphones and allows grounding one side of the headphone jack. Either batteries or an a.c. power supply can be used to operate this receiver, provided that the plate potential is not more than 180 volts.

1-10 M. SUPER-REGENERATIVE RECEIVER

Figures 35 and 36 illustrate a practical u.h.f. and microwave receiver which gives moderate loudspeaker volume with either 135- or 180-volt plate supply. A type 955 acorn triode serves as a superregenerative detector which is transformer-coupled to a high-gain 6V6G beam power pentode. The latter is similar to the 6L6G, except for its smaller size; it also requires less heater and plate current.

Five self-supporting coils of no. 14 enameled wire cover the range of from 1 to 11.8 meters by means of a 15-$\mu\mu$fd. tuning condenser. The coils plug into pin-jacks mounted in a strip of Victron, 1¼"x2". This strip is fastened to the 2"x4" bakelite subpanel by means of a pair of 2-inch 6-32 machine screws. This method of support brings the ends of the tip-jacks directly against the terminals of the u.h.f. variable condenser. The stator lead connects to the plate terminal of the acorn tube socket by means of a wire approximately ¼-inch long. The grid condenser is an extremely small, mica fixed condenser, connected between the grid terminal of the tube socket and the rotor lead of the tuning condenser.

The tuning condenser is driven by a vernier dial through an insulated coupling and extension shaft to the front panel. The tube socket is mounted on

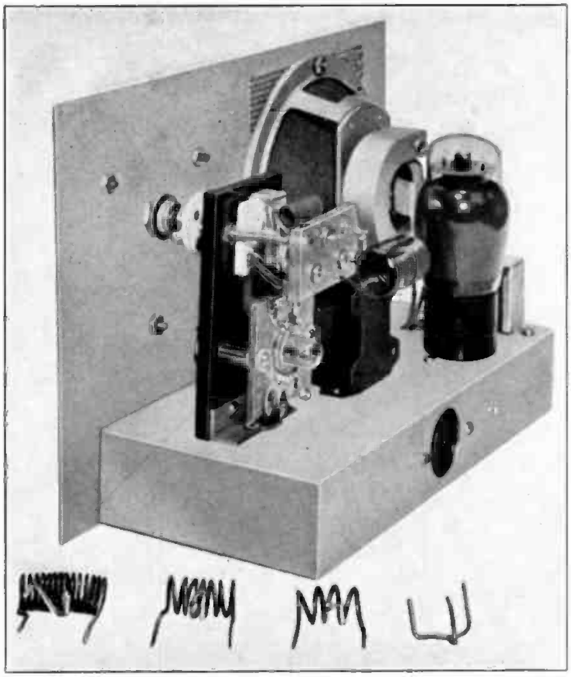


Figure 35.
CONTINUOUS COVERAGE U.H.F. SUPERREGENERATIVE RECEIVER.

Five coils cover the range from 1 to 10 meters. Note the arrangement of the tube socket and coil holder. The resulting short leads are responsible for the satisfactory operation on 1 meter.

standard socket bushings, secured to the same bakelite panel that supports the tuning condenser and coil. The cathode and one side of the heater of the 955 tube connect directly to the metal chassis by means of a soldering lug attached to one of the mounting screws on the subpanel.

A .006-μfd. mica condenser connects to one of the pin-jacks and to the same ground point on the chassis, so as to provide a short r.f. lead between the tap on the coil and the cathode terminal on the tube socket. This tap is used only on the two coils which cover the longer wavelengths. The coils which tune from 1 to 4.4 meters are center-tapped and plug into the other pin-jacks in order to connect the small r.f. choke into the circuit. This choke consists of 25 turns of no. 24 d.c.c. wire, closewound and self-supporting, ¼-inch in diameter. The choke is soldered directly to the two pin-jacks which are used only for the coil taps. The two lower pin-jacks connect to the tuning condenser and to the outer leads of the coils.

The r.f. choke has a natural period of about 7 meters and must be short-circuited when the large coil (6.5 to 11.8 meters) is plugged in. This is accomplished by soldering a length of no. 14 wire to the cathode tap of the coil, so that the coil plugs into all four pin-jacks. Figure 36 shows this method.

An audio volume control consisting of a half-megohm potentiometer regulates the gain of the beam-power amplifier and a 100,000-ohm potentiometer controls the superregeneration for the type 955 tube. A small 20- or 30-henry choke is shunted across the magnetic loudspeaker in order to provide a path for most of the d.c. plate current through the 6V6G tube.

This receiver will not superregenerate over the entire tuning range with the one-turn coil for 1-meter reception because the capacitance-to-inductance ratio becomes too great for condenser settings of more than approximately half scale. However, the coils are designed so that ample overlap is obtained in order to secure superregeneration over the complete range of from 1 to 10 meters.

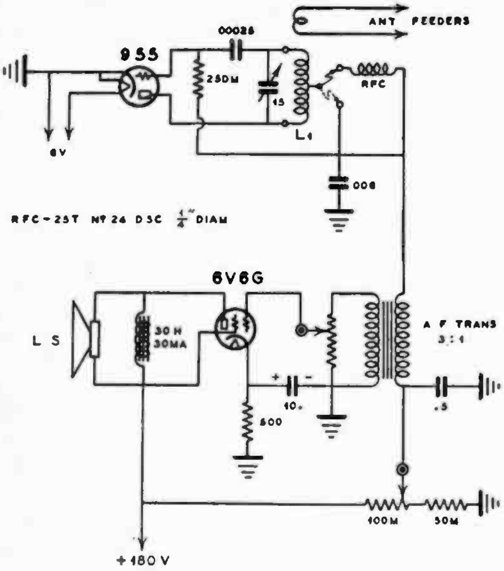


Figure 36.

WIRING DIAGRAM OF THE 1-10 METER RECEIVER.

Coil Data

The coil which covers the range of from 1 to 1.7 meters consists of slightly less than one full turn of no. 14 enameled wire. The actual wire length is approximately one inch from tip-jack to tip-jack and is *not* plugged all the way into the tip-jacks. If this coil is pushed clear into the pin-jacks, so that the cathode tap to the r.f. choke coil is flush with the tip-jack, the range is from 0.9 to approximately 1.6 meters. The range of from 1.7 meters to 2 meters is covered with a 4-turn coil, with a tap near the center for connection to the r.f. choke coil. This coil is spacewound to one inch length and has an inside diameter of ⅜ in.

A 7-turn coil of the same diameter and length covers the range of from 2.5 meters to 4.4 meters. This coil is tapped near the center and the tap plugs into the r.f. choke pin-jack. A 14-turn coil, ⅜-in.-dia., 1¼ in. long, tunes from 4 meters up to 6.8 meters. This coil is tapped at the 6th turn from the grid end of the coil, and the tap plugs into the cathode by-pass pin-jack. The largest coil consists of 14 turns, ⅝ in. inside diameter, 1⅛ in. long, tapped at 5 turns from the plate end and 6 turns from the grid end. The upper jacks are connected in such a manner as to short-circuit the r.f. choke. The tuning range of this coil is from 6.5 to 11.8 meters. The exact dimensions of the coils and locations of the taps will depend upon the physical layout of the r.f. circuit components. Enameled or bare no. 14 copper wire should be used in preference to tinned wire because of the lower r.f. resistance at the higher frequencies. Tinned wire has a much greater *skin effect* loss and should be avoided in all ultra-high-frequency receivers and transmitters.

The chassis is 5"x9"x1½", of no. 14 gauge aluminum, with a 12-gauge aluminum front panel 7"x11". The cathode by-pass condenser, cathode resistor for the 6V6G tube and the regeneration control by-pass condenser and 50,000-ohm resistor are mounted under the chassis.

It is recommended that the receiver not be used on the 5 and 10 meter bands when in the vicinity of other amateurs, as the receiver radiates sufficiently to cause bad QRM over an area having a radius of about one mile.

There are other types of receivers which are much more effective on 5 and 10 meters and do not cause interference. For this reason the usefulness of the receiver shown here is confined primarily to the 1¼ and 2½ meter bands.

SEVENTEEN

Antennas

RADIO waves consist of condensations and refractions of energy traveling through space with the speed of light (186,000 miles or 300,000,000 meters per second). These waves have an electrostatic and an electromagnetic component. The electrostatic component may be considered as corresponding to the voltage of the wave and the electromagnetic component to the wave current. Radio waves travel not only with speed of light but can be refracted and reflected much the same as light waves.

A simple transmitting antenna or radiating system sends out radio waves in nearly all directions, though the strength of the waves may be greater in certain directions, and at certain angles above the earth. High frequency energy radiated along the surface of the earth is rapidly attenuated and is of little use for consistent communication over distances exceeding 50 or 75 miles. That part of the radiated energy which is sent up at an angle above the horizon is partly returned to earth by the bending effect produced by the varying density of the ionized particles in the various layers of the *ionosphere.*

The ionosphere consists of layers of ionized particles of gas located above the stratosphere and extending up to possibly 750 miles above the earth. Thus we see that high-frequency radio waves may travel over short distances in a direct line from the transmitter to the receiver, or they can be radiated upward into the ionosphere to be bent downward in an indirect ray, returning to earth at considerable distance from the transmitter. The wave reaching a receiver via the ionosphere route is termed a *sky wave.* The wave reaching a receiver by traveling in a direct line from the transmitting antenna to the receiving antenna is commonly called a *ground wave* or *surface wave.*

The amount of bending which the sky wave undergoes depends upon the frequency of the wave and the amount of *ionization* in the ionosphere, which is in turn dependent upon radiation from the sun. The sun increases the density of the ionosphere layers and lowers their effective height. For this reason radio waves act very differently at different times of day and at different times of the year.

The higher the frequency of a radio wave the further it penetrates the ionosphere and the less it tends to be bent back toward the earth. The lower the frequency the more easily the waves are bent and the less they penetrate the ionosphere. 160-meter and 80-meter signals will usually be bent back to earth even when sent almost straight up, and may be considered as being *reflected* rather than *refracted.* As the frequency is raised beyond about 5,000 kc. (dependent upon the critical frequency of the ionosphere at the moment) it is found that waves transmitted at angles higher than a certain critical angle *never return to earth.* Thus on the higher frequencies it is usually desirable to confine radiation to low angles, since the high angle waves simply penetrate the ionosphere and keep right on going, never returning to earth.

Signals above about 45,000 kc. are bent so slightly that they seldom return to earth regardless of the vertical angle of radiation, although, under exceptional circumstances radio waves of 75,000 kc. have been known to return to earth for very short periods of time. Thus sky wave propagation does not permit *consistent* communication at frequencies of 45,000 kc. In fact, the results on frequencies above 22,000 kc. are not considered sufficiently consistent for commercial use.

Skip Distance

The ground wave of a 14,000-kc. transmitter can seldom be heard over 100 miles away. Also, the first bending of the sky wave rarely brings it back down to earth within 300 miles from the 14,000-kc. transmitting antenna at night. Thus there is an area including all distances between 100 and 300 miles from the transmitter in which the signals are not ordinarily heard. The closest distance at which sky waves return to earth is called the *skip distance*. In the skip zone no reception is possible, but moving closer to or farther away from the transmitter allows the signals to be heard.

Fading

The lower the angle of radiation of the wave, with respect to the horizon, the farther away will the wave return to earth and the greater the skip distance. The wave can be reflected back up into the ionosphere by the earth and then be reflected back down again, causing a second skip distance area. The drawing of figure 1 shows the multiple reflections possible. When the receiver receives signals which have traveled over more than one path between transmitter and receiver, the signal impulses will not all arrive at the same instant as they do not all travel the same distance. When two or more signals arrive in the same phase at the receiving antenna, the resulting signal in the receiver will be quite loud. On the other hand, if the signals arrive 180 degrees out of phase so they tend to neutralize each other, the received signal will drop—perhaps to zero if perfect neutralization occurs. This explains why high-frequency signals fade in and out.

Fading can be greatly reduced on the high frequencies by using a transmitting antenna with sharp vertical directivity, thus cutting down the number of multiple paths of signal arrival. A receiving antenna with similar characteristics (sharp vertical directivity) will further reduce fading. It is desirable when using antennas with sharp vertical directivity to use the lowest vertical angle consistent with good signal strength for the frequency used. This cuts down the number of hops the signal has to make to reach the receiver, and consequently reduces the chance for arrival via different paths.

Selective Fading

Selective fading affects all modulated signals. Modulated signals are not a single frequency signal but consist of a narrow band of waves perhaps fifteen kc. wide. It will be seen that the whole modulated signal band may not be neutralized at any instant, but only part of it.

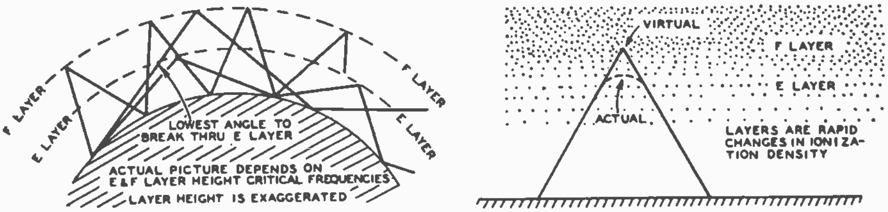


Figure 1.

ILLUSTRATING HOW THE IONIZED ATMOSPHERE OR IONOSPHERE LAYER CAN BEND RADIO WAVES BACK TO EARTH, AND SOME OF THE MANY POSSIBLE PATHS OF A HIGH-FREQUENCY SKY WAVE SIGNAL.

This causes a peculiar and changing form of audio distortion at the receiver, which suppresses some audio frequencies, emphasizes others, is known as *selective fading*.

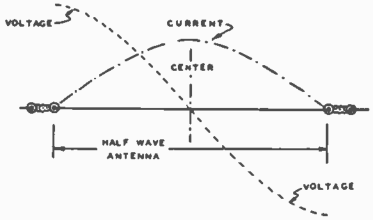
Angle of Radiation

For a certain frequency, ionosphere height and transmitting distance there is an optimum angle with the horizon at which the radio wave should be propagated. For extremely long distance communication the angle of radiation should be low (5 to 15 degrees above the horizon) regardless of the frequency used so that the wave may arrive in the fewest possible jumps. For short distance communication the optimum angle of radiation will be considerably higher, but because very high frequency waves are not readily bent and penetrate the ionosphere when striking it at too steep an angle, we see that the shorter wavelengths are not satisfactory for short distance communication. Thus we have the skip distance or zone of silence previously referred to. Different types of antennas have different major angles of radiation with respect to the earth and the antenna, as will be shown later.

Antenna Radiation

Alternating current passing through a conductor creates an alternating electromagnetic field around that conductor. Energy is alternately stored in the field and then returned to the conductor. As the frequency is raised, more and more of the energy does not return to the conductor but instead is radiated off into space in the form of electromagnetic waves, called radio waves. Radiation from a wire or wires is materially increased whenever there is a sudden *change* in the *electrical constants* of the line. These sudden changes produce reflection, which places *standing waves* on the line.

When a wire in space is fed radio frequency energy having a wavelength of approximately 2.08 times the length of the wire in meters it *resonates* as a *dipole* or half-wave antenna at that wavelength or frequency. The greatest possible change in the electrical constants of a line is that which occurs at the open end of a wire. Therefore a dipole has a great mismatch at each end, producing a high degree of reflection. We say that the dipole is terminated in an infinite impedance (open circuit). An incident radio frequency wave traveling to one end of the dipole is reflected right back towards the center of the dipole after reaching the end as there is no place else for it to go.



SHOWING HOW STANDING WAVES EXIST ON A RESONANT ANTENNA
CURRENT IS MAXIMUM AT CENTER — VOLTAGE IS MAXIMUM AT ENDS

Figure 2.

A returning wave which has been reflected meets the next incident wave and the voltage and current at any point along the antenna are the algebraic sum of the two waves. At the ends of the dipole the voltages add up while the currents and the two waves cancel, thus producing *high voltage* and *low current* at the *ends* of the dipole or half-wave section of wire. In the same manner it is found that the currents add up while the voltages cancel at the center of the dipole. Thus at the *center* there is *high current* but *low voltage*.

Inspection of figure 2 will show that the current in a dipole uniformly decreases towards either end while the voltage uniformly increases. The voltages at the two ends of the antenna are 180 degrees out of phase, which means that the polarities are opposite, one being plus while the other is minus at any instant. A curve representing either the voltage or current on a dipole represents a *standing wave* on the wire. If the voltage or current measured the same all along the wire it would indicate the absence of standing waves. The latter condition can exist only when energy is absorbed from one end of a wire or line exactly at the same rate it is supplied to the other end. The latter condition is covered thoroughly later in the chapter under the heading of "Untuned Transmission Lines." Many transmission lines do not have uniform voltage and current along their length and thus have standing waves the same as a dipole or antenna radiator.

A point of maximum current on a radiator or tuned resonant transmission line ordinarily corresponds to a point of minimum voltage. A *loop* means a point of *maximum* current or voltage, while a *node* refers to a point of *zero* or *minimum* current or voltage. Thus we see that a voltage loop corresponds to a current node and vice versa. In a wire or line containing reactance this is not strictly true, but in amateur work both antennas and tuned transmission lines are operated at resonance and the reactance therefore is negligible.

A two-wire resonant line does not radiate appreciably in spite of its high reflection and consequent standing waves because the radiation from the two adjacent wires is of opposite polarity or phase and equal in amplitude, thus cancelling out. In other words, the radiation from one point is absorbed or neutralized by the other wire and vice-versa.

Frequency, Wavelength, Antenna Length

All antennas commonly used by amateurs excepting the terminated rhombic are based on the fundamental Hertz type, which is a wire in space a half wavelength long electrically. A resonant dipole which is a half wavelength long *electrically* is actually slightly less than a half wave long *physically*, due to the "end effects" and the fact that the velocity of a high-frequency radio wave traveling along the conductor is not quite as high as it is in free space. Below 30,000 kc. this effect is relatively constant so that an electrical half wave is a fixed percentage shorter than a physical half wavelength. This percentage is approximately 5 per cent. Therefore most half-wave antennas are really 95 per cent of a half wave long. Thus a half-wave antenna resonant at exactly 80 meters would be one half of 0.95 times 80 meters in length. Another way of saying the same thing is that a wire resonates at a wavelength of about 2.1 times its length in meters.

Simple conversion into feet can be obtained by using the factor 1.56. To find the physical length of a half-wave 80-meter antenna we multiply 80 times 1.56 and get 124.8 feet for the length of the radiator.

It is more common to use frequency than wavelength when indicating a specific spot in the radio spectrum. For this reason the relationship between wavelength and frequency must be kept in mind. As the velocity of radio waves through space is constant at the speed of light, it will be seen that the more waves that pass a point per second (higher the frequency), the closer together the peaks of those waves must be (higher the wavelength). Therefore the higher the frequency the lower the wavelength.

Frequency describes the number of wave peaks passing a point per second. Wavelength describes the distance in meters between adjacent peaks of a wave train.

A radio wave in space can be compared to a wave in water. The wave in either case has peaks and troughs. One peak and one trough constitute a *full wave* or *one wavelength*.

As a radio wave travels 300,000,000 meters a second (speed of light), a frequency of one cycle per second corresponds to a wavelength of 300,000,000 meters. So if the frequency is multiplied by a million the wavelength must be divided by a million in order to maintain their correct ratio.

A frequency of one million cycles per second (one thousand kc.) equals a wavelength of 300 meters. Multiplying frequency by ten and dividing wavelength by ten, we find: a frequency of 10,000 kc. equals a wavelength of 30 meters. Multiplying by ten and dividing by ten again we get: a frequency of 100,000 kc. equals 3 meters wavelength. Therefore to change wavelength to frequency simply divide 300,000 by the wavelength in meters. The wavelength in meters equals 300,000 divided by frequency in kc.

$$F_{kc} = \frac{300,000}{\lambda}$$

$$\lambda = \frac{300,000}{F_{kc}}$$

Now that we have a simple conversion formula for converting wavelength to frequency and vice versa we can combine it with our wavelength versus antenna length formula and we have the following:

Wire length of half-wave radiator, in

$$\text{feet} = 1.56\lambda = \frac{467,400}{F_{kc}} = \frac{467.4}{F_{Mc}}$$

The slight discrepancy between the answers that will be obtained by the wavelength formula and by the frequency formula is due to the fact that the factor 1.56 is given only to two decimal places, this degree of accuracy being sufficient for ordinary purposes. Actually the factor is 1.558, but 1.56 is close enough and simplifies calculations.

Harmonic Resonance

A wire in space resonates at more than one frequency. The *lowest* frequency at which it resonates is called its *fundamental* frequency, and at that frequency it is approximately a half wavelength long. A wire can have two, three, four, five or more standing waves on it, and thus resonates at approximately the integral harmonics of its fundamental frequency. However, the higher harmonics are not exactly integral multiples of the lowest resonant frequency as end effects influence only the outer quarter waves.

As the end effect comes in *only* at the ends, regardless of whether the antenna has its minimum resonant length or any of the longer resonant lengths (harmonic resonance), the equivalent electrical length approaches the actual physical length more and more, as the antenna length, measured in wavelengths, increases.

The following two formulas can be used to determine either the frequency or length of a wire with a given number of half waves on it. These formulas are accurate between 3000 and 30,000 kc.

$$L = \frac{492\ (K - .05)}{F_{Mc}}$$

$$F_{Mc} = \frac{492\ (K - .05)}{L}$$

Where F equals frequency in *megacycles.*
L equals length in feet.
K equals number of half waves on wire.

Antenna Impedance

In many ways a half-wave antenna is like a tuned tank circuit. The main difference lies in the fact that the elements of inductance, capacity and resistance are *lumped* in the tank circuit and are *distributed* throughout the length of an antenna. The center of a half-wave radiator is effectively at ground potential as far as r.f. voltage is concerned, although the current is highest at that point. See figure 2.

When the antenna is resonant, and it always should be for best results, the impedance at the center is a pure resistance and is termed the radiation resistance. Radiation resistance is a fictitious term used to express the power radiated by the antenna. It is the value of resistance which would dissipate the same amount of power that is being radiated by the antenna.

The radiation resistance at the voltage node (current loop; in other words, minimum voltage and maximum current) depends on the length of the antenna and its proximity to nearby objects which either absorb or reradiate power, such as the ground, other wires, etc.

Before going too far with the discussion of radiation resistance an explanation of the Marconi (grounded quarter wave) antenna is in order. The Marconi antenna is a special type of Hertz antenna in which the earth acts as the "other half" of the dipole. In other words, the current flows into the earth instead of into a similar quarter-wave section. Thus the current loop of a Marconi antenna is at the *base* rather than in the *center*. In either case it is a quarter wavelength from the end (or ends).

A half-wave dipole far from ground and other reflecting objects has a radiation resistance at the center of 73.14 ohms. Radiation resistance is ordinarily referred to a current loop. Otherwise it has no particular significance because it could be most any value if the point on the antenna were not designated.

A Marconi antenna radiates only half as much energy as a dipole for a given impressed voltage. For that reason the radiation resistance is just half 73.14 ohms or 36.57 ohms.

Because the power throughout the antenna is the same, the impedance of the antenna at any point along its length merely expresses the ratio between voltage and current at that point. Thus the lowest impedance occurs where the current is highest, namely, at the center of a dipole or a quarter wave from the end of a Marconi. The impedance rises uniformly toward each end, where it is approximately 2400 ohms for a dipole remote from ground or 4800 ohms for a vertical Marconi.

If a vertical half-wave antenna is set up so that its lower end is at the ground level, the effect of the ground reflection is to increase the radiation resistance to approximately 100 ohms. When a horizontal half-wave antenna is used, the radiation resistance (and, of course, the amount of energy radiated for a given antenna current) depends on the height of the antenna above ground, since the height determines the phase angle between the wave radiated directly in any direction and the wave which combines with it after reflection from the ground.

The radiation resistance of an antenna generally increases with length, although this increase varies up and down about a constantly increasing average. The peaks and dips are caused by the reactance of the antenna when its length does not allow it to resonate at the operating frequency.

Antennas have a certain loss resistance as well as a radiation resistance. The loss resistance defines the power lost in the antenna due to ohmic resistance of the wire, ground resistance, corona discharge and insulator losses.

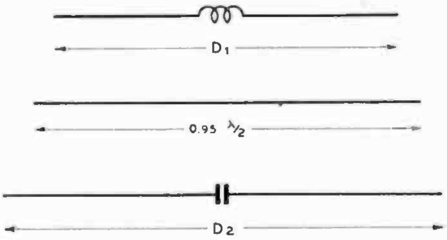


Figure 3.

THREE ANTENNAS, ALL EQUAL ELECTRICALLY TO ONE HALF WAVELENGTH.

The top antenna is inductively lengthened. The bottom one is capacitively shortened. A coil will have the most lengthening effect when located at a current loop.

Resonance

Most antennas operate best when resonated to the frequency of operation. This does not apply to the terminated rhombic antenna or to the *parasitic* elements of one popular type of close-spaced array to be described later in the chapter. However, in practically every other case it will be found that increased efficiency results when the entire antenna system is resonant whether it be a simple dipole or an elaborate array. The radiation efficiency of a resonant wire is many times that of a wire which is not resonant.

If an antenna is slightly too long it can easily be resonated by means of a variable capacitor. If it is slightly too short, it can be easily resonated by means of a variable inductance. These two methods are generally employed when part of the antenna is brought into the operating room.

With an antenna array, or an antenna fed by means of a transmission line, it is more common to cut the elements to exact resonant length by "cut and try" procedure. Exact antenna resonance is more important when the antenna system has low radiation resistance; an antenna with low radiation resistance has higher Q (tunes sharper) than an antenna system with high radiation resistance.

CHARACTERISTICS AND CONSIDERATIONS

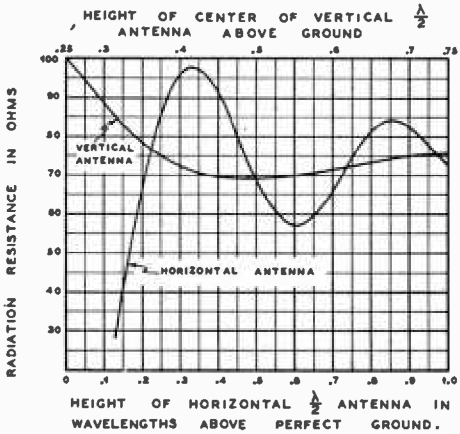


Figure 4.

EFFECT OF HEIGHT ON THE RADIATION RESISTANCE OF A DIPOLE SUSPENDED ABOVE PERFECT GROUND.

Radiation Resistance

Along a half-wave antenna the *impedance* varies from a minimum at the center to a maximum at the ends. The impedance is that property which determines the antenna current at any point along the wire for the value of radio-frequency voltage at that point. The main component of this impedance is the radiation resistance; normally the latter is referred to the center of the half-wave antenna where the current is at maximum. The square of the current multiplied by the radiation resistance is equal to the power radiated by the antenna. For convenience, these values are usually referred to the center of a half-wave section of antenna.

The curves of figure 4 indicate the theoretical center-point radiation resistance of a half-wave antenna for various heights above perfect ground. These values are of importance in matching untuned radio-frequency feeders to the antenna in order to obtain a good impedance match and an absence of standing waves on the feeders.

Above *average* ground, the actual radiation resistance of a dipole will vary from the exact value of figure 4, since the latter assumes a hypothetical perfect ground having no loss and perfect reflection. Fortunately, the curves for the radiation resistance over most types of earth will correspond rather closely with those of the chart, except that the radiation resistance for a horizontal dipole does not fall off as rapidly as is indicated for heights below an eighth wavelength. However, with the antenna so close to the ground and the soil in a strong field, much of the radiation resistance is actually represented by ground loss; this means that a good portion of the antenna power is being dissipated in the earth, which, unlike the hypothetical perfect ground, has resistance. The type of soil also has an effect upon the radiation *pattern,* especially in the vertical plane, as will be seen later.

When the radiation resistance of an antenna or array is very low, the current at a voltage node will be quite high for a given power. Likewise, the voltage at a current node will be very high. Even with a heavy conductor and excellent insulation, the losses due to the high voltage and current will be appreciable if the radiation resistance is sufficiently low.

Usually, it is not considered desirable to use an antenna or array with a radiation resistance of less than approximately 10 ohms unless there is sufficient directivity, compactness or other advantage to offset the losses resulting from the low radiation resistance.

Ground Resistance

The radiation resistance of a Marconi antenna, especially, should be kept as high as possible. This will reduce the antenna current for a given power, thus minimizing loss resulting from the series resistance offered by the earth connection. The radiation resistance can be kept high by making the Marconi radiator slightly longer than a quarter wave and shortening it by series capacity to an electrical quarter wave (five-sixteenths wave being about the maximum for a series-tuned quarter-wave Marconi). It should also be removed from ground as much as possible (vertical being ideal). Methods of minimizing the resistance of the earth connection will be found in the discussion of the Marconi antenna.

ANTENNA DIRECTIVITY

When choosing and orienting an antenna system, the radiation patterns of the various common types of antennas should be given careful consideration. The directional characteristics are of still greater importance when a directive antenna array is used.

There are two kinds of antenna directivity: vertical and horizontal. The latter is not generally desirable for amateur work except (1) for point-to-point work between stations regularly communicating with each other, (2) where several arrays are so placed as to cover most useful directions from a given location, and (3) when the beam may be directed by electrical or mechanical rotation.

Considerable horizontal directivity can be used to advantage for point-to-point work. Signals follow the great circle path or are within 2 or 3 degrees of that path a good share of the time.

For general amateur work, however, *too much* horizontal directivity is ordinarily undesirable, inasmuch as it necessitates having the beam pointed exactly at the station being worked. Making the array rotatable overcomes this obstacle, but arrays having extremely high horizontal directivity are too cumbersome to be rotated, except perhaps above 56 Mc. The horizontal directivity of a horizontal dipole depends upon the vertical angle being considered. Directivity is greater for lower vertical angles. This polar diagram shows the horizontal.

On the 28- and 14-Mc. bands, and to an extent on the 7-Mc. band, the matter of vertical directivity is of as much importance as is horizontal directivity. Only the power leaving the antenna at certain vertical angles is instrumental in putting a signal into a distant receiving antenna; the rest may be considered as largely wasted. In other words the important thing is the amount of power radiated in a desired direction *at the useful vertical angles,* rather than the actual shape of the directivity curves as read on the ground by a field strength meter, the latter giving only a pattern of the *ground wave.*

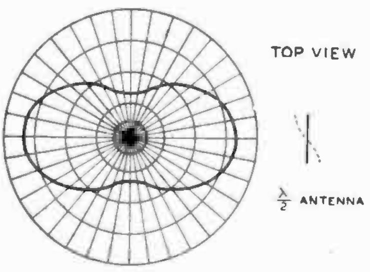


Figure 5.

RADIATION PATTERN OF A HALF-WAVE ANTENNA A HALF WAVE ABOVE PERFECT GROUND, FOR A FIXED VERTICAL ANGLE OF 30°.

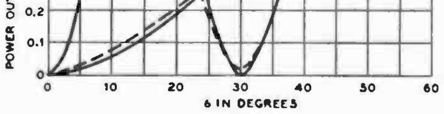


Figure 6.

PATTERNS OF VERTICAL DIRECTIVITY FOR HORIZONTAL DOUBLETS AT HEIGHT H ABOVE PERFECT AND HOLMDEL, N. J., GROUND.

Note that radiation from the Holmdel antennas is only slightly less than for perfect ground, and that maximum radiation occurs at the same vertical angles for either ground.

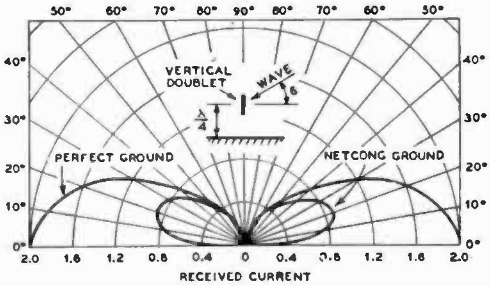


Figure 7.
VERTICAL DIRECTIVITY OF VERTICAL DOUBLETS ABOVE PERFECT GROUND AND ABOVE GROUND AT NETCONG, N. J.

These curves explain why a vertical radiator is not so efficient on 10 and 20 meters as might be expected, even though it is a "low angle" radiator.

A nondirectional antenna such as a vertical or horizontal dipole will give excellent results with general coverage on 28 and 14 Mc. if the vertical angle of radiation is favorable. The latter type is slightly directional broadside, especially on 28 Mc. where only very low angle radiation is useful, but is still considered as a "general coverage" type.

Effect of Average Ground on Antenna Radiation

Articles appearing in amateur journals discussing antenna radiation usually are based upon the perfect ground assumption in order to cover the subject in the most simple manner. Yet, little has been said about the real situation which exists, the ground generally being everything but a perfect conductor. Consideration of the effect of a ground that is not perfect explains many things.

When the earth is less than a perfect conductor, it becomes a dielectric or, perhaps in an extreme case, a leaky insulator. Let us first study the horizontal antenna above average ground, because it is less seriously affected.

The resulting change in the vertical pattern of a horizontal antenna is shown in figure 6, which includes a perfect ground comparison. The ground constants in this case are those for Holmdel, New Jersey. The country there is flat farmland, and probably is similar to midwestern farmland. It will be noted that there is only a slight loss in power due to the imperfect ground.

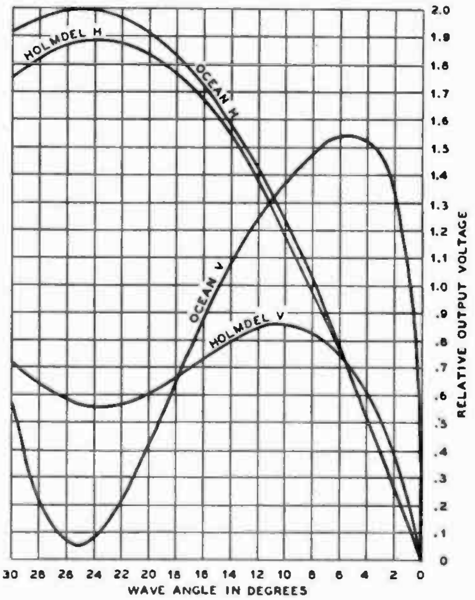


Figure 8.
VERTICAL - PLANE DIRECTIONAL CHARACTERISTICS OF HORIZONTAL AND VERTICAL DOUBLETS ELEVATED 0.6 WAVELENGTH AND ABOVE TWO TYPES OF GROUND.

These curves indicate the need for high conductivity earth (or ground radials) under a vertical radiator. Salt water has enough conductivity that the radiation approximates that obtained over perfect ground except for angles below 6 degrees.

The effect of the earth on the radiation pattern of a vertical dipole is apparent from figures 7 and 8. It shows how radiation from a half-wavelength vertical wire is severely reduced by deficiencies of the ground. Even over the most perfect ground available, sea water or salt marsh, radiation at the lowest angles approaches that for a horizontal antenna, and complete cancellation takes place at the horizontal.

Vertical vs. Horizontal Radiators

A very important factor in the advantages of horizontal or vertical dipoles, therefore, appears to be the condition of the ground. Figure 8 shows a comparison between such doublets elevated 0.6 wavelength above Rumson, New Jersey, salt marsh and Holmdel farmland. This suggests that the horizontal has some advantages for high angle waves, but none for very low angles over dry farmland. On the other hand, there is a substantial advantage favoring the vertical located over wet or marshland when very low angles are involved.

The best angle of radiation varies with frequency, layer height and many other factors. For instance, a lower optimum vertical angle is found to hold for high-frequency communication with South America from the U.S.A. than for Europe and the U.S.A.

FEEDING THE ANTENNA

Usually a high-frequency doublet or directional array is mounted as high and as much in the clear as possible for obvious reasons. Power can then be fed to the antenna system via one of the various transmission lines discussed in the latter portion of this chapter.

However, it is sometimes justifiable to bring part of the radiating system directly to the transmitter, feeding the antenna without benefit of a transmission line. This is permissible when (1) there is insufficient room to erect a 75- or 160-meter horizontal dipole and feed line, (2) when a long wire is operated on one of the higher frequency bands on a harmonic. In either case, it is usually possible to get the main portion of the antenna in the clear because of its length. This means that the power lost by bringing the antenna directly to the transmitter is relatively small.

Even so, it is not the best practice to bring the high-voltage end of an antenna into the operating room, especially for phone operation, because of the possibility of r.f. feedback from the strong antenna field. For this reason, one should dispense with a feed line in conjunction with a Hertz antenna only as a last resort.

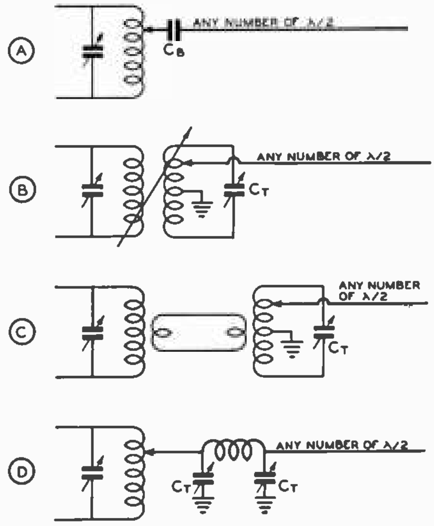


Figure 9.

FOUR METHODS OF END FEEDING AN ANTENNA.

The arrangement of "C" is to be recommended. The legality of arrangement "A" for amateur work is debatable if the blocking condenser is large. It is really a form of direct coupling, permitted by the regulations only when an untuned feed line is used.

End-Fed Antennas

The end-fed Fuchs (pronounced "Fooks") antenna has no form of transmission line to couple it to the transmitter, but brings the radiating portion of the antenna right down to the transmitter where some form of coupling system is used to transfer energy to the antenna.

This antenna is always voltage-fed and always consists of an *even* number of

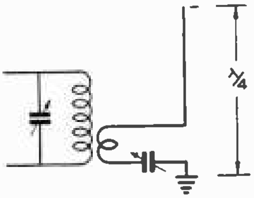


Figure 10.

THE SERIES-TUNED QUARTER-WAVE MARCONI, THE BASIC MARCONI ANTENNA SYSTEM.

The overall length to the earth connection, including lead in, is from 10% to 25% in excess of a quarter wavelength physically. The system is capacity-shortened and resonated by means of the series tuning condenser, which 160 meters should have from .00025 to .0005 μfd. for maximum capacity.

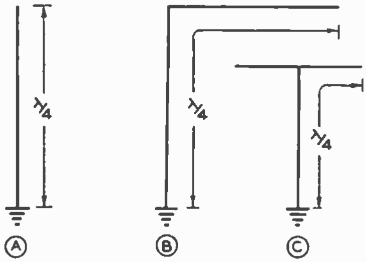


Figure 11.

THREE COMMON VARIATIONS OF THE MARCONI ANTENNA.

The bottom half of the radiator does most of the radiating, regardless of which type is used, because the current is greatest close to ground.

quarter wavelengths. Figure 9 shows several common methods of feeding the Fuchs antenna or end-fed Hertz. Arrangement "C" is to be recommended to minimize harmonics, as an end-fed antenna itself offers no discrimination against harmonics, either odd or even.

The Fuchs type of antenna has rather high losses unless at least three-quarters of the radiator can be placed outside the operating room and in the clear. As there is high r.f. voltage at the point where the antenna enters the operating room, the insulation at that point should be several times as effective as the insulation commonly used with low-voltage feeder systems. This antenna can be operated on all of its higher harmonics with good efficiency, and can be operated at half frequency against ground as a quarter-wave Marconi.

THE MARCONI ANTENNA

A grounded quarter-wave Marconi antenna is widely used on the 160-meter band due to the fact that a half-wave antenna at that low frequency is around 260 feet long, which is out of the question for those confined to an ordinary city lot. It is also widely used in u.h.f. mobile applications where a compact radiator is required.

The Marconi type antenna allows the use of half of the length of wire used for a half-wave Hertz radiator. The ground acts as a mirror, in effect, and takes the place of the extra quarter wave that would be required to resonate the wire, were it not grounded.

The Marconi antenna generally is not as satisfactory for long distance communications at the Hertz type, and the radiation efficiency is never as great, due to the losses in the ground connection. However, it can be made almost as good a radiator on 160 meters if *sufficient care is taken with the ground system.*

The fundamental Marconi antenna is shown in figure 10, and all Marconi antennas differ from this only in the method of feeding energy. Antenna A in figure 11 is the fundamental vertical type. Type B is the inverted-L type; type C is the T type with the two halves of the top portion of the T effectively in parallel.

The Marconi antenna should be as *high as possible,* and too much attention cannot be paid to getting a low resistance ground connection.

Importance of Ground Connection

With a quarter-wave antenna and a ground, the antenna current is generally measured with a meter placed in the antenna circuit close to the ground connection. Now, if this current flows through a resistor, or if the ground itself presents some resistance, there will definitely be a power loss in the form of heat. Improving the ground connection, therefore, provides a definite means of reducing this loss of antenna power and thus increasing the radiated power.

The best possible ground consists of as many wires as possible, each at least a quarter wave long, buried just below the surface of the earth and extending out from a common point in the form of radials. Copper wire of any size larger than no. 16 is satisfactory, though the larger sizes will take longer to corrode. In fact, the radials need not even be buried; they may be supported just above the earth and insulated from it. This arrangement is called a *counterpoise,* and operates by virtue of its high capacity to ground. Unless a large number of radials are used, fairly close to the ground, the counterpoise will act more like the bottom half of a half-wave Hertz than like a ground system. However, the efficiency with a counterpoise will be quite good, regardless. It is when the radials are buried or laid on the ground that a large number should be used for best efficiency. Broadcast stations use as many as 120 radials of from 0.3 to 0.5 wavelength long.

A large number of radials not only provide a low resistance earth connection but also, if long enough, give the effect of locating the radiator over highly conducting earth. The importance of the latter with regard to vertical antennas is illustrated in figures 7 and 8.

When it is impossible to extend buried radials in all directions from the ground connection for an inverted-L type Marconi, it is of importance that a few wires be buried directly below the flat top and spaced at least 10 feet from one another.

If the antenna should be physically shorter than a quarter wavelength, antenna current would be higher, due to lower radiation resistance. Consequently, the power lost in resistive soil would be greater. The importance of a good ground with short, inductive-loaded Marconi radiators is, therefore, quite obvious. With a good ground system, even very short antennas can be expected to give upwards from 90% of the efficiency of a quarter-wave antenna used with the same ground system.

Water Pipe Grounds

Water pipe, because of its comparatively large surface, and cross section, has about as low an r.f. resistance as copper wire. If it is possible to attach to a junction of several water pipes (where they branch in several directions and run for some distance under ground), a satisfactory ground connection will be obtained. If one of the pipes attaches to a lawn or garden sprinkler system in the immediate vicinity of the antenna, and runs hither and thither to several neighboring faucets within a radius of a hundred yards, the effectiveness of the system will approach that of buried copper radials.

The main objection to water pipe grounds is the possibility of high resistance joints in the pipe due to the "dope" put on the coupling threads. By attaching the ground wire to a junction with three or more legs, the possibility of requiring the main portion of the r.f. current to flow through a high resistance connection is greatly reduced.

The presence of water in the pipe adds but little to the conductivity; therefore it does not relieve the problem of high resistance joints. Bonding the joints is the best insurance, but this is, of course, impracticable where the pipe is buried. Bonding together with copper wire the various water faucets in your yard above the surface of the ground will improve the effectiveness of a water pipe ground system hampered by high resistance pipe couplings.

Marconi Dimensions

A Marconi antenna is exactly an odd number of electrical quarter waves long (usually only one quarter wave in length), and is always resonated to the operating frequency. The correct loading of the final amplifier is accomplished by varying the coupling *rather than by detuning the antenna from resonance.*

Physically, a quarter-wave Marconi may be made anything from one-eighth to nearly three-eighths wavelength overall, meaning the total length of the antenna wire and ground lead from the end of the antenna to the point where the ground lead attaches to the junction of the radials or counterpoise wires or the water pipe enters the ground. The longer the antenna is made physically, the higher will be the radiation resistance, the lower will be the current flowing in the ground connection and the greater will be the overall radiation efficiency. However, when the antenna length approaches three-eighths wavelength, the antenna becomes difficult to resonate by means of a series condenser, and it begins to take shape as an end-fed Hertz, requiring a different method of feed than that illustrated in figure 10 for current feed of a Marconi.

A radiator physically shorter than a quarter wavelength can be lengthened electrically by means of a series loading coil, and used as a quarter-wave Marconi. However, if the wire is made shorter than approximately one-eighth wavelength, the radiation resistance will be so low that good efficiency cannot be obtained even with a very good ground.

To inductively resonate an inductive-loaded Marconi, the inductance would have to be in the form of a variometer in order to permit continuous variation of the inductance. The more common practice is to use a tapped loading coil and a series tuning condenser. More than the required amount of inductance for resonance is clipped in series with the antenna, and the system is then resonated by means of the series variable condenser the same as though the radiator were actually too long physically.

To estimate whether a loading coil will probably be required, it is necessary only to note if the length of the antenna wire and ground lead is over a quarter wavelength; if so, no loading coil should be required, provided the series tuning condenser has a high maximum capacity.

Those primarily interested in the higher frequency bands but who like to work 160 meters for an occasional local ragchew can usually manage to resonate one of their antennas as a Marconi by working the whole system, feeders and all, against a water pipe ground and resorting to a loading coil if necessary. A high-frequency zepp, doublet or single-wire-fed antenna will make quite a good 160-meter Marconi if high and in the clear, with a rather long feed line to act as a radiator on 160 meters. Where two-wire feeders are used, the feeders should be tied together for Marconi operation.

TRANSMISSION LINES

For many reasons it is desirable to place a radiator as high and as much in the clear as possible, utilizing some form of nonradiating transmission line to carry energy with as little loss as possible from the transmitter to the radiating antenna.

There are many different kinds of transmission lines, and generally speaking, practically any type of transmission line or feeder system can be used with any type of antenna; however, certain types are often better adapted than others for use with a certain antenna.

Transmission lines are of two general types: resonant and nonresonant. Strictly speaking, the term *transmission line* should really only be applied to a *nonresonant line*. Strictly speaking, a *resonant* line should be termed a *feeder* system, such as zepp feeders, etc. However, *transmission line* has come to refer to either type of line, tuned or untuned.

The principal types of nonresonant transmission lines include the single-wire-feed, the two-wire open and the twisted-pair matched impedance, the coaxial (concentric) feed line and the multi-wire matched-impedance open line.

Voltage Feed and Current Feed

The half-wave Hertz antenna has high voltage and low current at each end, and it has low voltage and high current at its center. As any ungrounded resonant antenna consists merely of one or more half-wave antennas placed end to end, it will be seen that there will be a point of high r.f. voltage every half wave of length measured from either end of the antenna. Also, there will be a point of high r.f. current half-way between any two adjacent high voltage points.

A voltage-fed antenna is any antenna which is excited at one of these high voltage points or, in other words, a point of high impedance. Likewise, a current-fed antenna is one excited at a point along the antenna where the current is high and the voltage low, which corresponds to a point of low impedance.

THE ZEPP ANTENNA

The zepp antenna system is easy to tune up and can be used on several bands by merely retuning the feeders. The overall efficiency of the zepp antenna system is probably not quite as high for long feeder lengths as some of the antenna systems which employ nonresonant transmission lines, but where space is limited and where operation on more than one band is desired, the zepp has some decided advantages.

Zepp feeders really consist of an additional length of antenna which is folded back on itself so that the radiation from the two halves cancels out. In figure 12A is shown a simple Hertz antenna fed at the center by means of a pickup coil. Figure 12B shows another half-wave radiator tied directly on one end of the radiator shown in figure 12A. Figure 12C is exactly the same thing except that the first half-wave radiator, in which is located the coupling coil, has been folded back on itself. In this particular case, each half of the folded part of the antenna is exactly a quarter-wave long electrically.

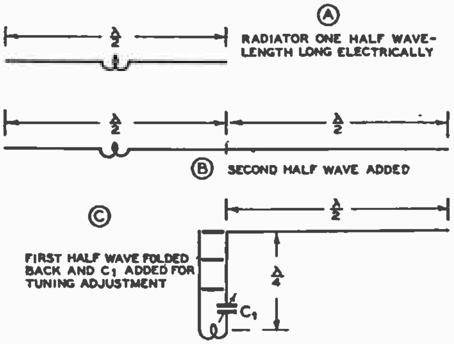


Figure 12.

THE EVOLUTION OF A ZEPP ANTENNA.

Addition of the coupling coil naturally will electrically lengthen the antenna; thus, in order to bring this portion of the antenna back to resonance, we must electrically shorten it by means of the series tuning condenser, C_1. The two wires in the folded portion of the antenna system do not have to be exactly a quarter wave long physically although the total *electrical* length of the folded portion must be equal to one-half wavelength electrically.

When the total electrical length of the two feeder wires plus the coupling coil is slightly greater than any odd multiple of one-quarter wave, then series condensers must be used to shorten the electrical length of the feeders sufficiently to establish resonance. If, on the other hand the electrical length of the feeders and the coupling coil is slightly less than any odd multiple of one-quarter wave, then parallel tuning (wherein a condenser is shunted across the coupling coil) must be used in order to increase the electrical length of the whole feeder system to a multiple of one-quarter wavelength.

As the radiating portion of the zepp antenna system must always be some multiple of a half wave long, there is always high voltage present at the point where the live zepp feeder attaches to the end of the radiating portion of the antenna. Thus, this type of zepp antenna system is *voltage fed*.

The idea that it takes two condensers to balance the current in the feeders, one condenser in each feeder, is a common misconception regarding the zepp type end-fed antenna. Balancing the feeders with tuning condensers for equal currents is useless anyhow, inasmuch as the feeders on an end-fed zepp can never be balanced for *both* current *and* phase because of the tendency for the end of the "dead" feeder to have more voltage on it than the one attached to the radiator.

Flat Top Length

The correct physical length for the flat top (radiating portion) of a zepp is *not* 0.95 of a half wavelength. Instead it is so close to a half wavelength that it may be taken as that figure. Thus, while a 7300-kc. doublet is 64 feet long, the flat top of a 7300-kc. *zepp* should be 67 feet 3 inches. The reason for this is readily apparent when it is remembered that the 5 per cent difference between a resonant doublet and a physical half wavelength is principally due to "end effects", 2½ per cent at each end of the radiator.

Obviously there is no end effect at the end of a radiator to which zepp feeders are attached. Hence we lengthen the radiator 2½ per cent. Now we must take into consideration that the end of the "dead" (unattached) feed wire has end effects and that the other feeder does not. We want the two voltage loops to come at the same point on the feed line in order to obtain the best possible balance so as to minimize radiation. So we make the dead feed wire 2½ per cent shorter than the other, or the attached feed wire 2½ per cent longer than the other. The latter is simplest, as it can be done quite easily merely by lengthening the flat top 2½ per cent. Thus the flat top is 5 per cent longer than if it were fed in the center.

THE TUNED DOUBLET

A current-fed doublet with spaced feeders, sometimes erroneously called a center-fed zepp, is an inherently balanced system (if the two legs of the radiator are exactly equal electrically) and there will be no radiation from the feeders regardless of what frequency the system is operated on. A series condenser may be put in *one* feeder (if right at the coupling coil) without affecting the balance of the system. The system can successfully be operated on most any frequency if the system as a whole can be resonated to the operating frequency. This is usually possible with a tapped coil and a tuning condenser that can optionally be placed either across the antenna coil or in series with it.

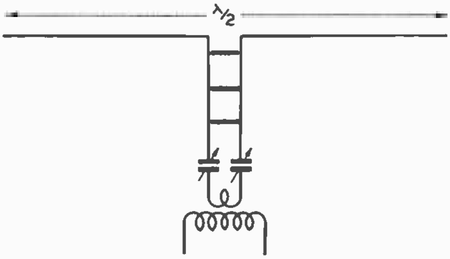


Figure 13.

THE TUNED DOUBLET USES AN OPEN-WIRE FEED SYSTEM

The flat top need not be exactly an electrical half wave in length so long as the whole system, both flat top and feeders, is resonant as a unit. Only one tuning condenser need be used if desired. Certain feeder lengths will require that the condenser be placed across the coil rather than in series with it.

This type of antenna system is shown in figure 13. It is a current-fed system on the lowest frequency for which it will operate, but becomes a voltage-fed system on all its even harmonics.

The antenna has a different radiation pattern when operated on harmonics, as would be expected. The arrangement used on the second harmonic is better known as the Franklin colinear array and is described later in this chapter. The pattern is similar to a half-wave doublet except that it is sharper in the broadside direction. On higher harmonics there will be multiple lobes.

TUNED FEEDER CONSIDERATIONS

If a transmission line is terminated in its *characteristic surge impedance,* there will be no reflection at the end of the line and the current and voltage distribution will be uniform along the line. If the end of the line is either open-circuited or short-circuited, the reflection at the end of the line will be 100 per cent, and *standing waves* of very great amplitude will appear on the line. There will still be practically no radiation from the line, but voltage nodes will be found along the line spaced a half wavelength. Likewise, voltage loops will be found every half wavelength, the voltage loops corresponding to current nodes.

If the line is terminated in some value other than the characteristic surge impedance, there will be some reflection, the amount being determined by the amount of mismatch. With reflection, there will be standing waves (excursions of current and voltage) along the line, though not to the same extent as with an open-circuited or short-circuited line. The current and voltage loops will occur at the same *points* along the line, and as the terminating impedance is made to approach the characteristic impedance of the line, the current and voltage along the line will become more uniform. The foregoing assumes, of course, a purely resistive (nonreactive) load.

A well built 500- to 600-ohm transmission line may be used as a resonant feeder for lengths up to several hundred feet with very low loss, so long as the amplitude of the standing waves (ratio of maximum to minimum voltage along the line) is *not too great.* The amplitude, in turn, depends upon the mismatch at the line termination. A line of no. 12 wire, spaced 6 inches with good ceramic or Lucite spreaders, has a surge impedance of approximately 600 ohms, and makes an excellent tuned feeder for feeding anything between 60 and 6000 ohms. If used to feed a load of higher or lower impedance than this, the standing waves become great enough in amplitude that some loss will occur unless the feeder is kept short.

If a transmission line is not perfectly matched it should be made *resonant,* even though the amplitude of the standing waves (voltage variation) is not particularly great. This prevents reactance from being coupled into the final amplifier. A feed system having moderate standing waves may be made to present a nonreactive load to the amplifier either by tuning or by pruning the feeders to approximate resonance.

Usually it is preferable with tuned feeders to have a current loop (voltage minima) at the transmitter end of the line. This means that when voltage-feeding an antenna the tuned feeders should be made an odd number of quarter wavelengths long, and when current-feeding an antenna the feeders should be made an even number of quarter wavelengths long. Actually, the feeders are made about 10 per cent of a quarter wave longer than the calculated value (the same value given in the tables) when they are to be series tuned to resonance by means of a condenser instead of being trimmed and pruned to resonance.

When tuned feeders are used to feed an antenna on more than one band, it is necessary to compromise and make provision for both series and parallel tuning, inasmuch as it is impossible to cut a feeder to a length that will be optimum for several bands. If a voltage loop appears at the transmitter end of the line on certain bands, parallel tuning of the feeders will be required in order to get a transfer of energy. It is impossible to transfer energy by inductive coupling unless current is flowing. This is effected at a voltage loop by the presence of the resonant tank circuit formed by parallel tuning of the antenna coil.

Methods of coupling to a transmitter are discussed later in the chapter.

UNTUNED TRANSMISSION LINES

A nonresonant or untuned line is a line with negligible standing waves. Physically, the line itself should be *identical throughout its length;* there will be a smooth distribution of voltage and current throughout its length, both tapering off very slightly towards the antenna end of the line as a result of line losses. The attenuation (loss) in certain types of untuned lines can be kept very low for line lengths up to several thousand feet. In other types, particularly where the dielectric is not air (such as in the twisted-pair line), the losses may become excessive at the higher frequencies unless the line is relatively short.

The termination at the antenna end is the only critical characteristic about the untuned line. It is the reflection from the antenna end which starts waves moving back toward the transmitter end. When waves moving in both directions along a conductor meet, standing waves are set up.

All transmission lines have distributed inductance, capacity and resistance. Neglecting the resistance, as it is of minor importance in short lines, it is found that the *inductance and capacity per unit length* determine the characteristic or surge impedance of the line. Thus, the surge impedance depends upon the nature and spacing of the conductors and the dielectric separating them.

When any transmission line is terminated in an impedance equal to its surge impedance, reflection of energy does not occur and no standing waves are present. When the load termination is exactly the same as the line impedance, it simply means that the load takes energy from the line just as fast as the line delivers it, no slower and no faster.

Thus, for proper operation of an untuned line (with standing waves eliminated), some form of impedance-matching arrangement must be used between the transmission line and the antenna so that the radiation resistance of the antenna is reflected back into the line as a nonreactive impedance equal to the line impedance. It is important that the *radiator itself be cut to exact resonance;* otherwise, it will not present a pure resistive load to the nonresonant line.

An untuned feeder system may consist of one, two, four or even more parallel wires. Increased constructional difficulties of the multi-wire type of line where three or more parallel wires are used and the danger of appreciable feeder radiation from an improperly adjusted single-wire feeder make the more familiar two-wire type of line the most satisfactory for general use.

Semi-Resonant Open Lines

As has been previously stated under "Tuned Feeder Considerations," a well built *open-wire* line has low losses even when standing waves with a ratio of as high as 10/1 are present. (The standing wave ratio will be found to approximate the ratio of mismatch at the feeder termination.) Of much greater importance is to make sure the line is *balanced,* which means that the antenna system must be electrically symmetrical or allowance made for the asymmetry. If the currents in the two feed wires are not equal in amplitude and exactly opposite in phase, there will be radiation from the line (or pickup by the line if used for receiving) regardless of the amplitude of standing waves.

Because moderate standing waves can be tolerated on open-wire lines without loss, a standing wave ratio of 2/1 or 3/1 is considered acceptable with this type of line *even when used in an "untuned" system.* Strictly speaking, a line is untuned or nonresonant only when the line is perfectly "flat," with a standing wave ratio of 1 (no standing waves). However, *some mismatch can be tolerated with open-wire untuned lines* so long as the reactance is not objectionable or else is eliminated by cutting the line to approximately a resonant length.

Thus we have a line that is a cross between a tuned and an untuned line. Most of the "untuned" open-wire lines used by amateurs fall in this class, because there is usually more or less of a mismatch at the line termination. Therefore *open-wire* lines with a standing wave ratio of *less than 3/1* may be classed as *nonresonant* or untuned lines, as standing waves will not affect the operation of an untuned line unless greater than this in magnitude.

The foregoing applies only to *open-wire lines.* The losses in other type lines, especially those having rubber dielectric, go up rapidly with the standing wave ratio, such lines being designed for perfectly "flat" operation. Also, the maximum power handling capability of lines such as the twisted pair and concentric is greatly reduced when standing waves are present, even though of only 2/1 or 3/1 magnitude. From this we can see that every attempt should be made to eliminate all traces of standing waves on a low impedance, close-spaced line, especially when the power is high enough that there is danger of arc-over at voltage loops, or when the frequency is high enough that the losses are already great enough that increased losses will be a serious item.

Construction of Two-Wire Open Lines

A two-wire transmission system is easy to construct. Its surge impedance can be calculated quite easily, and when properly adjusted and balanced to ground, undesirable feeder radiation is minimized; the current flow in the adjacent wires is in opposite directions and the magnetic fields of the two wires are in opposition to each other. When a two-wire line is terminated with the equivalent of a pure resistance equal to the surge impedance of the line, the line becomes a nonresonant line. It is, then, the problem to find a way to go about calculating the surge impedance of any two-wire transmission line, which impedance we will call Z_s.

It can be shown mathematically that the true surge impedance of any two-wire parallel line system is approximately equal to

$$Z_s = 276 \log_{10} \frac{2S}{d}$$

Where:

S is the exact distance between wire centers in some convenient unit of measurement, and

d is the diameter of the wire measured in the same units as the wire spacing, S.

Since $\frac{2S}{d}$ expresses a ratio only, the units of measurement may be centimeters, millimeters or inches. This makes no difference in the answer so long as the substituted values for S and d are in the *same units.*

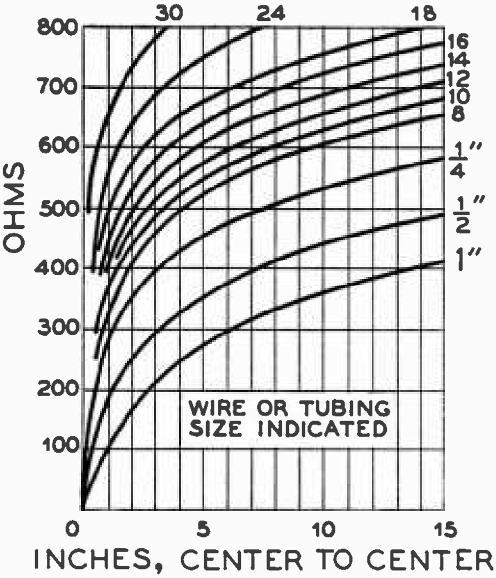


Figure 14.

CONDUCTOR SIZE AND SPACING VERSUS SURGE IMPEDANCE FOR TWO-WIRE OPEN LINE OR MATCHING TRANSFORMER.

The equation is accurate *so long as the wire spacing is relatively large as compared to the wire diameter.*

Surge impedance values of less than 200 ohms are seldom used in the open-type two-wire line and, even at this comparatively high value of Z_s, the wire spacing S is uncomfortably close, being only 5.3 times the wire diameter d.

Figure 14 gives in graphical form the surge impedance of any practicable two-wire line. The chart is self-explanatory and sufficiently accurate for practical purposes.

Twisted-Pair Untuned Lines

Low-loss, low-impedance transmission cable, marked by several manufacturers under the trade name of "EO1 cable", allows a very flexible transmission line system to be used to convey energy to the antenna from the transmitter. The low-loss construction is largely due to the use of untinned solid conductors, low-loss insulation, plus a good grade of weatherproof covering.

Twisted no. 12 or no. 14 outside house wire may be used on 160 and 80 meters if the length is not over 50 or 75 feet. On higher frequencies, however, the losses with such "homemade" twisted line will be excessive.

A twisted-pair line should always be used as an untuned line, as standing waves on the line will produce excessive losses and can easily break down the line insulation at the voltage loops.

For turning sharp corners and running close to large bodies of metal, the twisted pair is almost as good at the lower frequencies as the coaxial line.

Above 14 Mc., however, the rubber insulation causes appreciable dielectric loss even with the best EO1 cable, and the twisted-pair type of low-impedance line should not be used except where the length is short or where more efficient lines might not be suitable from a mechanical standpoint, as in certain types of rotary arrays.

The low surge impedance of the twisted-pair transmission line is due not only to the close spacing of the conductors, but to the rubber insulation separating them. The latter has a dielectric constant considerably higher than that of air. This not only lowers the surge impedance but also results in slower propagation of a wave along the conductors. As a result the voltage loops occur closer together on the line when standing waves are present than for an open-wire line working at the same frequency.

Coaxial Line

Several types of coaxial cable have come into wide use for feeding power to an antenna system. A cross-sectional end view of a coaxial cable (sometimes called concentric cable or line) is shown in figure 15.

As in the parallel-wire line, the power lost in a properly terminated coaxial line is the sum of the effective resistance losses along the length of the cable and the dielectric losses between the two conductors. In a well designed line using air or nitrogen as the dielectric, both are negligible, the actual measured loss in a good line being less than 0.5 db per 1000 feet at one megacycle.

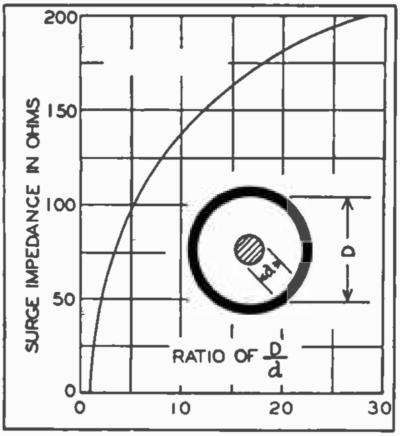


Figure 15.

CURVE FOR DETERMINATION OF SURGE IMPEDANCE OF ANY COAXIAL LINE HAVING AIR DIELECTRIC.

Presence of spacing insulators will lower the impedance somewhat below the calculated value as derived from this chart.

Of the two losses, the effective resistance loss is the greater; since it is largely due to the skin effect, the line loss (all other conditions the same) will increase directly as the square root of the frequency.

Figure 15 shows that, instead of having two conductors running side by side, one of the conductors is placed *inside* of the other. Since the outside conductor completely shields the inner one, no radiation takes place when the outside cable is grounded. The conductors may both be tubes, one within the other, or the line may consist of a solid wire within a tube.

In one type of cable (solid or semi-flexible low-loss type) the inner conductor is supported at regular intervals from the outside tube by a circular insulator of either pyrex or some non-hygroscopic ceramic material with low high frequency losses. The insulators are slipped over the inner conductor and held in place either by some system of small

COMPARATIVE R. F. FEEDER LOSSES

FREQUENCY	DB LOSS PER 100 FT.	TYPE OF LINE
7 Mc. 14 Mc. 30 Mc.	0.9 1.5 3	150-ohm impedance, rubber insulated twisted-pair with outer covering of braid.
7 Mc. 30 Mc.	0.4 0.9	W. E. ⅜" concentric pipe feeder with inner wire on bead spacers. Impedance. 70 ohms.
7 Mc. 30 Mc.	0.05 0.12	Open 2-wire line no. 10 wire. Impedance, 440 ohms.
7 Mc. 14 Mc. 30 Mc.	3 4½ 8	Twisted no. 14 solid weatherproof wire, weathered for six months (telephone wire).

clamps or by crimping the wire immediately in front of and behind each insulator.

Moisture must be kept out of the tube if best results are to be secured. It is, therefore, necessary to solder or otherwise to join tightly the line sections together so that no leak occurs. This prevents water from seeping into the line in outdoor installations.

To avoid condensation of moisture on the inside walls of the line, it is the general practice to fill the line with dry nitrogen gas at a pressure of approximately 35 pounds per square inch.

Filling a line with dry nitrogen gas also greatly increases its power capacity, a power capability rating of three to one being quite common for the nitrogen-filled line as compared to a line operating under normal atmospheric pressures.

Nearby metallic objects cause no loss and the cable can be run up air ducts, wire conduit or elevator shafts. Insulation troubles can be forgotten. The coaxial cable may be either buried in the ground or suspended above ground.

Highly flexible coaxial cable having continuous rubber dielectric for maintenance of spacing and an outer conductor of shield braid of the type used for ordinary shielded wire has become quite popular among amateurs for certain applications. Because of the rubber dielectric, the losses are about the same as for E01 cable on the higher frequencies, while on the lower frequencies (below 4000 kc.) the losses are nearly as low as for the air-dielectric type of coaxial line.

The chief advantage of rubber dielectric coaxial cable over E01 cable is its availability in lower values of surge impedance, making it possible to feed Marconi antennas and certain types of low radiation resistance arrays without need for an impedance matching device. Twisted-pair cable is not commonly available with a surge impedance of less than 70 ohms, while rubber dielectric coaxial cable is available with a surge impedance of as low as 28 ohms.

Coaxial cable, like twisted-pair cable, is most commonly used without a matching system. Cable is chosen to have a surge impedance that approximates the terminal radiation resistance of the antenna (current loop at which point the line is connected).

While coaxial cable is best suited to use with Marconi antennas, because the outside conductor is ordinarily grounded, it can be used successfully to feed a balanced dipole. This is permissible because the impedance is low and therefore no great unbalance results from each operation. The outer conductor of the coaxial cable connects to one half the dipole and the inner conductor connects to the other half. In this case the outer conductor is often left ungrounded.

MATCHING NONRESONANT LINES TO THE ANTENNA

From the standpoint of economy and efficiency, the most practical untuned line is an open line having a surge impedance of from 440 to 600 ohms. Unfortunately, it is seldom that the antenna system being fed has an impedance of similar value either at a current loop or at a voltage loop. It is sometimes necessary with current-fed antennas to match the line to an impedance as low as 8 or 10 ohms, while with voltage-fed antenna systems and arrays it is occasionally necessary to match the line to an impedance of many thousands of ohms. There are many ways of accomplishing this, the more common and most satisfactory methods being discussed here.

Delta-Matched Antenna System

The delta type matched-impedance antenna system is quite widely used. Figure 16 shows this feeder system. The impedance of the transmission line is transformed gradually into a higher value by the fanned-out Y portion of the feeders, and the Y portion is tapped on the antenna at points where the antenna impedance is a compromise between the impedance at the ends of the Y and the impedance of the unfanned portion of the line.

The constants of the system are rather critical, and the antenna must resonate at the operating frequency in order to minimize standing waves on the line. Some slight readjustment of the taps on the antenna is desirable if appreciable standing waves persist in appearing on the line. It is almost impossible to get the standing wave ratio below 2/1 with this system, and as standing waves of this order are not objectionable on an open line if it is cut to such a length that it is non-reactive, this ratio is considered as indicating the best match that can be expected with a "Y" or delta-matched doublet.

The constants are determined by the following formulas:

$$L_{feet} = \frac{467.4}{F \text{ megacycles}}$$

$$D_{feet} = \frac{175}{F \text{ megacycles}}$$

$$E_{feet} = \frac{147.6}{F \text{ megacycles}}$$

where L is antenna length; D is the distance *in from each end* at which the Y taps on; E is the height of the Y section.

As these constants are correct only for a 600-ohm transmission line, the spacing S of the line must be approximately 75 times the diameter of the wire used in the transmission line. For no. 14 B & S wire, the spacing will be slightly less than 5 inches. For no. 12 B & S, the spacing should be 6 inches. This system should never be used on either its even or odd harmonics as entirely different constants are required when more than a single half wavelength appears on the radiating portion of the system.

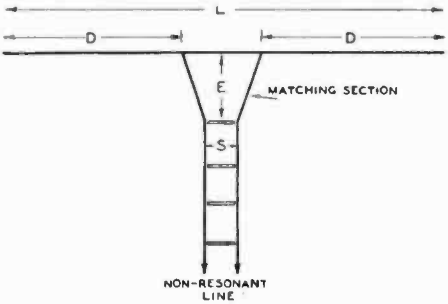


Figure 16.

THE DELTA-MATCHED ANTENNA SYSTEM.

This system is sometimes called a "Y matched" doublet. For dimensions refer to page 432.

The Multi-Wire Doublet

When a doublet consists of two or more wires instead of the more usual single wire, the radiation resistance (impedance at the current loop) is raised. This is due to the fact that each wire tends to induce an opposing current in the opposite wire, but cannot because the two wires are tied together at either end. See "A," figure 17.

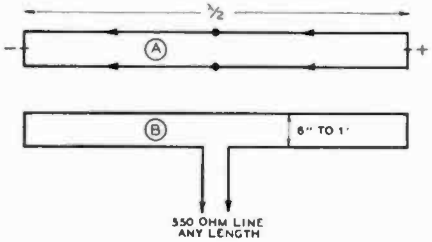


Figure 17.

KRAUS VERSION OF THE TWO-WIRE DOUBLET. THE ANTENNA HAS HIGH RADIATION RESISTANCE AND PERMITS USE OF AN OPEN-WIRE LINE WITHOUT NEED FOR A MATCHING SYSTEM. ARROWS INDICATE DIRECTION OF CURRENT FLOW AT ANY INSTANT; DOTS INDICATE LOCATION OF CURRENT LOOP.

Frequency Kilocycles	$L = \frac{467.4}{F_{mc}} = \frac{.95\lambda}{2}$ feet	$D = \frac{175}{F_{mc}}$ feet	$E = \frac{147.6}{F_{mc}}$ feet
3500	133′ 7″	50′	42′ 2″
3600	129′ 10″	48′ 7″	41′
3700	126′ 4″	47′ 4″	39′ 11″
3800	123′	46′ 1″	38′ 10″
3900	119′ 10″	44′ 9″	37′ 11″
3950	118′ 4″	44′ 3″	37′ 5″
4000	116′ 10″	43′ 9″	36′ 11″
7000	66′ 9″	25′	21′ 1″
7050	66′ 4″	24′ 10″	20′ 11″
7100	65′ 10″	24′ 8″	20′ 9″
7150	65′ 4″	24′ 6″	20′ 7.5″
7200	64′ 11″	24′ 4″	20′ 6″
7250	64′ 6″	24′ 2″	20′ 4.5″
7300	64′	24′	20′ 3″
14,000	33′ 5″	12′ 6″	10′ 6″
14,100	33′ 2″	12′ 5″	10′ 5″
14,200	32′ 11″	12′ 4″	10′ 4″
14,300	32′ 9″	12′ 3″	10′ 3.5″
14,400	32′ 6″	12′ 2″	10′ 3″
28,000	16′ 8.5″	75″	63″
28,500	16′ 5″	74″	62″
29,000	16′ 1.5″	72.5″	61″
29,500	15′ 10.5″	71″	60″
30,000	15′ 7.5″	70″	59″
56,000	100″	37.5″	31.5″
57,000	98.4″	37″	31″
58,000	96.5″	36″	30.5″
59,000	94.8″	35.5″	30″
60,000	93″	35″	29.5″

DIMENSIONS FOR DELTA MATCHED-IMPEDANCE ANTENNA SYSTEM.

The delta matched-impedance antenna system is an old stand-by that has withstood the test of time. When properly adjusted, the losses are low. The main drawback is that it is inherently a one-band affair. The dimensions L, D and E refer to figure 16.

The dimensions are quite critical, and the values given above should be closely adhered to, then altered slightly, if necessary, for the particular installation until there is a minimum of standing waves on the line. Usually, slight adjustment of the dimension D will reduce standing waves to an acceptable value; this should be tried first.

If we split just one wire of such an antenna, as at "B" in figure 17, and feed the antenna at this point, we find that the *terminal* radiation resistance is much higher than the theoretical 72 ohms of a conventional doublet. The terminal radiation resistance is the impedance into which the feed system works. Because each wire of the two-wire doublet carries half the total current and the feed line serves only one wire, the terminal radiation resistance is twice the radiation resistance of the antenna taken as a whole, which already is considerably higher than that of a regular doublet.

The terminal radiation resistance of a two-wire doublet such as that of "B" when well removed from earth is about 400 ohms. This means that we can use an ordinary 500 to 600 ohm open line to feed the antenna directly, without need for a matching system. When used with a 500-ohm line (no. 12 spaced 4 inches) the standing waves will be quite low (approximately 2/1 ratio) over a range in frequency of several per cent either side of resonance. The broad tuning characteristic is a result of the high radiation resistance.

The magnitude of standing waves with this system when using the feed line specified will result in standing waves comparable to the average Q matched single-wire doublet (described on page 439) and somewhat better than the delta-matched doublet (previously described).

The spacing of the two wires is not at all critical, and need not be exactly uniform just so the system is symmetrical. The overall length of the "loop" is just twice that of a regular doublet wire. Just subtract the wire spacing from the customary doublet length for the same frequency to obtain the correct length for each of the two elements, and split the lower element in the exact center.

Single-Wire-Fed Antenna

The matched-impedance single-wire-fed antenna system is quite satisfactory where the length of the transmission line may be kept short. The losses and radiation are somewhat higher than for the two-wire types of transmission lines, but are not serious for lengths up to a few hundred feet.

A single-wire feed line has a characteristic surge impedance of from 500 to 600 ohms, depending upon the diameter of the feeder wire. This type feeder makes use of the earth as a return circuit through the earth's capacity effect to the antenna and feeder. The actual earth connection to the transmitter may have a relatively high resistance without causing appreciable loss of r.f. energy. It may even be represented by the capacity of the transmitter and house wiring to earth.

The single-wire feeder should be tapped to either side of a *current loop* in a resonant antenna at a point of proper impedance match.

The current loop occurs at the center of a half-wave antenna and at the center of each half-wave section in a long-wire antenna. In order to match perfectly the 500- or 600-ohm impedance of the feeder, it is necessary to connect it to a dipole at a point approximately one-seventh of the total length of the antenna wire either side of center. There will be no standing waves on the feeder when the impedances are perfectly matched, and maximum efficiency will then result.

This point of perfect impedance match, unfortunately, is not suitable for harmonic operation of the antenna. By having a small impedance mismatch at the fundamental frequency, the single-wire-fed antenna can be used on several harmonically related short-wave bands. The feeder should be connected to the antenna at a point *one-sixth,* rather than one-seventh, of the total length of the antenna wire from the mid point. A simple manner in which to find this point is to divide the antenna into three equal lengths, and then connect the feeder to the antenna at a point which is a third of the total length from either end.

This all-wave type of antenna feeder connection results in a slight mismatch (not enough to be serious) on the fundamental frequency of operation.

In a perfectly matched design at the fundamental frequency of operation, the impedance mismatch is very great when

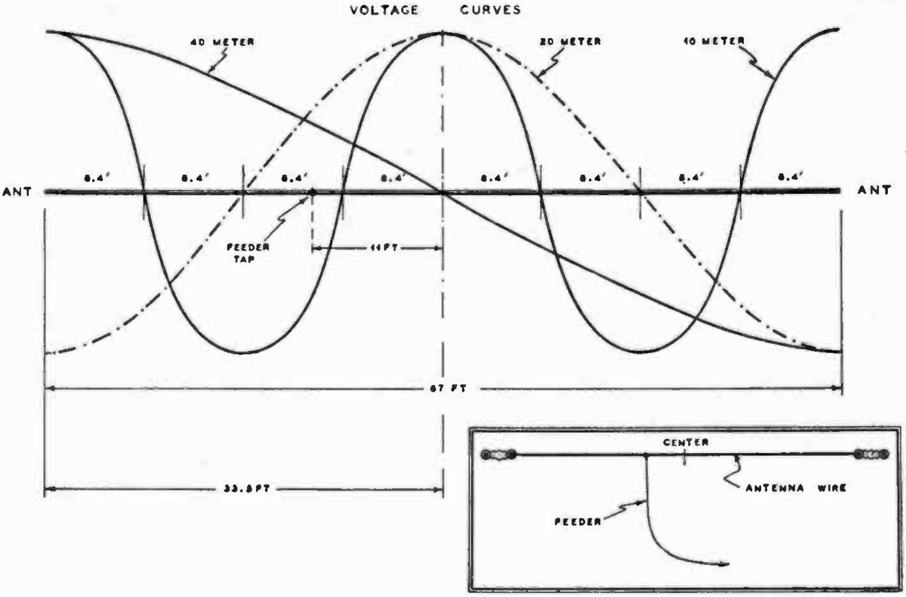


Figure 18.

SINGLE-WIRE-FED ANTENNA FOR ALL-BAND OPERATION.

An antenna of this type for 40-, 20- and 10-meter operation would have a radiator 67 feet long, with the feeder tapped 11 feet off center. The feeder can be 33, 66 or 99 feet long. The same type of antenna for 80-, 40-, 20- and 10-meter operation would have a radiator 134 feet long, with the feeder tapped 22 feet off center. The feeder can be either 66 or 132 feet long. This system should be used only with those coupling methods which provide good harmonic suppression.

the antenna is operated on its harmonics. It is better to compromise by connecting the feeder to the antenna as shown in figure 18.

It is almost impossible to find a combination that will allow the standing waves to be entirely eliminated on two or more bands with this antenna, but when tuned for the higher frequency band it will give satisfactory results on the next lower frequency band.

The effect on the final amplifier of small standing waves on the feeder can be practically eliminated by making the feeder some multiple of a quarter wave in length on the lowest frequency band. The impedance at the transmitter end will then be purely resistive and no detuning effect will be evident in the final amplifier circuit when the feeder is either connected or disconnected from the amplifier. The formula for calculating a desirable feeder length in feet is:

$$L = \frac{234{,}000}{f_1}$$

where L is the feeder length in feet, f_1 is the lowest frequency of operation in kilocycles.

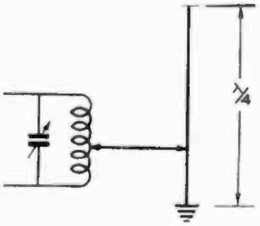
The length of the antenna wire in figure 18 is also a compromise for all-band operation. The harmonics of an antenna wire for any given length are not exact multiples due to the *end effects* of the antenna. This was explained on page 415.

Harmonic Resonance

The antenna wire should be cut so that it will resonate at the *middle of the highest frequency band desired* on its fourth harmonic; this gives the best compromise for operation in three harmonically related bands. The method of calculation will be found on page 415, quick reference tables are also given, making it easy

Figure 19.

Marconi with single-wire feed.



to calculate the proper radiator length for harmonic operation.

These multi-band single-wire-fed antennas are generally designed for three bands of operation, such as 80, 40 and 20, or 40, 20 and 10 meters.

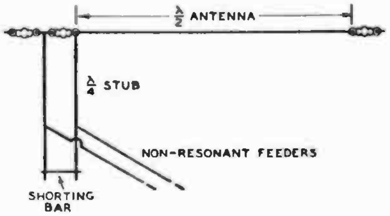
A single-wire feeder for all-band operation should preferably be some multiple of a quarter wave (of the lowest frequency band) in length. For single-band operation, the feeder can be any length *provided it is attached to the antenna at the point of exact impedance match,* as indicated by an absence of standing waves. When a single-wire-fed antenna is to be used on just one frequency, it is desirable to adjust the feeder by cut-and-try methods.

The feeder should always run at right angles to the antenna wire proper for a distance of at least a sixth wavelength at the lowest frequency of operation. A good "earth" ground connection should be made to the transmitter for most effective operation of a single-wire feeder, though it need not be as elaborate as for a Marconi antenna.

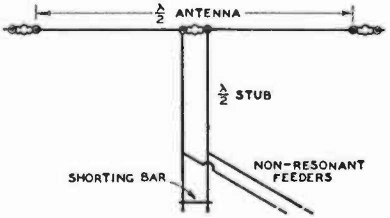
It is often desirable to feed a grounded Hertz or Marconi antenna with a single-wire feeder. Figure 19 shows such an arrangement. The feeder can be tapped about 14 per cent of a half wave up from the ground point. This type of antenna does not operate well on its harmonics and is principally used on 30, 60 and 120 megacycles for mobile work, the car body acting as the ground.

Figure 20.

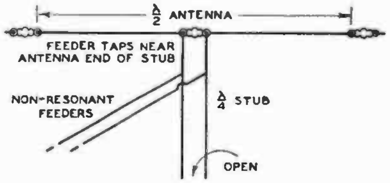
MATCHING-STUB APPLICATIONS.



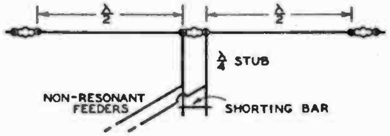
(A) Half-wave antenna with quarter-wave matching stub.



(B) Center-fed half-wave antenna with half-wave matching stub.



(C) Center-fed half-wave antenna with stub line cut to exact length without shorting bar.



(D) Two half-wave sections in phase with quarter-wave stub.

MATCHING STUBS

It is possible to hang a resonant length of Lecher wire line (called a matching stub) from either a voltage or current loop and attach 600-ohm nonresonant feeders to the resonant stub at a suitable voltage (impedance) point. The stub is made to serve as an autotransformer. Thus, by putting up a half-wave zepp with quarter-wave feeders at a distance from the transmitter and attaching a 600-ohm line from the transmitter to the zepp feeders at a suitable point, we have a stub-matched antenna. The example cited here is commonly called a J antenna, especially when both radiator and stub are vertical. Many variations from this example are possible; stubs are particularly adapted to matching an open line to certain directional arrays as will be described later in this chapter.

Voltage Feed

When the stub attaches to the antenna at a voltage loop, the stub should be a quarter wavelength long electrically and be shorted at the bottom end. The stub can be resonated by sliding the shorting bar up and down before the nonresonant feeders are attached to the stub, the antenna being shock-excited from a separate radiator during the process. Slight errors in the length of the radiator can be compensated for by adjustment of the stub if both sides of the stub are connected to the radiator in a symmetrical manner. Where only one side of the stub connects to the radiating system, as in the J antenna example given here, the radiator length must be exactly right in order to prevent excessive unbalance in the untuned line.

If only one leg of a stub is used to voltage-feed a radiator, it is impossible to secure a perfect balance in the transmission line due to a slight inherent unbalance in the stub itself when one side is left floating. This unbalance, previously discussed under the *zepp antenna system,* should not be aggravated by a radiator of improper length.

Current Feed

When a stub is used to current-feed a radiator, the stub should either be left *open* at the bottom end instead of shorted or else made a *half wave* long. The open stub should be resonated in the same manner as the shorted stub before attaching the transmission line; however, in this case, it is necessary to prune the stub to resonance as there is no shorting bar.

Sometimes it is handy to have a stub hang from the radiator to a point that can be reached from the ground in order to facilitate adjustment of the position of the transmission-line attachment. For this reason, a quarter-wave stub is sometimes made three-quarters wavelength long at the higher frequencies in order to bring the bottom nearer the ground. Operation with any *odd* number of quarter waves is the same as for the quarter-wave stub.

Any number of *half waves* can be added to either a quarter-wave stub or a half-wave stub without disturbing the operation though losses will be lowest if the shortest usable stub is employed. This can be fully understood by inspection of the accompanying table.

Stub Length (Electrical)	*Current-Fed Radiator*	*Voltage-Fed Radiator*
¼-¾-1¼-etc. wavelengths	**Open**	**Shorted**
½-1-1½-2-etc. wavelengths	**Shorted**	**Open**

Shorted-Stub Tuning Procedure

When the antenna requires a shorted stub (odd number of quarter waves if the antenna is voltage-fed; even number of quarter waves if radiator is current-fed), the tuning procedure is as follows:

Shock-excite the radiator (or one of the half-wave sections if harmonically operated) by means of a makeshift doublet strung directly underneath where possible and just off the ground a few inches, connected to the transmitter by means of any kind of twisted pair or open line handy.

With the feeders and shorting bar disconnected from the stub, slide along an r.f. milliammeter or low-current dial light at about where you calculate the shorting bar should be and find the point of maximum current (in other words, use the meter or lamp as a shorting bar).

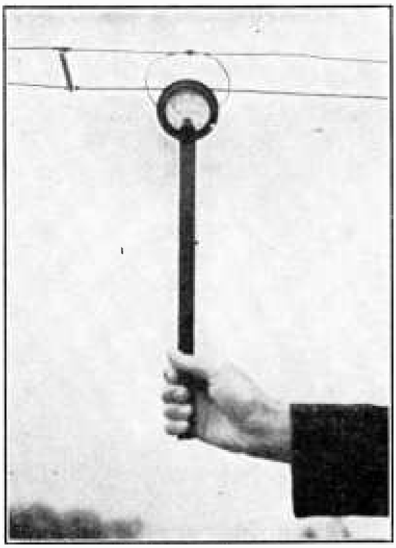
Make sure it is impossible for there to be plate voltage on the feed line before attempting this procedure. *Inductive coupling to the final amplifier by means of a few turns of high tension ignition wire is recommended during any tuning up process where the operator must come in contact with the antenna or feeders.*

It is best to start with reduced power to the transmitter until you see how much of an indication you can expect; otherwise, the meter or lamp may be blown on the initial trial. The leads on the lamp or meter should be no longer than necessary to reach across the stub.

After finding the point of maximum current, remove the lamp or meter and connect a piece of wire across the stub at that point.

Starting at a point about a quarter of a quarter wave (8 feet at 40 meters) from the shorting bar, connect the feeders to the stub. Then, move the feeders up and down the stub until the standing waves on the line are at a minimum. The makeshift doublet should, of course, be disconnected and the regular feeders connected to the transmitter instead during this process. Slight readjustment of the shorting bar will usually result in further improvement.

When checking for standing waves, take readings no closer than several feet to the stub as the proximity of the stub will affect the reading of the standing wave indicator and lead one to false conclusions. The standing wave indicator may be either a voltage device, such as a neon bulb, or a current device, such as an r.f. milliammeter connected to a pickup coil. A high degree of accuracy is not required.



Open-Ended Stub Tuning Procedure

If the antenna requires an open stub (even number of quarter waves if the antenna is voltage-fed; odd number of quarter waves if radiator is current-fed), the tuning procedure is as follows:

Shock-excite the radiator as described for tuning a shorted-stub system, feeders disconnected from the stub and stub cut slightly longer than the calculated value. Place a field strength meter (the standing wave indicator can be very easily converted into one by addition of a tuned tank) close enough to one end of the radiator to get a reading, and as far as possible from the makeshift exciting antenna. Now, start folding and clipping the stub wires back on themselves a few inches at a time, effectively shortening their length, until you find the peak as registered on the field meter.

Now, attach the feeders to the stub as described for the shorted-stub system, but, for the initial trial connection, the feeders will attach at a distance more nearly three-quarters of a quarter wave from the end of the stub instead of a quarter of a quarter wave as is the case for a shorted stub. After attaching the feeders, move them along the stub as necessary to minimize standing waves on the line. If sliding the feeders along the stub a few inches makes the standing waves worse, it means the correct connecting point is in the other direction.

Figure 21.

A SIMPLE "STANDING WAVE DETECTOR."

It may consist of either an r.f. thermogalvanometer or a 0-1 ma. d.c. milliammeter connected in series with a carborundum crystal rectifier (detector). A pickup coil of about two turns is mounted as shown and the whole affair attached to a stick in order to minimize body capacity. The pickup coil must be held in the same relationship to the line as it is moved along the line if accurate results are desired.

LINEAR R. F. TRANSFORMERS

Q - Matching Section

A resonant quarter-wave line has the unusual property of acting much as a transformer. Let us take, for example, a quarter-wave section consisting of no. 12 wire spaced six inches, which happens to have a surge impedance of 600 ohms. Let the far end be terminated with a pure resistance and let the near end be fed with radio-frequency energy at the frequency for which each feeder is a quarter wavelength long. If an impedance measuring set is used to measure the impedance at the near end while the impedance at the far end is varied, an interesting relationship between the 600-ohm characteristic surge impedance of this particular quarter-wave matching line and the impedance at the two ends will be discovered.

When the impedance at the far end of the line is the same as the characteristic surge impedance in the line itself (600 ohms), the impedance measured at the near end of the quarter-wave line will also be found to be 600 ohms.

Under these conditions, the line would not have any standing waves on it due to the fact that it is terminated in its characteristic impedance. Now, let the resistance at the far end of the line be doubled, or changed to 1200 ohms. The impedance measured at the near end of the line will be found to have been cut in half and is now 300 ohms. If the resistance at the far end is made half the original value of 600 ohms, or 300 ohms, the impedance at the near end doubles the original value of 600 ohms and becomes 1200 ohms. Therefore, as one resistance goes up, the other goes down proportionately.

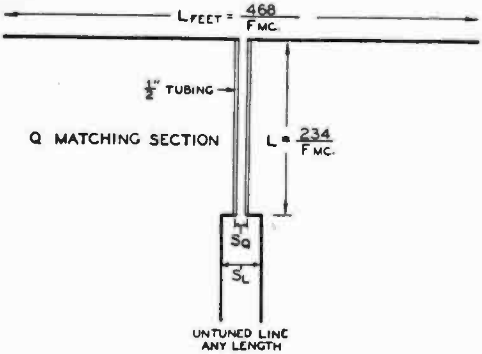


Figure 22.
METHOD OF FEEDING A HALF-WAVE RADIATOR BY MEANS OF Q BARS. REFER TO TABLES FOR DIMENSIONS.

CORRECT VALUES OF SURGE IMPEDANCE OF λ/4 MATCHING SECTIONS FOR DIFFERENT LENGTHS OF ANTENNAS

Antenna Length in Wavelength	Surge Impedance for Connection Into Two-Wire Open Lines with Impedance of	
	500 Ohms	600 Ohms
½	190	212
1	210	235
2	235	257
4	255	282
8	280	305

Matching section connects into center of a current loop, such as middle of a half-wave section.

It will always be found that the characteristic surge impedance of the quarter-wave matching line is the geometric mean between the impedance at both ends. This relationship is shown by the following formula:

$$Z_{MS} = \sqrt{Z_A Z_L}$$

where

Z_{MS} = Impedance of matching section.
Z_A = Antenna resistance.
Z_L = Line impedance.

Johnson-Q Feed System

The standard form of Johnson-Q feed to a doublet is shown in figure 22. An impedance match is obtained by utilizing a matching section the surge impedance of which is the geometric mean between the transmission line surge impedance and the radiation resistance of the radiator. A sufficiently good match can usually be obtained by either designing or adjusting the matching section for a dipole to have a surge impedance that is the geometric mean between the line impedance and 72 ohms, the latter being the theoretical radiation resistance of a half-wave doublet either infinitely high or a half wave above a perfect ground.

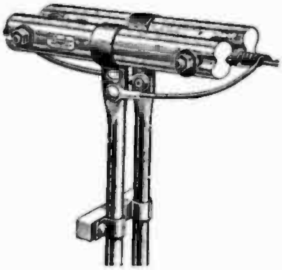


Figure 23.
PICTORIAL SKETCH OF JOHNSON Q.

Though the radiation resistance may depart somewhat from 72 ohms under actual conditions, satisfactory results will be obtained with this assumed value so long as the dipole radiator is more than a quarter wave above effective earth and reasonably in the clear. The small degree of standing waves introduced by a slight mismatch will not increase the line losses appreciably, and any *small* amount of reactance present can be tuned out at the transmitter termination with no bad effects. If the reactance is objectionable, it may be minimized by making the untuned line an integral number of quarter waves long.

A Q-matched system can be adjusted precisely, if desired, by constructing a matching section to the calculated dimensions with provision for varying the spacing of the Q section conductors slightly, after the untuned line has been checked for standing waves.

The Q section will usually require about 200 ohms surge impedance when used to match a half-wave doublet, actually varying from about 150 to 250 ohms with different installations. This impedance is difficult to obtain with a two-wire line as very close spacing would be required. For this reason either a four-wire line or a line consisting of two half-inch aluminum tubes is ordinarily used. The four-wire section has the advantage of lightness and cheapness, and can be used where the approximate radiation resistance is known with certainty, thus making it possible to design the matching section for a certain value of surge impedance with some assurance that it will turn out to be sufficiently accurate.

The apparent complexity of the Q-matched dipole comes from the large number of antennas and line combinations which the Q section is able to match.

The length of the flat top or radiating portion of the half-wave Q-fed antenna equals 468 divided by the frequency in *megacycles*. The answer is in feet. The length of the Q section will be exactly half the total length of the flat-top radiator, or 234 divided by the frequency in *megacycles*. The formulas are shown in the diagram.

The untuned transmission line between the transmitter and the input, or lower end of the Q section, can be any length (within reason).

PARALLEL TUBING SURGE IMPEDANCE FOR MATCHING SECTIONS.

Center to Center Spacing in Inches	Impedance in Ohms for ½" Diameters	Impedance in Ohms for ¼" Diameters
1	170	250
1.25	188	277
1.5	207	298
1.75	225	318
2	248	335

Q System with Four-Wire Transformer

The reduction in impedance obtained by the use of four conductors instead of two makes the four-wire line highly useful for matching transformer applications. For instance, the order of impedance ordinarily required for Q-matching sections is easily obtained by spacing four wires around a circular insulating spacer of suitable diameter.

Plastic iced-tea coasters of suitable diameter can be used for spacers. The usual dime store price is five cents each. When purchasing the coasters, one should take precaution to get the correct type of material. It seems that some are made from bakelite, while others are made of a plastic that has much better high frequency insulation qualities than

Frequency in Kilocycles	Quarter-wave matching section or stub $\frac{234}{F_{mc}} = \frac{.95\lambda}{4} = N$	Half-wave radiator $\frac{467.4}{F_{mc}} = \frac{.95\lambda}{2} = L$	Dis. from end of radiator to feeder tap $D = \frac{169.2}{F_{mc}}$ (single-wire feed)
3500	66′ 10″	133′ 7″	48′ 4″
3600	64′ 11″	129′ 10″	46′ 8″
3700	63′ 2″	126′ 4″	45′ 7″
3800	61′ 6″	123′	44′ 6″
3900	59′ 11″	119′ 10″	43′ 3″
3950	59′ 2″	118′ 4″	42′ 8″
4000	58′ 5″	116′ 10″	42′ 1″
7000	33′ 5″	66′ 9″	24′ 2″
7050	33′ 2″	66′ 4″	23′ 11″
7100	32′ 11″	65′ 10″	23′ 9″
7150	32′ 9″	65′ 4″	23′ 7″
7200	32′ 6″	64′ 11″	23′ 4″
7250	32′ 3″	64′ 6″	23′ 3″
7300	32′	64′	23′ 2″
14,000	16′ 9″	33′ 5″	12′ 1″
14,100	16′ 7″	33′ 2″	12′
14,200	16′ 5″	32′ 11″	11′ 10.5″
14,300	16′ 4″	32′ 9″	11′ 9″
14,400	16′ 3″	32′ 6″	11′ 8″
28,000	100″	16′ 8.5″	72″
28,500	98.4″	16′ 5″	71″
29,000	96.5″	16′ 1.5″	70″
29,500	94.8″	15′ 10.5″	69″
30,000	93″	15′ 7.5″	68″
56,000	50″	100″	36″
57,000	49.2″	98.4″	35.5″
58,000	48.3″	96.5″	35″
59,000	47.4″	94.8″	34.5″
60,000	46.5″	93″	34″

DIMENSIONS FOR MATCHED-IMPEDANCE J, Q AND SINGLE-WIRE-FED ANTENNAS

Quick-reference guide for determining radiator and matching section or stub length for the J, Q and single-wire-fed antennas. Also, for determining the proper point at which to attach a single-wire feeder for optimum results for ONE-BAND operation. For operation on more than one band, the flat top should be cut for the highest frequency band and the single-wire feeder tapped one-third of the way in from one end, disregarding the figures given in the right-hand column of the above chart. The antenna will then work equally well on several bands with but a slight reduction in efficiency. The stub for a J should be adjusted as described under stub matching, after being cut slightly longer than the value given in the above table.

bakelite. The plastic ones can easily be identified: they are translucent, while the bakelite ones are not.

The spacers should be oriented so that they will not collect water when it rains. The wires of the matching section can be secured to the spacers by means of short serving wires a few inches long. This method is much simpler than using screws or clamps, and just as satisfactory. Incidentally, it is simpler to drill four holes around the edge of the coasters and insert the *serving wires* through the holes than it is to thread the coasters along the four wires of the matching section.

The line is flexible and must be used under slight tension to keep the wires from twisting. Spacers should be placed approximately every two feet. The *diagonally opposite* wires should be connected together at each end of the four-wire section.

Assuming that the antenna is resonant at the operating frequency, there are two values that must be known to calculate the impedance of the quarter-wave matching transformer. These are the impedance of the antenna at the point where it is being fed and the impedance of the transmission line. The correct impedance for the matching transformer can be determined quickly and quite closely by referring to the accompanying table which shows correct transformer impedance for various antennas and line impedances.

Commonly used matching section impedances are found in the left-hand column. Spacing refers to adjacent wires, not diagonally-opposed wires. Both fractional and decimal equivalents are given for convenience. No. 14 wire is easier to handle, and is to be recommended for this reason for impedances above 200 ohms. Below 200 ohms no. 12 is to be preferred, as it is difficult to keep the wires from whipping together when the spacing is much less than 1.5 inch, and the larger wire permits greater spacing for a given surge impedance.

	Nº 12 WIRE			Nº 14 WIRE		
	COL. 1	COL. 2	COL. 3	COL. 4	COL. 5	COL. 6
Zo OHMS	SPACING INCHES	SPACING INCHES	CIR. DIA. INCHES	SPACING INCHES	SPACING INCHES	CIR. DIA. INCHES
175	1.415	1 7/16	2.001	1.120	1 1/8	1.585
184	1.495	1 1/2	2.110	1.185	1 3/16	1.675
187	1.535	1 9/16	2.175	1.215	1 1/4	1.720
193	1.630	1 5/8	2.305	1.280	1 5/16	1.820
200	1.720	1 3/4	2.434	1.361	1 3/8	1.935
202	1.820	1 13/16	2.560	1.440	1 7/16	2.100
203						
206	2.020	2	2.858	1.600	1 5/8	2.261
207						
210	2.120	2 1/8	3.000	1.630	1 11/16	2.378
211						
212						
216	2.301	2 5/16	3.122	1.825	1 13/16	2.581
219	2.420	2 7/16	3.421	1.920	1 15/16	2.719
223	2.662	2 11/16	3.700	2.110	1 1/8	2.890
224						
225						
228	2.910	2 15/16	4.110	2.310	2 5/16	3.375
232	3.075	3 1/16	4.350	2.435	2 7/16	3.440
234	3.150	3 1/8	4.450	2.497	2 1/2	3.530
238	3.320	3 5/16	4.690	2.625	2 5/8	3.720
240	3.420	3 7/16	4.835	2.721	2 11/16	3.853
245	3.640	3 5/8	5.150	2.881	2 7/8	4.075
250	4.040	4 1/16	5.710	3.204	3 3/16	4.540
256	4.360	4 3/8	6.160	3.460	3 7/16	4.890
261	4.650	4 5/8	6.580	3.683	3 11/16	5.202

Figure 24.

FOUR-WIRE MATCHING SECTION DESIGN TABLE.

OPERATING AN ANTENNA ON ITS HARMONICS

Zepp-fed, single-wire-fed, and direct-fed antennas have always been the most popular antennas for multi-band operation. This is due to the fact that practically all of the antennas that are fed by two-wire nonresonant transmission lines reflect a bad mismatch into the line when operated on two, four or eight times the fundamental antenna frequency. Thus, the twisted-pair doublet, the Johnson Q, the matched-impedance J or T types, all are unsuitable for even-harmonic operation.

The radiating portion of an antenna does not resonate on integral harmonics of its fundamental frequency. This point is not generally appreciated. It is a common assumption that a half-wave antenna cut, for example, for 3500 kc. (133′ 7″) resonates on all the integral harmonics of 3500 kc. and, thus, can be used on 7000, 14,000 and 28,000 kc. Actually, a half-wave antenna cut for 3500 kc. resonates 7182, 14,553 and 29,312 kc. These frequencies are related by the formulas

$$L = \frac{492\,(K-.05)}{F_{Mc}}$$

$$F_{Mc} = \frac{492\,(K-.05)}{L}$$

Where F equals frequency in *megacycles.*
L equals length in feet.
K equals number of half waves on wire.

These formulas are accurate for all frequencies between 1800 and 30,000 kc.

It is sometimes desirable to determine the harmonic frequencies at which a given antenna wire resonates. This can be done very quickly if the fundamental frequency is known simply by referring to the following table:

	Multiply fundamental frequency by
Fundamental or first harmonic	1.000
Second harmonic	2.052
Third harmonic	3.106
Fourth harmonic	4.158
Eighth harmonic	8.375
Sixteenth harmonic	16.790

Thus, a wire which is a half wavelength long at 1000 kilocycles resonates on its second harmonic at 2052 kc.; third harmonic at 3106 kc., etc.

The table can also be used to determine what length to cut a harmonic radiator for operation on a given frequency. Look up the correct length for a half-wave doublet for that frequency and multiply the length by the factor given here for the harmonic on which you wish to work. Thus a third harmonic 14,000-kc. antenna is just 3.106 times as long as a 14,000-kc. doublet.

When designing an antenna for operation on more than one band, it should be cut for harmonic resonance at its highest operating frequency. If it is to be operated off resonance on some band, it is better to have it off resonance on a low frequency band because any errors then become a smaller percentage of a half wave.

COUPLING TO THE TRANSMITTER

When coupling either an antenna or antenna feed system to a transmitter, the important considerations are as follows: (1) means should be provided for varying the load on the amplifier, (2) the two tubes in a push-pull amplifier should be equally loaded, (3) the load presented to the final amplifier should be nonreactive; in other words, it should be a purely resistive load.

The first item is often referred to as "matching the feeder impedance to the transmitter" or "matching the impedance". It is really a matter of *loading.* The coupling is increased until the final amplifier draws the correct plate current. Actually, all the matching and mismatching we worry about pertains to the junction of the feeders and *antenna.*

The matter of equal load on push-pull tubes can be taken care of by simply making sure that the coupling system is symmetrical, both physically and electrically. For instance, it is not the best practice to connect a single-wire feeder directly to the tank coil of a push-pull amplifier.

The third consideration, that of obtaining a nonreactive load, is important from the standpoint of efficiency, radiated harmonics, and voice quality in the case of a phone transmitter. If the feeders are clipped directly on the amplifier plate tank coil, either the surge impedance of the feeders must match the antenna impedance perfectly (thus avoiding standing waves) or else the feeders must be cut to exact resonance.

If an inductively-coupled auxiliary tank is used as an antenna tuner for the purpose of adjusting load and tuning out any reactance, one need not worry about feeder length or complete absence of standing waves. For this reason, it is always the safest procedure to use such an antenna coupler rather than connect directly to the plate tank coil.

Function of an Antenna Coupler

The function of an output coupler is to transform the impedance of the feed line, or the antenna, into that value of plate load impedance which will allow the final amplifier to operate most effectively. The antenna coupler is, therefore, primarily an impedance transformer. It may serve a secondary purpose in filtering out harmonics of the carrier frequency. It may also tune the antenna system to resonance.

Practically every known antenna coupler can be made to give good results when properly adjusted. Certain types are more convenient to use than others, and the only general rule to follow in the choice of an antenna coupler is to use the simplest one that will serve your particular problem.

There is practically nothing that an operator can do at the station end of a transmission line that will either increase or decrease the standing waves on the line as that is entirely a matter of the coupling between the line and the antenna itself. However, the coupling at the station end of the transmission line has a very marked effect on the efficiency and the power output of the final amplifier in the transmitter. Whenever we adjust antenna coupling and thus vary the d.c. plate current on the final amplifier, all we do is vary the ratio of impedance transformation between the feed line and the tube plate (or plates).

Coupling Methods

Figure 25 shows several of the most common methods of coupling between final amplifier and feed line.

The fixed condenser C_b is a large capacity mica condenser in every case. It has no effect upon tuning or operation; it is merely a blocking condenser keeping high voltage d.c. off the transmission line.

Capacitive Coupling

Figure 25A shows a simple method of coupling a single-wire nonresonant feeder to an unsplit plate tank. The coupling is increased by moving the tap away from the voltage node and toward the plate end of the plate tank coil. Either the center or the bottom end of the coil may be by-passed to ground.

The system shown in figure 25B shows a means of coupling an untuned two-wire line to a split plate tank. If it is desired to couple a two-wire untuned line to an unsplit plate tank, it will be necessary to use some form of inductive coupling. See figure 25E.

The circuit of figure 25C shows a π-section filter coupling an unsplit tank to any end-fed antenna or single-wire line. Figure 25D shows the two-wire version of the π-section coupler, sometimes called the *Collins* coupler.

Inductive Coupling

Inductive coupling methods may be classified in two types: direct inductive coupling and link coupling. Direct inductive coupling has been very popular for years, but link coupling between the plate tank and the antenna coupler proper is usually more desirable. Figure 25E shows inductive coupling to an untuned two-wire line. This same arrangement can be used to couple from a split plate tank to a single-wire untuned feeder by grounding one side of the antenna coil.

The circuit shown in figure 25F is the conventional method of coupling a zepp

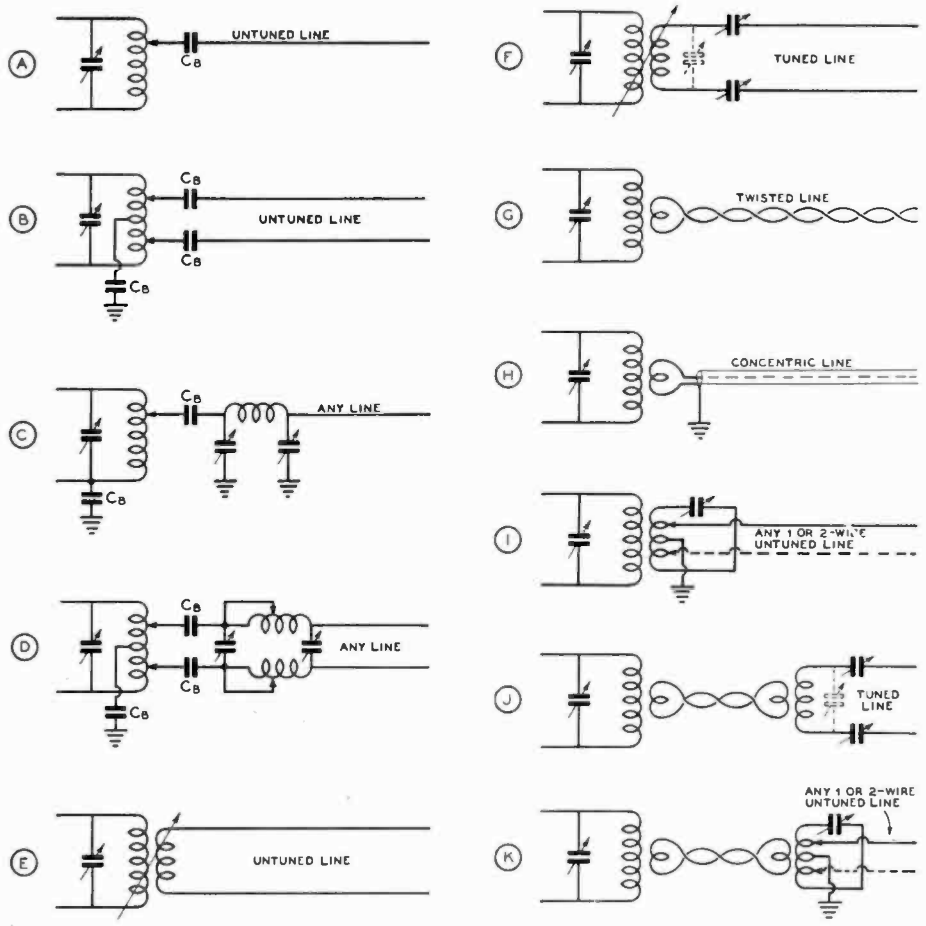


Figure 25.

COMMON METHODS OF COUPLING TRANSMISSION LINES TO THE OUTPUT TANK OF THE TRANSMITTER.

Balanced two-wire lines are assumed, whether of the resonant or "flat" (untuned) type. Coupling turns should always be placed around the "cold" portion of the coil; whether this is the center or end will be determined by whether the coil has one end grounded or is balanced to ground (center at ground r.f. potential). Tank tuning condensers can be split stator where balanced tanks are shown (center at low r.f. potential) without affecting operation of coupling circuit. C_b indicates mica blocking condenser to keep d.c. plate voltage off the feeder; these condensers should have a working voltage in excess of peak plate voltage and be at least .001 μfd.

or tuned feed line to a plate tank circuit, but the arrangement shown in figure 25J is easier to adjust. Circuit shown in figure 25I is for coupling either a single or two-wire untuned feeder to either a split or unsplit plate tank circuit. The arrangement shown in figure 25K is easier to adjust. All coupling links anywhere in a transmitter should be coupled at a point of low r.f. potential to avoid undesired capacitive coupling.

Untuned low impedance lines of the twisted pair and coaxial types can best be coupled inductively by means of a one- or two-turn coupling link around the plate tank coil at the voltage node.

Tuning Pi-Section Filter

To get good results from the π-section antenna coupler, certain precautions must be followed. The ratio of impedance transformation in π networks depends on the ratio in capacity of the two condensers C_1 and C_2 (figure 25C and D).

The first step in tuning is to disconnect the π-section coupler from the plate tank entirely. Then, apply low plate voltage and tune the plate tank condenser to resonance. Remove the plate voltage and tap the π-section connection or connections approximately half way between the cold point on the coil and the plate or plates. Adjust C_2 to approximately half maximum capacity and apply plate voltage. Quickly adjust C_1 to the point where the d.c. plate current dips, indicating resonance.

At the minimum point in this plate current dip, the plate current will either be higher or lower than normal for the final amplifier. If it is lower, it indicates that the coupling is too loose; in other words, there is too high a ratio of impedance transformation. The plate current can be increased by *reducing* the capacity of C_2 and then restoring resonance with condenser C_1. At no time after the π-section coupler is attached to the plate tank should the plate tuning condenser be touched. If the d.c. plate current with C_1 tuned to resonance is too high, it may be reduced by *increasing* the capacity of C_2 in small steps, each time restoring resonance with condenser C_1.

Should the plate current persist in being too high even with C_2 at maximum capacity, it indicates either that C_2 has too low maximum capacity or that the π-section filter input is tapped too close to the plate of the final amplifier. If the plate current *cannot* be made to go high enough even with condenser C_2 at minimum capacity, it indicates that the input of the π-section is not tapped close enough to the plate end of the plate tank coil.

Mechanical Considerations

If inductive coupling to the final amplifier is contemplated, attention must be given to the mechanical or physical considerations. Variable coupling is a desirable feature which facilitates correct loading of the amplifier. It is more easily incorporated if but a few turns are involved. This explains the popularity of link coupling methods (such as figure 25K) over directly coupled systems of the type illustrated in figure 25I. Untuned lines of 600 ohms or less, when operating correctly, seldom require more than a half dozen turns in the coupling link to provide sufficient coupling, especially on the higher frequency bands. Twisted-pair lines or coaxial cable may require only one or two turns. Marconi antennas (no feed line) may require anywhere from 1 to 10 turns, depending upon the fequency and radiation resistance.

Because sometimes the next integral turn provides too much coupling while without it there is insufficient coupling, it is necessary to provide means for obtaining coupling intermediate between that provided by integral turns. This can be done by adding the next integral turn and then either pulling the coupling coil away from the tank coil a little, or enlarging the turns so that the coupling coil does not fit snugly over the tank coil.

One very satisfactory method of providing continuously variable coupling calls for a set of split tank coils, with 1- or 1½-inch spacing between the two halves of the coils (depending upon diameter of the coils). A swinging coupling link, with sufficient tension or friction on the hinge to maintain the link in position after it has been adjusted, can be inserted between the two halves of the tank coil to give any degree of coupling desired. Manufactured coils can be obtained with this system of adjustable coupling. Another type manufactured coil is wound on a ceramic coil form with individual link turning inside the form on a shaft supported on bearings inserted in the form. The latter type requires two extra contacts on the coil jack bar.

If one uses the simpler method of pushing turns down between the turns of the tank coil until sufficient coupling is obtained, high tension ignition cable is recommended if the plate voltage of more than 500 volts appears on the plate tank coil. Hookup wire or house wire is satisfactory for lower voltages.

The coupling link should never be placed at a point of high voltage on the tank coil. This means that the coupling link should be placed around the *center* of a *split* plate tank or near the "cold" *end* of an *unsplit* tank coil.

For a given number of turns in the coupling link, greatest coupling will occur when the link is placed around the center of the coil, regardless of the location of the node on the coil. For this reason it is sometimes difficult to get sufficient coupling with an unsplit tank, as the link must be placed at the cold end of the coil in such a system to prevent detuning of the tank circuit, possible arcing between tank coil and link, and capacity coupling of harmonics.

Suppressing Harmonic Radiation

Harmonics are present in the output of nearly all transmitters, though some transmitters are worse offenders in this respect than others. Those that are strong enough to be bothersome are usually the second and third harmonics.

Current-fed antennas, such as the twisted-pair-fed doublet and the Johnson Q-fed doublet, discriminate against radiation of the even harmonics. This is what keeps these antennas from being used effectively as all-band antennas. However, they *are* responsive to the *odd* harmonics, working about as well on the third harmonic as on the fundamental. For this reason, any third harmonic energy present in the output of the transmitter will be radiated unless a harmonic trap is used or other means taken to prevent it.

Most all-band antennas are responsive to both odd and even harmonics, and therefore are still worse as regards the possibility of harmonic radiation.

The delta-matched antenna, and radiators fed by means of a shorted stub and untuned line provide about the best discrimination against harmonics, but even these will radiate some third and other odd harmonic energy, and the odd harmonics always fall outside the amateur bands.

Best practice indicates the reduction of the amount of harmonic component in the transmitter output to as low a value as possible, then further attenuation between the transmitter and antenna *regardless of what antenna and feed system is used.* If you follow this practice you need not have fear of getting a citation from the Radio Inspector for harmonic radiation.

Three definite conditions must exist in the transmitter before harmonic radiation can take place. First, the final amplifier must either be generating or amplifying the undesired harmonics; second, the coupling system between the amplifier and the feeders or antenna system must be either capable of radiating them or transmitting them to the antenna, and third, the antenna system (or its feeders) must be capable of radiating this harmonic energy.

One effective method of reducing capacity coupling is through the use of a Faraday shield. The Faraday shield, however, offers no attenuation to anything but *capacity coupling* of the undesired energy. Since a great deal of the harmonic energy (the third and other odd harmonics) is *inductively* coupled to the antenna system, an arrangement which will attenuate both capacitively and inductively coupled harmonics (both odd and even) would be desirable. A Faraday shield is not a cure-all. However, its performance is effective enough to warrant inclusion as standard equipment. Construction of a Faraday screen for a transmitting antenna is the same as for a receiving antenna, figure 62, except that it necessarily is larger.

A simple and very effective method of harmonic supression is shown in figure 26. The link from the final tank to the antenna tank should consist of either a length of low impedance cable (E01 or similar) or a *closely spaced* line of no. 12 or larger wire. This link should be

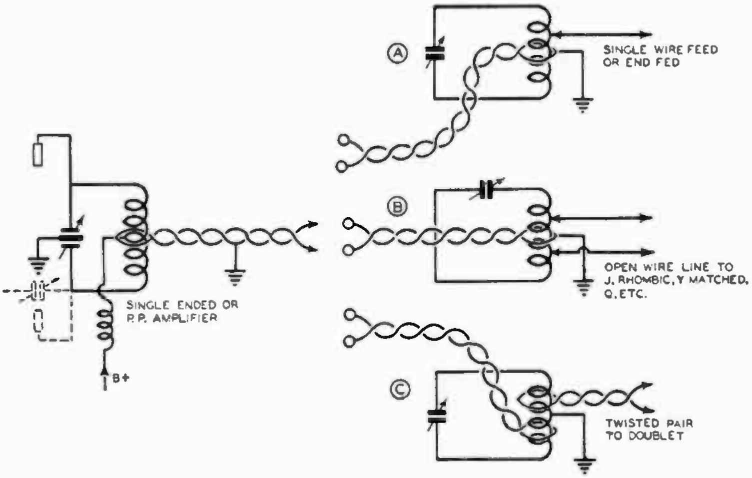


Figure 26.
SIMPLE METHODS OF HARMONIC SUPPRESSION WITH AN AUXILIARY TANK CIRCUIT.

loosely coupled by means of a single turn on 10, 20 and 40 meters (2 turns on 80 and 160 meters) at either end to both tank circuits. One side of the link should be effectively grounded near the final tank.

The antenna tank itself should be of medium C (a Q of about 10 or 12) at the operating frequency. At figure 26C the two links, the one to the final and the one to the antenna, should be spaced about two inches or so apart and at equal distances from the grounded center of the antenna coil. The balance of the diagram should be self-explanatory.

This coupling system operates by virtue of the fact that capacity coupling between the final tank and the antenna is eliminated by the grounded link and the grounded center tap of the antenna tank; also, due to the selectivity of the antenna tank against the harmonic frequencies, inductive coupling of them into the antenna system will also be attenuated.

In closing, a few general "don'ts" might be in order:

Don't use two tubes in parallel. Put them in push-pull if possible.

Don't use a doubler to feed an antenna unless it is of the push-push type. In a single-ended doubler, there is a high percentage of half and three-times frequency present in the output tank.

Don't use more bias and excitation than necessary for reasonable efficiency or (in a phone transmitter) good linearity.

Don't use a 75-meter zepp on 160 meters, a 40-meter zepp on 80 meters, etc. Although it is usually the odd harmonics that are inductively coupled, in this case the second harmonic will be inductively coupled and elimination of capacity coupling will not remove the second harmonic.

Don't use an all-band antenna unless you do not have room for separate antennas. If you must use such an antenna, use a harmonic-attenuating tank as shown in the accompanying diagrams.

Don't wait till you get a ticket for interfering with other services. Run a test with some local amateur close enough to give you an accurate check and see if your harmonics are objectionable.

A Simple Universal Coupler

A split-stator condenser of 200 μμfd. or more per section can be mounted on a small board along with a large and a small multitapped coil to make a very useful and versatile antenna coupler and harmonic suppressor. With this unit it is possible to resonate and load almost any conceivable form of radiator and tuned feed system, and to adjust the loading and provide harmonic suppres-

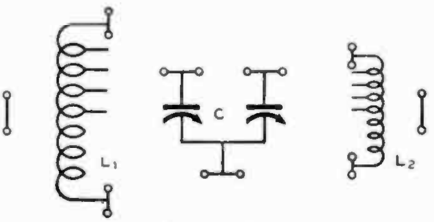


Figure 27.

CIRCUIT DIAGRAM OF THE UNIVERSAL COUPLER.

The dots indicate heavy Fahnestock clips. For coil and condenser constants, see text.

sion with most any untuned transmission line.

To facilitate connecting the coil and condenser combination in the many different ways possible, 12 large-size dual Fahnestock connectors are mounted on the coils and condenser terminals and generously scattered around. Two are mounted on standoff insulators to act as terminals for ground, antenna or other wires. A dozen lengths of heavy flexible wire of random lengths between 6 and 18 inches enable one to connect up the components in an almost infinite variety of combinations. Low-voltage auto ignition cable or heavy flexible hookup wire will do nicely.

Because under certain conditions and in certain uses both rotor and stator will be hot with r.f., an insulated extension is provided for the condenser shaft in order to remove the dial from the condenser by a few inches. This effectively reduces body capacity. It also precludes the possibility of being bitten by the dial set-screw.

The large coil consists of 30 turns of no. 12 wire, 4 inches in diameter and spaced to occupy 5¾ inches of winding space. The small coil consists of 14 turns, 2 inches in diameter, spaced to occupy 3¼ inches of winding space. Heavy duty 80- and 20-meter coils of commercial manufacture will serve nicely.

Both coils have taps brought out every other turn from one end to the center to facilitate clipping to the coils. A copper or brass clip is preferable to a steel clip for shorting out turns as the circulating current may be quite high.

Rather than short out too much of the large coil, we put the smaller coil into service. In fact, the two coils can even be used together in series should the large coil alone ever lack sufficient inductance for any purpose. However, for every common application, the large coil alone should possess sufficient inductance.

Now to cover some of the things we can do with this simple contraption:

At A in figure 28 the unit is used as a harmonic suppression tank as advocated earlier in this chapter.

Combination B may be used for either an end-fed or center-fed zepp that requires parallel tuning. It may also be used to feed an untuned open line, providing harmonic suppression. It may be used to tune an antenna counterpoise

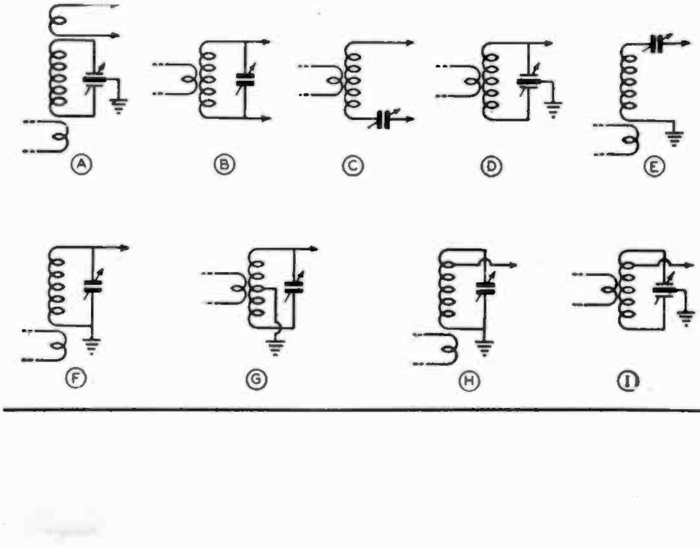


Figure 28.

APPLICATIONS OF THE UNIVERSAL ANTENNA COUPLER.

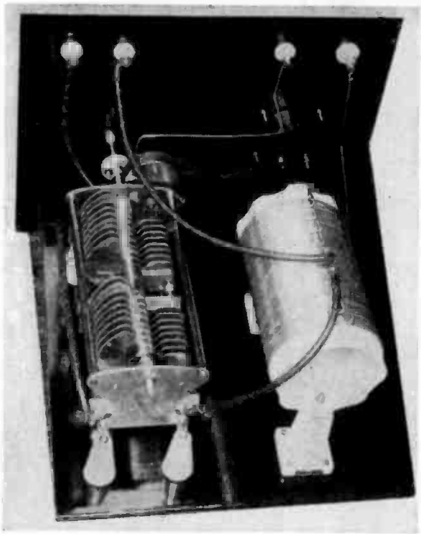


Figure 29.

THE UNIVERSAL ANTENNA COUPLER CAN BE MOUNTED IN A METAL CABINET, AS ILLUSTRATED HERE, IF DESIRED.

The unit shown above was designed for use only on the two lower frequency bands; hence the smaller coil (L_2 of figure 27) was omitted. An r.f. ammeter has been added for convenience in tuning.

system that has a higher natural frequency than that upon which it is desired to operate. It may be used with any system utilizing tuned feeders where the system cannot be resonated with series tuning (see C).

Combination C may be used for either an end-fed or center-fed zepp that requires series tuning. It may be used to feed an antenna counterpoise system that is too long electrically to resonate at the operating frequency at its natural period. It may be used with a multi-band antenna where the feeders are too long. It may be used for most any system utilizing tuned feeders where the system cannot be resonated using B.

Arrangement D may be used for feeding an end-fed antenna (even number of quarter waves long). It is usually preferable to F which is sometimes used for the same purpose.

System F also is used to tune a Marconi that is slightly shorter than an odd number of quarter waves long.

System E is the common method for tuning a Marconi where the antenna is slightly longer than an odd number of quarter waves.

G is commonly used to end-feed an antenna an even number of quarter waves long. It is a variation of D.

H and I are used for feeding either a single-wire-fed antenna or for end-feeding a very long-wire antenna (6 or more wavelengths long). For the latter purpose these are preferable to D, F and G.

In each case the link is coupled around the coil being used and one side of the twisted pair feeding the link is grounded.

DUMMY ANTENNAS

The law requires the use of some form of dummy antenna when testing a transmitter in order to minimize unnecessary interference.

The cheapest form of dummy antenna is an electric light globe coupled to the plate tank circuit by means of a four to eight turn pickup coil (or even clipped directly across a few turns of the tank

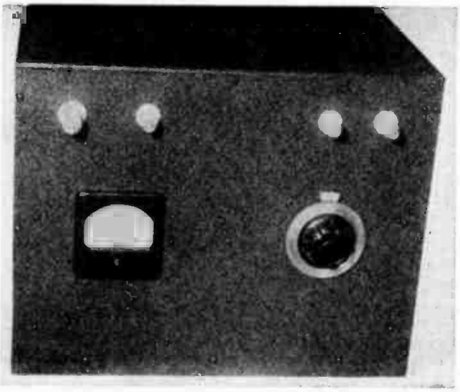


Figure 30.

FRONT VIEW OF THE DE LUXE COUPLER OF FIGURE 29.

This universal antenna coupler has many uses, is simple and inexpensive to construct. Its applications and operations are discussed in the text.

coil). Another good form of dummy antenna that is relatively nonreactive is a bar of carbon tapped across enough of the tank turns to load the amplifier properly. The plaque (noninductive) types of wirewound resistors also are ideal for use as a dummy antenna load.

If a lamp or lamps are chosen of such value that they light up to approximately normal brilliancy at normal transmitter input, the output may be determined with fair accuracy by comparing the brilliancy of the lamps with similar lamps connected to the 100-volt line.

It is difficult to obtain a highly accurate measurement of the output by measuring the r.f. current through the light bulb and applying Ohm's law, because the resistance of the bulb cannot be determined with accuracy. The resistance of a light bulb varies considerably with the amount of current passing through the filament.

For highly accurate measurement of r.f. output, dummy antenna resistors having a resistance that is substantially constant with varying dissipation are offered in 100 watt and 250 watt ratings. These resistors are available in either 73 or 600 ohm types, and can be considered purely resistive at frequencies below 15 Mc. It will be noted that the two stock resistance values correspond to the surge impedance of the most common twisted-pair untuned line and the most common open-wire line respectively. This increases their usefulness.

These resistors are hermetically sealed in glass bulb containers, the latter containing a gas which accelerates the conduction of heat from the resistor element (filament) to the outer surface of the bulb. These resistors glow a dull red at full dissipation rating; though they somewhat resemble an incandescent lamp physically, they do not produce appreciable light. They may be used in series, parallel, or series parallel to get other resistance values or greater dissipation.

A correction chart is furnished so that one can correct for the slight non-linearity when a high degree of accuracy is required. With an r.f. ammeter of suitable range in series with the resistor, it is only necessary to note the reading and refer to the chart to determine the exact amount of power being dissipated in the resistance.

DIRECTIVE ANTENNAS

No antenna except a single vertical element (no reflectors), radiates energy equally well in all directions. All horizontal antennas have directional properties, these usually depend upon the length in wavelengths, the height above ground and the slope.

The various forms of the half-wave horizontal antenna produce maximum radiation at right angles to the wire, but the directional effect is not very great excepting for very low vertical angles of radiation (such as would be effective on 10 meters). Nearby objects also minimize the directivity of a dipole radiator so that it hardly seems worth while to go to the trouble to rotate a simple half-wave dipole in an attempt to improve transmission and reception in any direction.

The half-wave doublet, zepp, single-wire-fed, matched impedance and Johnson Q antenna all have practically the same radiation pattern *when properly built and adjusted*. They are all dipoles, and the feeder system should have no effect on the radiation pattern.

When a multiplicity of radiating dipoles are so located and phased as to reinforce the radiation in certain desired directions and to neutralize radiation in other directions, a directive antenna array is formed.

The function of a directive antenna when used for transmitting is to give an increase in signal strength in some direction at the expense of reduced signal in other directions. For reception, one might find useful an antenna giving little or no gain in the direction from which it is desired to receive signals if the antenna is able to *discriminate against interfering* signals and static arriving from other directions. A good directive transmitting antenna, however, can generally also be used to good advantage for reception. This is covered in detail later in this chapter.

If radiation can be confined to a narrow beam, the signal intensity can be increased a great many times in the desired direction of transmission. This is equivalent to increasing the power output of the transmitter. On the higher frequencies it is more economical to use a directive antenna than to increase transmitter power if more than a few watts power is being used.

Directive antennas can be designed to give as high as 23 db gain over that of a single half-wave antenna. However, this high gain (nearly 200 times as much power) is confined to such a narrow beam that it can be used only for commercial applications in point-to-point communication.

The increase in radiated power in the desired direction is obtained with a corresponding loss in all other directions. Gains of 3 to 10 db seem to be of more practical value for amateur communication because the angle covered by the beam is wide enough to sweep a fairly large area. Three to 10 db means the equivalent of increasing power from 2 to 10 times.

Horizontal Pattern vs. Vertical Angle

For each of the amateur high-frequency bands, there is a certain optimum vertical angle of radiation. Energy radiated at an angle much higher than this optimum angle is largely lost, while radiation at angles much lower than this optimum angle oftentimes is not nearly so effective in producing signals at a distant station.

For this reason, the horizontal directivity pattern as measured on the ground is of no import when dealing with frequencies and distances dependent upon sky wave propagation. It is the horizontal directivity (or gain or discrimination) *measured at the most useful vertical angles of radiation* that is of consequence. The horizontal radiation pattern as measured on the ground is considerably different from the pattern obtained at a vertical angle of 15 degrees, and still more different from a pattern obtained at a vertical angle of 30 degrees. In general, a propagation angle of anything less than 30° above the horizon has proved to be effective for 40- and 80-meter operation over long distances. The energy which is radiated at angles higher than approximately 30° above the earth is not very effective at these frequencies for dx.

For operation at higher frequencies (lower wavelengths), such as in the vicinity of 20 meters, the most effective angle of radiation is usually about 15° above the horizon, from *any* kind of antenna. The most effective angles for 10-meter operation are those in the vicinity of 10°. These angles give best results for long-distance communication because the waves are most effectively reflected from the *Heaviside layer* for the various frequencies or wavelengths mentioned.

The fact that many simple arrays give considerably more gain at 10 and 20 meters than one would expect from consideration of the horizontal directivity can be explained by the fact that, besides providing some horizontal directivity, they concentrate the radiation at a lower *vertical* angle. The latter may actually account for the greater portion of the gain obtained by some simple 10-meter arrays. The gain that can be credited to the increased horizontal directivity is never more than 4 or 5 db at most with the simpler arrays. At 40 and 80 meters this effect is not so pronounced, most of the gain from an array resulting from the increased horizontal directivity. Thus, a certain type of array may provide 12 to 15 db *effective* gain over a dipole at 10 meters, and only 3 or 4 db gain at 40 meters.

There is an endless variety of directive arrays that give a substantial power gain

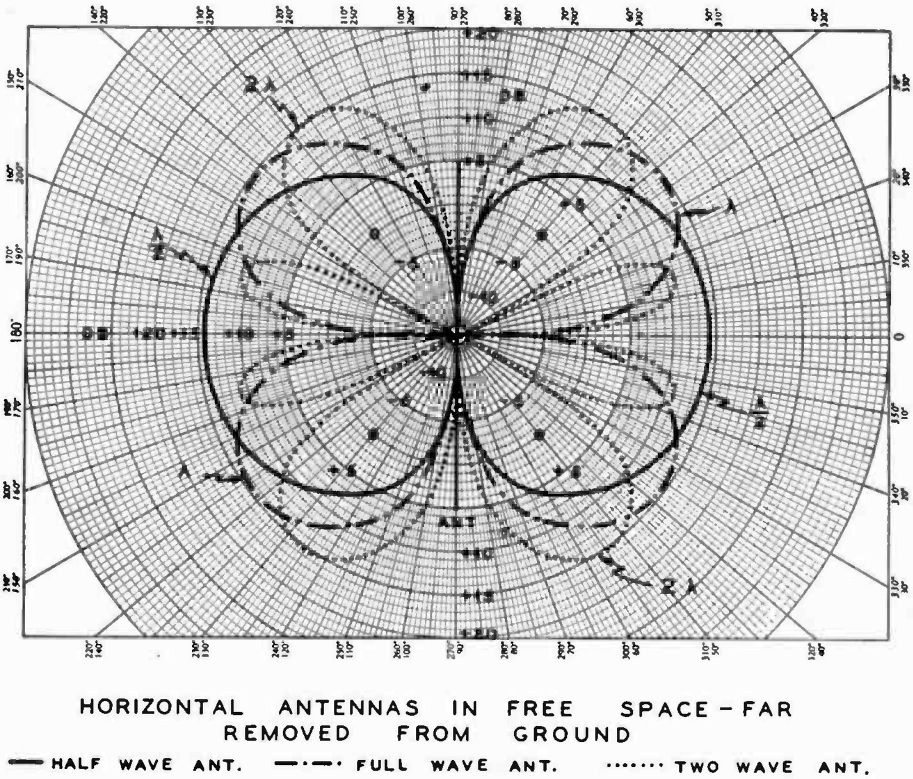


Figure 31.

THEORETICAL FIELD STRENGTH IN DB UNITS OF THREE TYPES OF ANTENNAS IN FREE SPACE.

To obtain a true picture, one must visualize the radiation lobes in space as encircling the antenna and cutting the page on the dotted lines. The presence of the earth distorts the patterns considerably unless the antenna is several wavelengths above ground.

in the favored direction. However, some are more effective than others taking up the same space, some are easier to feed, and so forth. *For this reason, only those arrays that are specifically recommended as being highly satisfactory for amateur work are described in this book.* To include all the various directive antennas that have been developed in the last decade alone would take more space than can be devoted to the subject here. Those desiring a more comprehensive treatment are referred to the RADIO ANTENNA HANDBOOK.

LONG WIRE RADIATORS

Harmonically operated antennas radiate better in certain directions than others, but cannot be considered as having appreciable directivity unless several half wavelengths long. The current in adjoining half-wave elements flows in opposite directions, and thus the radiation from the various elements, being out of phase, adds in certain directions and neutralizes in others.

A half-wave doublet in free space has a "doughnut" of radiation surrounding it. A full wave has two; three half waves three; and so on. When the radiator is made more than four half wavelengths long, the *end* lobes (cones of radiation) begin to show noticeable power gain over a half-wave doublet, while the

LONG-ANTENNA DESIGN CHART

Length in Feet End-Fed Antennas

Frequency in Mc.	1λ	1½λ	2λ	2½λ	3λ	3½λ	4λ	4½λ
30	32	48	65	81	97	104	130	146
29	33	50	67	84	101	118	135	152
28	34	52	69	87	104	122	140	157
14.4	66½	100	134	169	203	237	271	305
14.2	67½	102	137	171	206	240	275	310
14.0	68½	103½	139	174	209	244	279	314
7.3	136	206	276	246	416	486	555	625
7.15	136½	207	277	347	417	487	557	627
7.0	137	207½	277½	348	418	488	558	628
4.0	240	362	485	618	730	853	977	1100
3.9	246	372	498	625	750	877	1000	1130
3.8	252	381	511	640	770	900	1030	1160
3.7	259	392	525	658	790	923	1060	1190
3.6	266	403	540	676	812	950	1090	1220
3.5	274	414	555	696	835	977	1120	
2.0	480	725	972	1230	1475			
1.9	504	763	1020	1280				
1.8	532	805	1080					

broadside lobes get smaller and smaller in amplitude, even though numerous.

The horizontal radiation pattern of such antennas depends upon the vertical angle of radiation being considered. If the wire is more than four wavelengths long, the maximum radiation at vertical angles of 15 to 20 degrees (useful for dx) is in line with the wire, being slightly greater a few degrees either side of the wire than directly off the ends. The directivity of the main lobes of radiation is not particularly sharp, and the minor lobes fill in between the main lobes to permit working stations in nearly all directions, though the power radiated broadside to the radiator will not be great if the radiator is more than a few half wavelengths in length.

To maintain the out-of-phase condition in adjoining half-wave elements throughout the length of the radiator, it is necessary that a harmonic antenna be fed either at *one end* or at a *current* loop. If fed at a voltage loop, the adjacent sections will be fed *in* phase, and a different radiation pattern will result.

The directivity of a long wire does not increase very much as the length is increased beyond about 15 wavelengths. In fact, the directivity does not go up in proportion to the additional cost of the long wire after about 8 wavelengths are used. This is due to the fact that all long-wire antennas are adversely affected by the r.f. resistance of the wire. This resistance also affects the Q or selectivity of the long wire, and as the length is increased, the tuning of the antenna becomes quite broad. In fact, a long wire about 15 waves long is practically aperiodic and works almost equally well over a wide range of frequencies.

The following table gives the radiation characteristics of harmonically operated antennas in *free space:*

RADIATION RESISTANCE OF HARMONIC ANTENNAS

No. of λ/2	Radiation resistance ohms	Angle of maximum radiation	Power in major lobe of radiation
1	72	90°	1
2	90	55°	1.15
3	100	46.5°	1.25
4	110	37°	1.35
5	115	34.5°	1.5
6	122	30.5°	1.7
7	125	28°	1.85
8	131	27°	2.1
9	135	25.5°	2.3
10	139	24°	2.55
11	142	22.5°	2.75
12	145	21°	3.1
13	148	20.5°	3.3
14	150	20°	3.65
15	152	19.5°	3.9
16	154	19°	4.25
17	156	18.5°	4.55
18	158	18°	4.9
19	160	17.5°	5.25
20	162	17°	5.65

V-ANTENNA DESIGN TABLE.

Frequency In Kilocycles	L = λ δ = 90°	L = 2λ δ = 70°	L = 4λ δ = 52°	L = 8λ δ = 39°
28000	34′ 8″	69′ 8″	140′	280′
28500	34′ 1″	68′ 6″	137′ 6″	275′
29000	33′ 6″	67′ 3″	135′	271′
29500	33′	66′ 2″	133′	266′
30000	32′ 5″	65′	131′	262′
14050	69′	139′	279′	558′
14150	68′ 6″	138′	277′	555′
14250	68′ 2″	137′	275′	552′
14350	67′ 7″	136′	273′	548′
7020	138′ 2″	278′	558′	1120′
7100	136′ 8″	275′	552′	1106′
7200	134′ 10″	271′	545′	1090′
7280	133′ 4″	268′	538′	1078′

One of the most practical methods of feeding a long-wire antenna is to bring one end of it into the radio room for direct connection to a tuned antenna circuit which is link-coupled to the transmitter. The antenna can be tuned to exact resonance for operation on any harmonic by means of the tuned circuit which is connected to the end of the antenna. This tuned circuit corresponds to an adjustable, nonradiating half-wave section of the antenna. A ground is sometimes made to the center of the tuned coil.

If desired the antenna can be opened and current-fed at a point of maximum *current* by means of a twisted-pair feeder, concentric line, or a Q matching system and open line.

If opened at a voltage loop to accommodate a two-wire feeder or stub, the phasing will be disturbed. Hence, it is usually fed at one end when voltage-fed. This permits multi-band operation if tuned feeders are used.

THE V ANTENNA

If two long-wire antennas are built in the form of a V, it is possible to make two of the maximum lobes of one leg shoot in the same direction as two of the maximum lobes of the other leg of the V. The resulting antenna is a bidirectional (two opposite directions) for the main lobes of radiation. Each side of the V can be made any odd or even multiple of quarter wavelengths, depending on the method of feeding the apex of the V. The complete system must be a multiple of half waves, If each leg is an even number of quarter waves long, the antenna must be voltage-fed; if an odd number of quarter waves long current feed must be used.

By choosing the proper angle δ, figure 32, the lobes of radiation from the two long-wire antennas aid each other to form a bidirectional beam. Each wire by itself would have a radiation pattern similar to that shown for antennas operated on harmonics. The reaction of one upon the other removes two of the four main lobes and increases the other two in such a way as to form two lobes of still greater magnitude.

The correct wire lengths and the degree of the angle δ are listed in the *V-Antenna Design Table* for various frequencies in the 10-, 20- and 40-meter amateur bands. These values must sometimes be reduced slightly if one of the wires is in the vicinity of some large object.

The legs of a very long wire V antenna are usually so arranged that the included

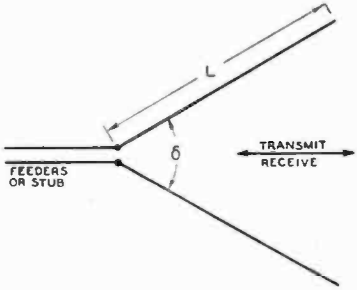


Figure 32.

TYPICAL V-BEAM ANTENNA.

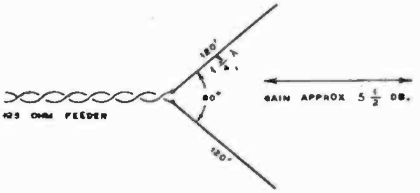


Figure 33.
20-METER V ANTENNA, SMALLEST WORTHWHILE SIZE.

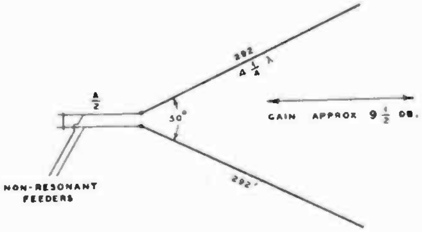


Figure 34.

MORE DIRECTIVE 20-METER V THAN SHOWN ABOVE, WITH MORE EFFICIENT METHOD OF FEED.

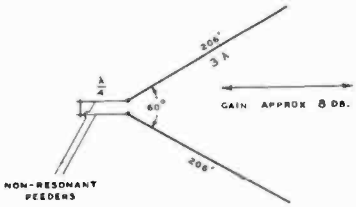


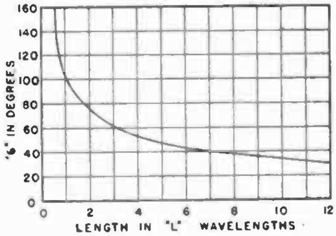
Figure 35.

20-METER V WITH MODERATE GAIN AND DIRECTIVITY, BEST SUITED FOR GENERAL AMATEUR USE.

angle is twice the angle of the major lobe from a single wire if used alone. This arrangement concentrates the radiation of each wire along the bisector of the angle and permits part of the other lobes to cancel each other.

With legs shorter than three wavelengths, the best directivity and gain are obtained with a somewhat smaller angle than that determined by the lobes. Optimum directivity for a one-wave V is obtained when the angle is 90° rather than 108° as determined by the ground pattern alone.

If very long wires are used in the V, the angle between the wires is almost unchanged when the length of the wires in wavelengths is altered. However, an error of a few degrees causes a much larger loss in directivity and gain in the case of the longer V than in the shorter one which is broader.



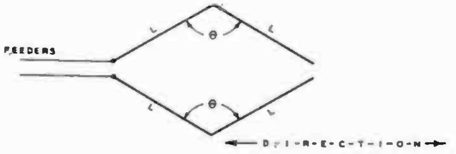
V-BEAM CURVE
Showing the included angle between the two legs of a V-beam antenna for various leg lengths. The included angle is sometimes made slightly less than that indicated by the curve when the legs are shorter than three wavelengths.

The V antenna can have each leg either an even or an odd number of quarter waves long. If an even number of quarter waves long, the antenna must be voltage-fed at the apex of the V, while if an odd number of quarter waves long, current feed can be used.

The vertical angle at which the wave is best transmitted or received from a horizontal V antenna depends largely upon the included angle. The sides of the V antenna should be at least a half wavelength above ground; commercial practice dictates a height of approximately a full wavelength above ground.

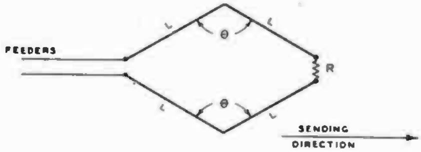
THE RHOMBIC ANTENNA

The terminated *rhombic* or *diamond* is probably the most effective directional antenna that is practical for amateur communication. This antenna is nonresonant, with the result that it can be used on three amateur bands, such as



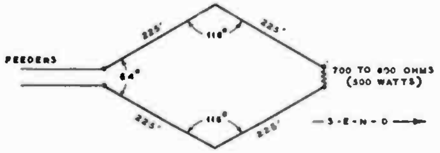
TUNED RHOMBIC ANTENNA

Figure 36.



UNTUNED RHOMBIC ANTENNA

Figure 37.

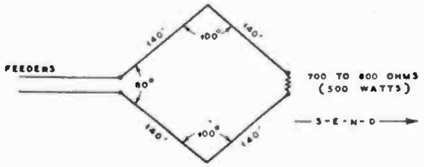


HEIGHT ABOVE GROUND 30 FT OR MORE
LENGTH DIMENSIONS ARE NOT CRITICAL

GAIN APPROX 14 DB ON MAIN LOBE.

RHOMBIC ANTENNA FOR 7, 14 & 28MC. BANDS

Figure 38.



SMALLER RHOMBIC OR DIAMOND ANTENNA
SUITABLE FOR 7, 14 & 28MC. BANDS

Figure 39.

10, 20 and 40 meters. When the antenna is non-resonant, i.e., properly terminated, the system is unidirectional and the wire dimensions are not critical. The rhombic antenna can be suspended over irregular terrain without greatly affecting its practical operation.

The *tuned* diamond antenna consists of two V antennas, end to end, and *without a free end termination,* as shown in figure 36. This antenna is *bidirectional,* in which case the lengths are very critical, and the system must be tuned to exact resonance with the operating frequency. It has less gain than a properly terminated rhombic of the same size.

If the free end is terminated with a resistance of a value between 700 and 800 ohms, as shown in figures 37, 38 and 39, the backwave is eliminated, the forward gain is increased and the antenna can be used on several bands without changes. The terminating resistance should be capable of dissipating one-third the power output of the transmitter and should have very little reactance. A bank of lamps can be connected in series parallel for this purpose or heavy duty carbon rod resistances can be used. For medium or low power transmitters, the noninductive *plaque* resistors will serve as a satisfactory termination. Several manufacturers offer special resistors suitable for terminating a rhombic antenna.

The terminating device should, for technical reasons, present a small amount of inductive reactance at the point of termination. However, this should not be too great. By using a bank of lamps in series-parallel, this qualification will be met. The total power dissipated by the lamps will be roughly a third of the transmitter output.

Because of the high temperature coefficient of resistance for both carbon and Mazda lamps, neither type is any too satisfactory when used alone, especially in a keyed transmitter. However, by connecting both types in parallel, the resistance can be made fairly constant. This is because the coefficient of one type of lamp is positive, while that of the other is negative. The most constant combination will utilize a 110-volt carbon lamp of 2X watts across each 125-volt Mazda lamp of X watts. Thus, a 60-watt Mazda lamp would have a 120-watt carbon lamp across it. The desired resistance can be obtained by series-connecting or series-paralleling several such units.

A compromise terminating device commonly used consists of a terminated 250-

foot or longer length of line made of resistance wire which *does not have too much resistance per unit length.* If the latter qualification is not met, the reactance of the line will be excessive. A 250-foot line consisting of no. 25 nichrome wire, spaced 6 inches and terminated with 800 ohms will serve satisfactorily. Because of the attenuation of the line, the lumped resistance at the end of the line need dissipate but a few watts even when high power is used. A half-dozen 5000-ohm 3-watt carbon resistors in parallel will serve for all except very high power. The attenuating line may be either coiled or folded back on itself to take up less room.

The determination of the best value of terminating resistor must be made while *transmitting,* as the input impedance of the average receiver is considerably lower than 800 ohms. This mismatch will *not* impair the *effectiveness* of the array on *reception,* but as a result the value of resistor which gives the best directivity on reception will not give the most gain when transmitting. It is preferable to adjust the resistor for maximum gain when transmitting, even though there will be but little difference between the two conditions.

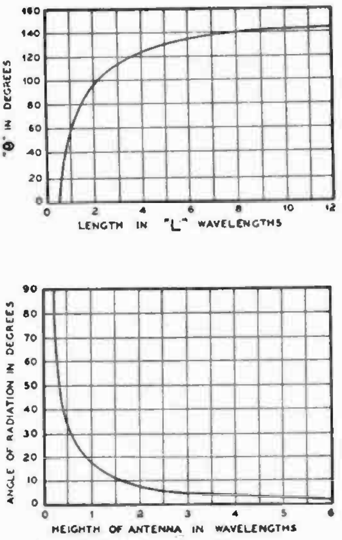


Figure 40 A and B.

DIAMOND-ANTENNA DESIGN CHARTS.

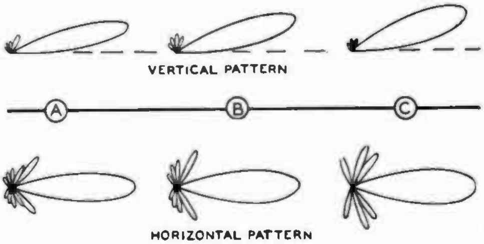


Figure 41.

RADIATION PATTERNS OF THREE RHOMBIC ANTENNAS: VERTICAL DIRECTIVITY ABOVE AND HORIZONTAL DIRECTIVITY BELOW.

A, pattern of rhombic antenna 4 waves on a side and one wavelength high. B, 3 waves on a side and ¾ wavelength high. C, 2 waves on a side and a half wavelength high. The above conditions also hold for a single antenna worked over a frequency range of 2/1.

The input resistance of the diamond which is reflected into the transmission line that feeds it is always somewhat less than the terminating resistance, and is around 700 or 750 ohms when the resistor is 800 ohms.

The antenna should be fed with a nonresonant line, preferably with an impedance of approximately 700 ohms. The four corners of the diamond, when possible, should be at least a half wavelength above ground at the lowest frequency of operation. For three-band operation, the proper angle θ for the center band should be observed.

The diamond antenna transmits a horizontally polarized wave at a low angle above the horizon in the case of a large antenna. The angle of radiation above the horizon goes down as the height above ground is increased.

The directivity of a typical rhombic antenna suitable for amateur communication is shown in figure 41. The smaller lobes of radiation prevent the antenna from being truly unidirectional; the amplitude, however, is relatively small in comparison to the main lobe of radiation.

Unless unavoidable the diamond antenna should not be tilted in any plane. In other words, the poles should be the same height and the plane of the antenna should be parallel with the ground. Tilting the antenna simply sacrifices about half the directivity due to the fact that the reflection from the ground does not combine with the incident wave in the desired phase unless the antenna is parallel with the ground.

A good deal of directivity is lost when the terminating resistor is left off and it is operated as a resonant antenna. If it is desired to reverse the direction of maximum radiation, it is much better practice to run feeders to both ends of the antenna and mount terminating resistors also at both ends. Then, with either mechanically- or electrically-controlled, remote-controlled double-pole double-throw switches located at each end of the antenna, it becomes possible to reverse the array quickly for transmission or reception to or from the opposite direction.

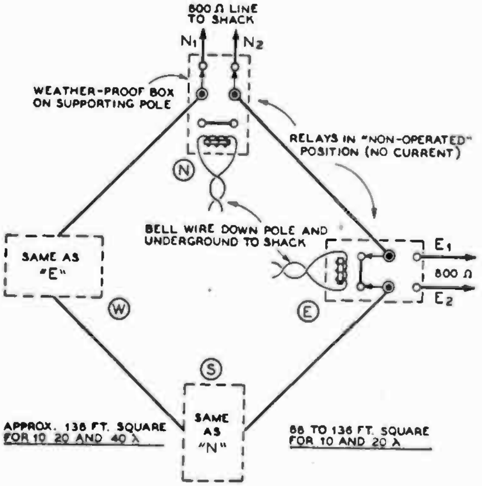


Figure 42.

SCHEMATIC OF THE "QUADIRECTIONAL" RHOMBIC.

Best length for legs of 10- and 20-meter array is 100 ft. R.f. lines should leave antenna at right angles or bisect the angle made by adjacent legs for at least 20 feet. 10-, 20- and 40-meter array should be about 60 ft. high. 10- and 20-meter array should be about 40 ft. high. ("Effective" height above ground.) Note that connections for relays N and S are different from those of E and W. Relay lines may be paralleled and a single twisted line run to control position if latter is remote from antenna.

The directive gain of the rhombic antenna is dependent on the height above ground and the side angle as well as the overall length of each of the four radiating wires in the array. Therefore, the gain is not easy to calculate.

The Quadirectional Rhombic Antenna

By a system of switches and four feed lines, it is possible to make a unidirectional rhombic antenna that can be used in four directions. Obviously, such a rhombic antenna must be square. Such an arrangement, the Evans Quadirectional array, is compact compared to the usual rhombic antenna installation, and can be used on two or three bands.

A general idea of the switching arrangement is given in figures 42 and 43. The relays atop the poles supporting the legs of the rhombic need not have elaborate insulation, wide throw, or especially heavy contacts, because neither voltage nor current is particularly high, even when high power is used. The type of d.p.d.t. relay commonly used as a send-receive switch for switching a 500- to 600-ohm untuned line from receiver to transmitter will be quite satisfactory.

The relays are not operated individually, but rather as a group. With all relays operated the antenna transmits or receives in either of two opposite directions (depending upon position of terminating resistor) and with them non-operated it transmits or receives in the other two directions. The markings "N", "E", "S", and "W", are merely for reference and do not *necessarily* indicate compass directions.

The r.f. lines to the operating position should have a surge impedance of between 700 and 800 ohms. No. 20 copper, spaced 6 inches, makes a suitable line. The r.f. lines should preferably run down the poles for at least 20 feet before going off to the control position.

The control switch, shown in figure 43, may be of the ceramic insulated,

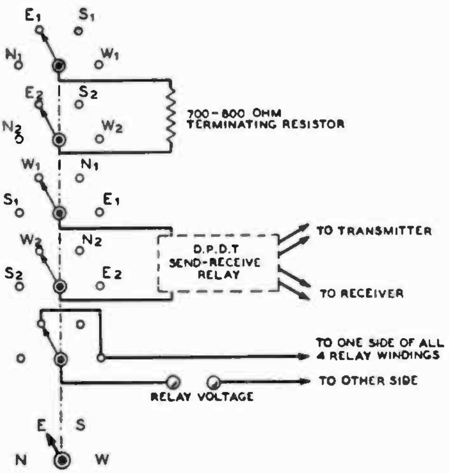


Figure 43.

A FIVE-GANG, FOUR-POSITION SWITCH PERMITS CHANGING OF DIRECTIVITY BY JUST "AIMING THE POINTER."

Note that each wire of each r.f. feed line connects to two different gangs. For instance, N_1 on one gang should be jumpered to N_1 on the other gang. These jumpers were omitted from the diagram for the sake of clarity.

ganged selector switch type. A five-gang, four-position switch such as the Centralab 2546 or Yaxley 165-C will have sufficient spacing for any power up to about 500 watts. It should be noted that each feed wire connects to a contact on each of *two* gangs. The jumpers were omitted from the diagram to keep it from appearing confusing.

With all the lines connected, transmission or reception will be in the direction indicated by the pointer.

Termination

The best value of terminating resistor can be determined only by experiment. It should be adjusted until the forward gain is best when transmitting. This will usually correspond to the value that gives the most uniform current distribution on the legs of the array. Do not worry about a *slight* indication of standing waves on the feed lines; they are relatively unimportant. The only trouble they can cause is unequal loading of the transmitter as the antenna direction is switched. If this effect is bad enough as to be objectionable, it can be corrected by adding to the lengths of the various feeders until they load the transmitter uniformly. It is not necessary that the feeders be of the same length; it is only necessary that they be of the same amount too long or too short of an integral number of half waves. Thus it can be seen that adding a few feet at most will result in equal loading in spite of the presence of moderate standing waves.

Adjustment of the terminating resistor is made easy by its location at the operating position. It will be somewhere between 700 and 1000 ohms. The best way to determine the correct value is to run low power to the transmitter, 10 or 15 watts, and then with a handful of carbon resistors try different combinations until the best value is found. Measure the resistance with an accurate ohmmeter (don't rely upon the resistor marking; they may be off 10 per cent) and then duplicate this value of resistance with a non-inductive resistor of sufficient wattage to dissipate approximately half the maximum transmitter output.

STACKED DIPOLE ANTENNAS

The characteristics of a half-wave dipole have already been described. When another dipole is placed in the vicinity and excited either directly or parasitically, the resultant radiation pattern will depend upon the spacing and phase differential as well as the relative magnitude of the currents. With spacings less than 0.65 wavelength, the radiation is mainly broadside to the two wires (bidirectional) when there is no phase difference, and *through* the wires (end fire) when the wires are 180 degrees out of phase. With phase differences between 0 and 180 degrees (45, 90 and 135 degrees for instance), the pattern is somewhat unsymmetrical, the radiation being *greater in one direction* than in the opposite direction. In fact, with certain critical spacings the radiation will be practically unidirectional for phase differences of 45, 90 and 135 degrees. However, phase differences of other than 0 and 180 degrees are difficult to obtain except with parasitically excited elements.

With spacings of more than 0.7 wavelength, more than two main lobes appear for all phasing combinations; hence, such spacings are seldom used.

With the dipoles driven so as to be in phase, the most effective spacing is between 0.5 and 0.65 wavelength. The latter provides greater gain, but two minor lobes are present which do not appear at 0.5-wavelength spacing. The radiation is broadside to the plane of the wires and the gain is slightly greater than can be obtained from two dipoles out of phase. The gain falls off rapidly for spacings less than 0.375 wavelength, and there is little point in using spacing of 0.25 wavelength or less with in-phase dipoles except where it is desirable to increase the radiation resistance. (See *Multi-Wire Doublet.*)

When the dipoles are fed 180 degrees *out of phase,* the directivity is through the plane of the wires and is greatest with *close spacing,* though there is but little difference in the pattern after the spacing is made less than 1.125 wavelength. The radiation resistance becomes so low for spacings of less than 0.1 wavelength that such spacings are not practicable for antenna arrays except for receiving.

The best *unidirectional* pattern is obtained with 0.1- or 0.125-wavelength spacing and 135-degrees phase lag. As it is rather difficult to get other than 0- and 180-degree phasing in driven radiators, parasitic directors and reflectors are usually resorted to for odd values of phasing. These are driven parasitically rather than directly by feeders, and the phasing can be varied by altering the length of the parasitic elements.

In the three foregoing examples, most of the directivity provided is in a plane at a right angle to the two wires, though when out of phase, the directivity is in a line *through* the wires, and when in-phase, the directivity is *broadside* to them. Thus, if the wires are oriented vertically, mostly horizontal directivity will be provided. If the wires are oriented horizontally, most of the directivity obtained will be *vertical* directivity.

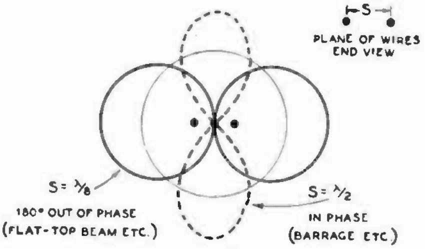


Figure 44.

FIELD STRENGTH PATTERNS OF TWO DIPOLES WHEN IN PHASE AND WHEN OUT OF PHASE.

It can be readily seen that if the dipoles are oriented horizontally most of the directivity will be in the vertical plane; if oriented vertically most of the directivity will be horizontal directivity.

To increase the sharpness of the directivity in all planes that include one of the wires, additional identical elements are added *in the line of the wires* and fed so as to be *in phase.* The familiar H array is one array utilizing both types of directivity in the manner prescribed. The two-section Kraus flat-top beam is another.

These two antennas in their various forms are directional in a horizontal plane in addition to being low angle radiators, and are perhaps the most practicable of the *bidirectional* stacked-dipole arrays for amateur use. More phased elements can be used to provide greater directivity in planes including one of the radiating elements. The H then becomes a barrage or Sterba array.

For unidirectional work, the most practicable stacked dipole arrays for amateurs are those using close-spaced directors and reflectors (0.1 to 0.125 wavelength spacing).

While there is almost an infinite variety of combinations when it comes to obtaining directivity by means of stacked dipoles, only those systems which are most practical from an amateur standpoint will be discussed at length.

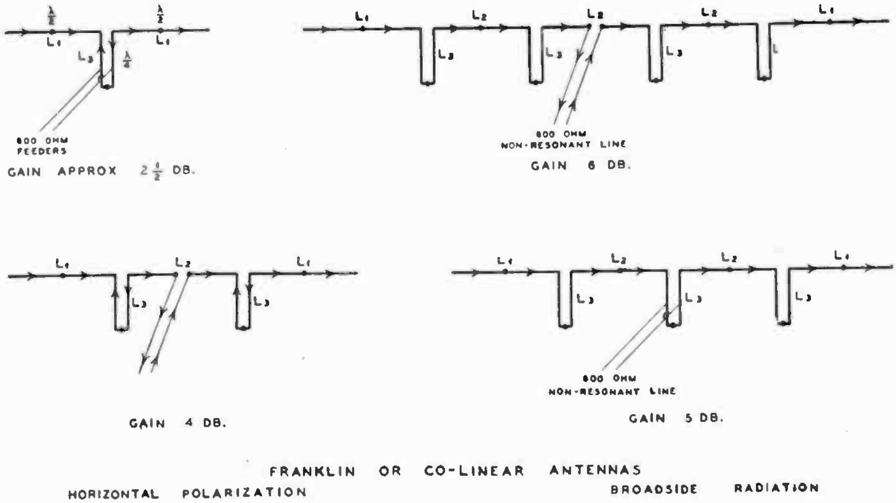


Figure 45.

COLINEAR ANTENNAS

Franklin or *colinear* antennas are widely used by amateurs. The radiation is bidirectional broadside to the antenna. The antenna consists of two or more half-wave radiating sections with the current *in phase* in each section. This is accomplished by quarter-wave stubs between each radiating section or by means of a tuned coil and condenser or resonant loading coil between each half-wave radiating section. The quarter-wave stub is a folded half-wave wire in which the wires are sufficiently together so that the radiation is neutralized.

Two half waves *in phase* will give a gain of slightly more than 2 db with respect to a single half-wave antenna; three sections will give a gain of approximately 4 db. Additional half-wave sections increase this power gain approximately one db per section. The two section colinear antenna is commonly called a *double zepp*.

Various feeder systems are shown in the accompanying sketches. A tuned feeder can be used in place of a quarter-wave stub and 600-ohm line. The latter will allow a two-section *colinear* antenna to be operated as a single section half-wave antenna (current-fed doublet) on the next longer wave amateur band. For example, an antenna of this type would be a half-wave antenna on 40 meters and a two-section *colinear* antenna on 20 meters. The direction of current at a given instant and the location of the current loops are indicated in the sketches by means of arrowheads and dots, respectively.

Practically all directivity provided by colinear sections is in a horizontal plane. The effect on the vertical directivity is negligible when additional sections are provided. For this reason, the Franklin array is useful particularly on the 40-, 80- and 160-meter bands, where low angle radiation is not so important. On the higher frequency bands, 20 and 10 meters, an array providing *vertical directivity in addition to horizontal directivity is desirable.* Hence, the Franklin antenna is not as suited for use on the latter two bands as are some of the arrays to be described.

As additional colinear elements are added to a doublet, the radiation resistance goes up much faster than when additional half waves are added out of phase (harmonic operated antenna).

COLINEAR ANTENNA DESIGN CHART

BAND	FREQUENCY IN MC.	L_1	L_2	L_3
10 METERS	30	16′	16′ 5″	8′ 2″
	29	16′ 6″	17′	8′ 6″
	28	17′ 1″	17′ 7″	8′ 9″
20 METERS	14.4	33′ 4″	34′ 3″	17′ 1″
	14.2	33′ 8″	34′ 7″	17′ 3″
	14.0	34′ 1″	35′	17′ 6″
40 METERS	7.3	65′ 10″	67′ 6″	33′ 9″
	7.15	67′	68′ 8″	34′ 4″
	7.0	68′ 5″	70′ 2″	35′ 1″
75 METERS 80	4.0	120′	123′	61′ 6″
	3.9	123′	126′	63′
	3.6	133′	136′ 5″	68′ 2″

It should be borne in mind that the *gain* from a Franklin antenna depends upon the *sharpness* of the horizontal directivity. An array with several colinear elements will give considerable gain but will cover only a very limited arc.

Double Extended Zepp

The gain of a conventional two-element Franklin antenna can be increased to a value approaching that obtained from a three-element Franklin simply by making the two radiating elements 230 degrees long instead of 180 degrees long. The phasing stub is shortened correspondingly to maintain the whole array in resonance. Thus, instead of having 0.5 wavelength elements and a 0.25 wavelength stub, the elements are made 0.64 wavelength long and the stub 0.11 wavelength long.

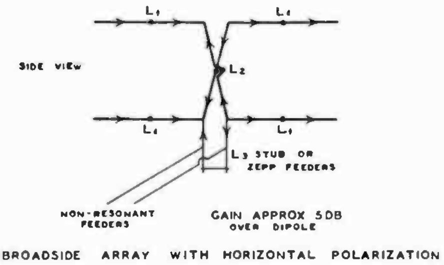


Figure 46.

THE POPULAR "LAZY H" BI-DIRECTIONAL ARRAY.

Stacking the colinear elements results in both vertical and horizontal directivity. On 10 and 20 meters the effective gain over a doublet is greater than the theoretical value of 5 db, due to the fact that the earth has less detrimental effect upon the low angle radiation when stacking is used.

The correct dimensions for a 230 degree double zepp can be obtained from the *Colinear Antenna Design Chart* simply be multiplying the L_1 values by 1.29 and the L_3 values by 0.44.

The *vertical* directivity of a colinear antenna having 230 degree elements is the same as for one having 180 degree elements. However, small parasitic lobes occur in the horizontal pattern with the extended version. The radiation resistance of the extended version is slightly lower.

MULTIPLE-STACKED BROADSIDE ARRAYS

Colinear elements may be stacked above or below another similar string of elements, thus providing vertical directivity. Two horizontal colinear elements stacked two above the other and separated by a half wavelength form the popular "lazy H" array of figure 46. It is highly recommended for amateur work on 10 and 20 meters when substantial gain without too much directivity is desired. It has high radiation resistance. This results in low voltages and a broad resonance curve, which permits use of inexpensive insulators and enables the array to be used over a fairly wide range in frequency. For dimensions see figure 48.

The X-H Array

As previously mentioned under the *double extended zepp*, greater horizontal directivity can be obtained from two horizontal colinear dipoles by extending each to 230 degrees. It also has been explained previously that cophased dipoles in a curtain arrangement do not show maximum broadside directivity or gain at the common 0.5 wavelength spacing, but at approximately 0.65 wavelength spacing.

Observation of the dimensions of the Smith X-H array in figure 47 will show that the radiating element lengths have been increased to 230 degrees and that the spacing has been increased to almost 0.7

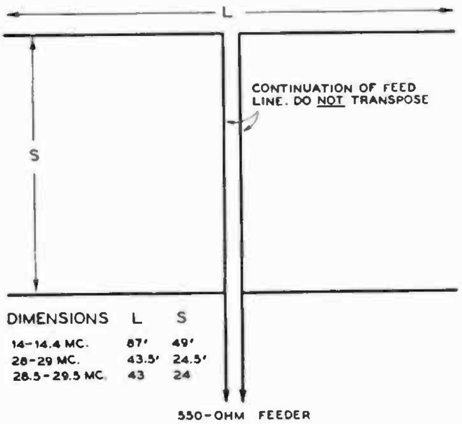


Figure 47.

THE X-H ARRAY.

Good results can be obtained using the 10-meter array on 20 meters and the 20-meter array on 40 meters. Let the phasing section (length S) hang loosely, so that the actual separation of the elements is slightly less than dimension "S".

wavelength; otherwise it looks exactly like the familiar Lazy H with two exceptions: the phasing section is *not transposed* and *no matching stub is used.*

Increasing the element lengths and spacing beyond 0.5 wavelength results in parasitic lobes being radiated both in a vertical and a horizontal plane. However, the magnitude of these lobes is small, and effects of their presence can be ignored.

The X-H array can be used with good results on *half* (not twice) frequency with no changes whatsoever, thus permitting two-band operation.

The gain at half frequency will not be as great as when the array is used on its regular frequency, but there is still gain over a regular dipole. The general shape of the pattern is the same on both bands, but it will not be so sharp when the array is used on half frequency.

To give a perfect match on both bands, the line should have a surge impedance in the neighborhood of 250-300 ohms, but a line of this surge impedance is awkward of construction. A perfect match may be obtained on *one band* with the 550-ohm feeders by sliding them up the phasing stub a short distance or fanning them out a little either side of the center of the bottom section. The point of attachment shown is a compromise which will result in current excursions of about 3 to 1 on both bands.

If the slight reactance resulting from the compromise connection appears objectionable, the line should be made an exact integral number of half waves long on the lowest frequency band. Thus if a 10 meter X-H array is to be used on both 10 and 20 meters, the line should be a multiple of 34 feet.

Do not attempt to pull the phasing stub tight. It does not hurt to allow the phasing section to whip around a little; so let it hang loosely. It is better to have *slightly less* than rather than slightly more than 0.7 wavelength spacing between elements. For best results the bottom of the array should be at least 10 feet above ground for either a 10- or 20-meter array.

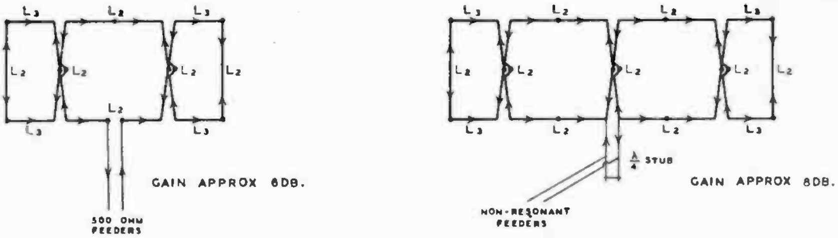
The Sterba "Barrage"

Vertical stacking may be applied to strings of colinear elements longer than two half waves. In such arrays the end quarter wave of each string of radiators is usually bent in to meet a similar bent quarter wave from the opposite end radiator. This provides better balance and better coupling between the upper and

Figure 48.

STACKED-DIPOLE DESIGN TABLE

BAND	FRE-QUENCY IN MC.	L₁	L₂	L₃
1.25 METERS	240	24"	24½"	12"
	232	25"	25½"	12½"
	224	26"	26½"	13"
2.5 METERS	120	4'	4' 1"	24"
	116	4' 1½"	4' 3"	25"
	112	4' 3"	4' 5"	26"
5 METERS	60	8'	8' 2"	4' 1"
	58	8' 3"	8' 6"	4' 3"
	56	8' 7"	8' 9"	4' 5"
10 METERS	30	16'	16' 5"	8' 2"
	29	16' 6"	17'	8' 6"
	28	17'	17' 7"	8' 9"
20 METERS	14.4	33' 4"	34' 2"	17'
	14.2	33' 8"	34' 7"	17' 3"
	14	34' 1"	35'	17' 6"
40 METERS	7.3	65' 10"	67' 6"	33' 9"
	7.0	68' 2"	70'	35'



HORIZONTALLY POLARIZED BARRAGE BROADSIDE ANTENNAS.

Figure 49.

lower elements when the array is current-fed. Arrays of this type are shown in figure 49, and are commonly known as Sterba or barrage arrays.

Correct length for the elements and stubs can be determined for any stacked dipole from the *Stacked-Dipole Design Table,* figure 48.

In these sketches the arrowheads represent the direction of flow of current at a given instant; the dots represent the points of maximum current and lowest impedance. All arrows should point in the *same direction* in each portion of the radiating sections of an antenna in order to provide a field *in phase* for broadside radiation. This condition is satisfied by the arrays illustrated in figure 49.

If four or more sections are used in a barrage array, the horizontal directivity will be great enough that the array can be used only over a narrow arc (in two opposite directions). For this reason such an array should be oriented with great care.

END-FIRE DIRECTIVITY

By spacing two half-wave dipoles or colinear arrays at a distance of from 0.1 to 0.25 wavelength and driving the two 180 degrees out of phase, directivity is obtained *through the two wires* at right angles to them. Hence, this type of bidirectional array is called *end fire.* A better idea of end-fire directivity can be obtained by referring to figure 44.

Remember that *end fire* refers to the radiation with *respect to the two wires* in the array, rather than with respect to the array as a whole.

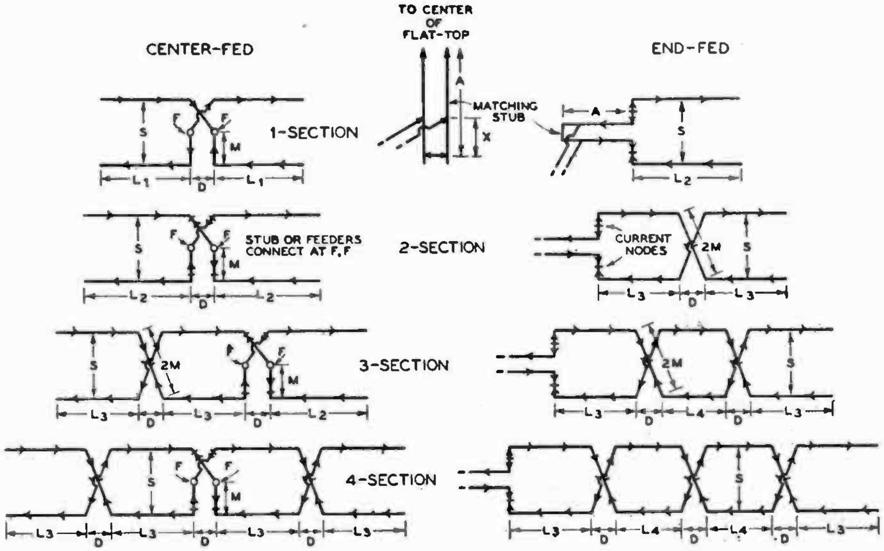
The vertical directivity of an end fire bidirectional array which is oriented horizontally can be increased by placing a similar end-fire array a half wave below it and excited in the same phase. Such an array is a combination broadside and end-fire affair. However, most arrays are made either broadside *or* end fire rather than a combination of both, though the latter are quite satisfactory if designed properly.

Kraus Flat-Top Beam

A very effective bidirectional end-fire array is the Kraus *Flat-Top Beam.* Essentially, this antenna consists of two close-spaced dipoles or colinear arrays. Because of the close spacing, it is possible to obtain the proper phase relationships in multisection flat tops by crossing the wires at the voltage loops rather than by resorting to phasing stubs. This greatly simplifies the array. (See figure 50.) Any number of sections may be used though the one- and two-section arrangements are the most popular. Little extra gain is obtained by using more than four sections, and trouble from phase shift may appear.

A center-fed single-section flat-top beam cut according to the table can be used quite successfully on its second harmonic, the pattern being similar except that it is a little sharper. The single-section array can also be used on its fourth harmonic with some success though there will then be four cloverleaf lobes, much the same as with a full-wave antenna.

FIGURE 50. FLAT-TOP BEAM DESIGN DATA.



FREQUENCY	Spacing	S	L_1	L_2	L_3	L_4	M	D	A (¼) approx.	A (½) approx.	A (¾) approx.	X approx.
7.0-7.2 Mc.	λ/8	17′4″	34′	60′	52′8″	44′	8′10″	4′	26′	60′	96′	4′
7.2-7.3	λ/8	17′0″	33′6″	59′	51′8″	43′1″	8′8″	4′	26′	59′	94′	4′
14.0-14.4	λ/8	8′8″	17′	30′	26′4″	22′	4′5″	2′	13′	30′	48′	2′
14.0-14.4	.15λ	10′5″	17′	30′	25′3″	20′	5′4″	2′	12′	29′	47′	2′
14.0-14.4	.20λ	13′11″	17′	30′	22′10″	....	7′2″	2′	10′	27′	45′	3′
14.0-14.4	λ/4	17′4″	17′	30′	20′8″	....	8′10″	2′	8′	25′	43′	4′
28.0-29.0	.15λ	5′2″	8′6″	15′	12′7″	10′	2′8″	1′6″	7′	15′	24′	1′
28.0-29.0	λ/4	8′8″	8′6″	15′	10′4″	....	4′5″	1′6″	5′	13′	22′	2′
29.0-30.0	.15λ	5′0″	8′3″	14′6″	12′2″	9′8″	2′7″	1′6″	7′	15′	23′	1′
29.0-30.0	λ/4	8′4″	8′3″	14′6″	10′0″	....	4′4″	1′6″	5′	13′	21′	2′

Dimension chart for flat-top beam antennas. The meanings of the symbols are as follows:

L_1, L_2, L_3 and L_4, the lengths of the sides of the flat-top sections as shown in figure 50. L_1 is length of the sides of single-section center-fed, L_2 single-section end-fed and 2-section center-fed, L_3 4-section center-fed and end-sections of 4-section end-fed, and L_4 middle sections of 4-section end-fed.

S, the spacing between the flat-top wires.

M, the wire length from the outside to the center of each cross-over.

D, the spacing lengthwise between sections.

A (¼), the approximate length for a quarter-wave stub.

A (½), the approximate length for a half-wave stub.

A (¾), the approximate length for a three-quarter wave stub.

X, the approximate distance above the shorting wire of the stub for the connection of a 600-ohm line. This distance, as given in the table, is approximately correct only for 2-section flat-tops.

For single-section types it will be smaller and for 3- and 4-section types will be larger.

The lengths given for a half-wave stub are applicable only to single-section center-fed flat-tops. To be certain of sufficient stub length, it is advisable to make the stub a foot or so longer than shown in the table, especially with the end-fed types. The lengths, A, are measured from the point where the stub connects to the flat-top.

Both the center and end-fed types may be used horizontally. However, where a vertical antenna is desired, the flat-tops can be turned on end. In this case, the end-fed types may be more convenient, feeding from the lower end.

The approximate gains of the different types over a half-wave comparison antenna are as follows: Single-section, 4 db; 2-section, 6 db; 3-section, 7 db; and 4-section, 8 db. These correspond to power gains of about 2.5, 4, 5, and 7, respectively.

If a flat-top beam is to be used on more than one band, it is necessary to use tuned feeders.

The radiation resistance of a flat-top beam is rather low, especially when only one section is used. This means that the voltage will be high at the voltage loops. For this reason, especially good insulators should be used for best results in wet weather.

The exact lengths for the radiating elements are not especially critical because slight deviations from the correct lengths can be compensated for in the stub or tuned feeders. Proper stub adjustment is covered on page 437. Suitable radiator lengths and approximate stub dimensions are given in the accompanying design table.

Figure 50 shows *top views* of eight types of flat-top beam antennas. The dimensions for using these antennas on different bands are given in the design table. The 7- and 28-Mc. bands are divided into two parts, but the dimensions for either the low- or high-frequency ends of these bands will be satisfactory for use over the entire band.

In any case, the antennas are tuned to the frequency used by adjusting the shorting wire on the stub or tuning the feeders if no stub is used. The data in the table may be extended to other bands or frequencies by applying the proper factor. Thus, for 56- to 58-Mc. operation, the values for 28 to 29 Mc. are divided by two.

All of the antennas have a bidirectional horizontal pattern on their fundamental frequency. The maximum signal is broadside to the flat top. The single-section type has this pattern on both its fundamental frequency and second harmonic. The other types have four main lobes of radiation on the second and higher harmonics. The nominal gains of the different types over a half-wave comparison antenna are as follows: Single-section, 4 db; 2-section, 6 db; 3-section, 7 db; 4-section, 8 db.

The current directions on the antennas at any given instant are shown by the arrows on the wires in the figure. The voltage maximum points, where the current reverses phase, are indicated by small X's on the wires.

The maximum spacings given make the beams less critical in their adjustment. Up to one-quarter wave spacing may be used on the fundamental for the 1-section types and also the 2-section center-fed, but it is not desirable to use more than 0.15 wavelength spacing for the other types.

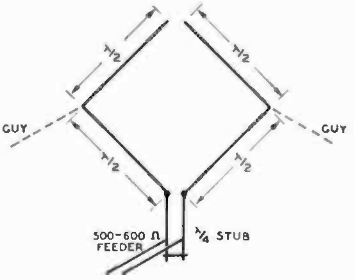


Figure 51.

THE BI-SQUARE ARRAY.

This system shows considerable gain for so simple an array. It can be hung from a single pole, is used mostly for 28-Mc. work. It gives low angle radiation with a fairly broad horizontal pattern.

Although the center-fed type of flat top is generally to be preferred because of its symmetry, the end-fed type is often convenient or desirable. For example, when a flat-top beam is used vertically, feeding from the lower end is in most cases more convenient.

If a multisection flat-top array is end-fed instead of center-fed and tuned feeders are used, stations off the ends of the array can be worked by tying the feeders together and working the whole affair, feeders and all, as a long-wire harmonic antenna. A single-pole double-throw switch can be used for changing the feeders and directivity.

Bi-Square Beam

Four dipoles can be formed into the shape of a square as in figure 51 to produce a broadside radiator that has characteristics similar to the lazy-H stacked colinear array except for slightly less directivity.

The array can be supported from a single pole, and makes an excellent 10-meter array when moderate gain and directivity are desired. The dimensions for the 28-Mc. band are as follows: Each leg, 17 ft.; stub, 8 ft. to 8 ft. 6 in. The array has a broad resonance peak, and when adjusted for the middle of the band can be used over the whole band. Exact adjustment of the shorting bar and position of the feeder attachment to the stub can be obtained by following the general procedure given for adjustment of shorted stubs, page 436. A crystal that hits the center of the band should be used during the stub adjustment procedure. Exact length of the radiator elements is not particularly critical because proper adjustment of the shorting bar will compensate for small errors in radiator length.

The radiation is horizontally polarized and bidirectional, maximum radiation occurring at *right angles* to the plane of the radiator square.

Unidirectional Arrays

If two dipoles or colinear arrays are not exactly 0 or 180 degrees out of phase, the pattern becomes unsymmetrical. For certain phasing combinations and spacings, a very good unidirectional pattern is obtained. The required odd values of phasing can be obtained by cutting a parasitically driven element so as to present just the right amount of reactance. Whether the parasitic element acts as a director or reflector depends upon whether the reactance is inductive or capacitive. A parasitic reflector is made just a little longer than an electrical half wavelength, and a director a little shorter than an electrical half wave.

The presence of one or more parasitic elements affects the driven element itself, introducing some reactance so that slight compensation in the physical length is necessary for resonance. The presence of parasitic elements also reduces the radiation resistance; the more elements, the lower the radiation resistance. Reducing the spacing between the driven dipole and parasitic elements further reduces the radiation resistance.

The older data by Yagi on the parasitically operated director-reflector array called for quarter-wave spacing for the back reflector, half-wave spacing for side reflectors if any and three-eighths-wave spacing for directors. Subsequent work by Brown indicates the desirability of considerably closer spacing for both directors and the back reflector. Spacings of 0.1 to 0.125 wavelength are highly satisfactory for either a director or reflector.

The phasing adjustment (length of parasitic elements) is quite critical with respect to frequency, and can best be accomplished by cut-and-try and the help of a field strength meter. This is especially true when more than one parasitic element is utilized. It will be found that the adjustment which gives the best forward gain is not the same as that which gives best front to back discrimination, though they are approximately the same.

If only one parasitic element is used, the nose of the directivity pattern will be quite broad though the front-to-back radiation ratio will be quite high. The pattern resembles a valentine heart except that the tip is rounded instead of pointed. If the phasing is adjusted for maximum forward gain rather than maximum discrimination, a small lobe in the backward direction will appear and the nose of the main lobe will be slightly sharper.

The foregoing applies to the horizontal directivity when the driven and parasitic dipoles are *vertical.* When the dipoles are orientated *horizontally,* as in most amateur applications for wavelengths above 5 meters, the pattern is somewhat different, the horizontal directivity *depending upon the vertical angle of radiation.* The horizontal directivity is greatest for low vertical angles of radiation when the dipoles are oriented horizontally. For this reason, such an array will exhibit greater discrimination on 10 meters than on 40 meters, for instance.

A close-spaced parasitic director or reflector will lower the radiation resistance of the driven element. If two parasitic elements are used, the radiation resistance will be lowered still more. Consequently, the voltage at the ends of the dipoles of such an array is high and good insulation is essential, not only because of loss but because the phasing will be affected by wet weather if poor insulators are used at the high voltage points. Self-supporting quarter-wave rods permit construction of 10- and 20-meter arrays of this type without the need for insulators.

The low radiation resistance makes the problem of current (center) feed quite difficult. Twisted pair or concentric line cannot be used without incorporating a matching transformer. A linear transformer of tubing (Q section) cannot be practically designed to have a low enough surge impedance to match a 600-ohm line. A *simple* feed method that is satisfactory is a delta-matched open-wire line of from 400 to 600 ohms. The feeder should be fanned out and attached a short distance each side of the center of the driven dipole. The feeders should be slid back and forth equidistant from the center until standing waves on the line are at a minimum.

A horizontal driven dipole and close-spaced director or director and reflector are commonly used as a rotatable array on 10 and 20 meters; such an arrangement is discussed at length later in this chapter.

ORIENTATION OF BEAM ANTENNAS

Directive antennas, especially those sharp enough to give a large effective power gain, should be so oriented that the line or lines of maximum radiation fall in the desired direction or directions.

To do this, the direction of *true north* must be known with reasonable accuracy. This may vary in the United States by as much as 20 degrees from magnetic north as indicated by a compass.

The magnetic declination (variation of magnetic north in degrees east or west of true north) for your locality can be obtained by referring to a map compiled by the U. S. Coast and Geodetic Survey and available from the Superintendent of Documents, Washington, D. C. The number of the map is 3077 and it is sent only on receipt of 20 cents in *coin*.

A simpler method of determining your declination is to inquire of your city engineers or any surveyor or civil engineer in your locality. Any amateur astronomer can also help you to determine the direction of true north.

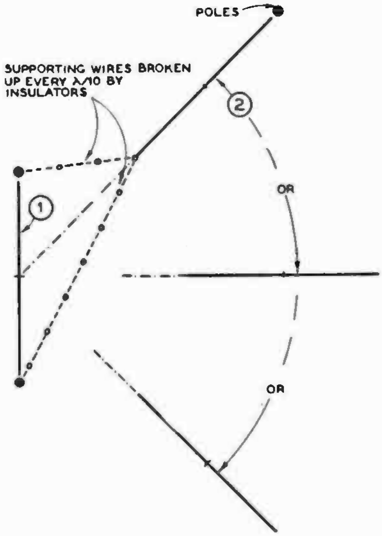


Figure 52.

Illustrating how two dipoles or arrays with horizontal elements can be supported from three poles with a minimum of coupling between the two systems. This is an important consideration if maximum directivity is desired.

The next problem is to determine the *great circle* direction of the country at which you wish to aim your beam, as this is the path taken by radio signals to a distant point. This can be done with great accuracy by means of spherical trigonometry, but the method is rather involved and requires a set of tables and considerable calculation. A simpler method is to stretch a thread from the corresponding two points on a large globe of the world (not a cheap one—they are often inaccurate).

Great circle maps, as given in the RADIO ANTENNA HANDBOOK, can also be used to determine the direction in which a beam antenna should be aimed to hit a certain area or spot.

Coupling Between Antennas

If two dipoles or bidirectional arrays are used to cover four directions, one will excite the other as a result of electrostatic and electromagnetic coupling *unless* they are well separated or care is taken in their orientation. This mutual coupling will result in decreased directivity and a slight loss in gain.

To minimize coupling between two horizontally polarized arrays resonant on the same band, they should be oriented so that a line extended through one of them can be made to intersect the center of the other array. This is illustrated in figure 52. To eliminate the necessity for four poles, antenna no. 2 is supported at one end by means of a "V" branching out to both of the other two poles. These two wires should be broken up thoroughly with insulators every few feet as they are right in the field of array or antenna no. 1.

ROTATABLE ARRAYS

The amateur confined to an apartment top or a small city lot is at a marked disadvantage when it comes to erecting antennas that will lay down a strong signal at distant points. Even at 10 and 20 meters it is difficult to string up arrays for various points of the compass without more ground space than is available to the average city amateur. And if the arrays are not placed just right or separated sufficiently, there will be coupling from one array to another, resulting in poor discrimination and directivity. As a result, the city amateur oftentimes turns to a rotatable affair, one which takes up but little ground space and can be aimed in the desired direction.

UNIDIRECTIONAL ROTARY ARRAYS

An effective unidirectional array which is small enough to be rotated without too much difficulty consists of a horizontal dipole and close-spaced parasitic reflector and director.

The use of two parasitic elements instead of one adds little to the mechanical difficulties of rotation, and the gain and discrimination (especially the latter) are considerably improved over that obtained with a single director or a single reflector instead of a combination of both. The three-element Brown array using a close-spaced director, driven element, and close-spaced reflector will exhibit as much as 30 db front-to-back ratio and 20 db front-to-side ratio for *low angle radiation*. The theoretical gain is approximately 8 db over a dipole in free space. In actual practice the array will usually show 10 db or more gain over a horizontal dipole of the same height above ground (at 28 and 14 Mc.).

There is little to be gained by using more than three elements (one driven and two parasitic). The gain and discrimination are improved very little, and the radiation resistance becomes somewhat low for good efficiency.

There is little to choose as regards the exact spacing of the parasitic elements. Any spacing from 0.1 to 0.15 wavelength may be used for either the director or reflector. However, changes in the spacing will call for slightly different parasitic element lengths. The chart of figure 53 is based on a director spacing of 0.15 wavelength and reflector spacing of 0.1 wavelength; therefore *these spacings must be used if the chart is to be relied upon.*

While the elements may consist of wire supported on a wood framework, self-supporting elements of tubing are to be preferred. The latter type array is easier to construct, looks better, is no more expensive, and avoids the problem of getting sufficiently good insulation at the ends of the elements. The voltages reach such high values towards the ends of the elements that losses will be excessive unless the insulation is excellent.

The elements may be fabricated of thin-walled steel conduit, hard drawn thin-walled copper tubing, or duralumin tubing. Or, if you prefer, you may pur-

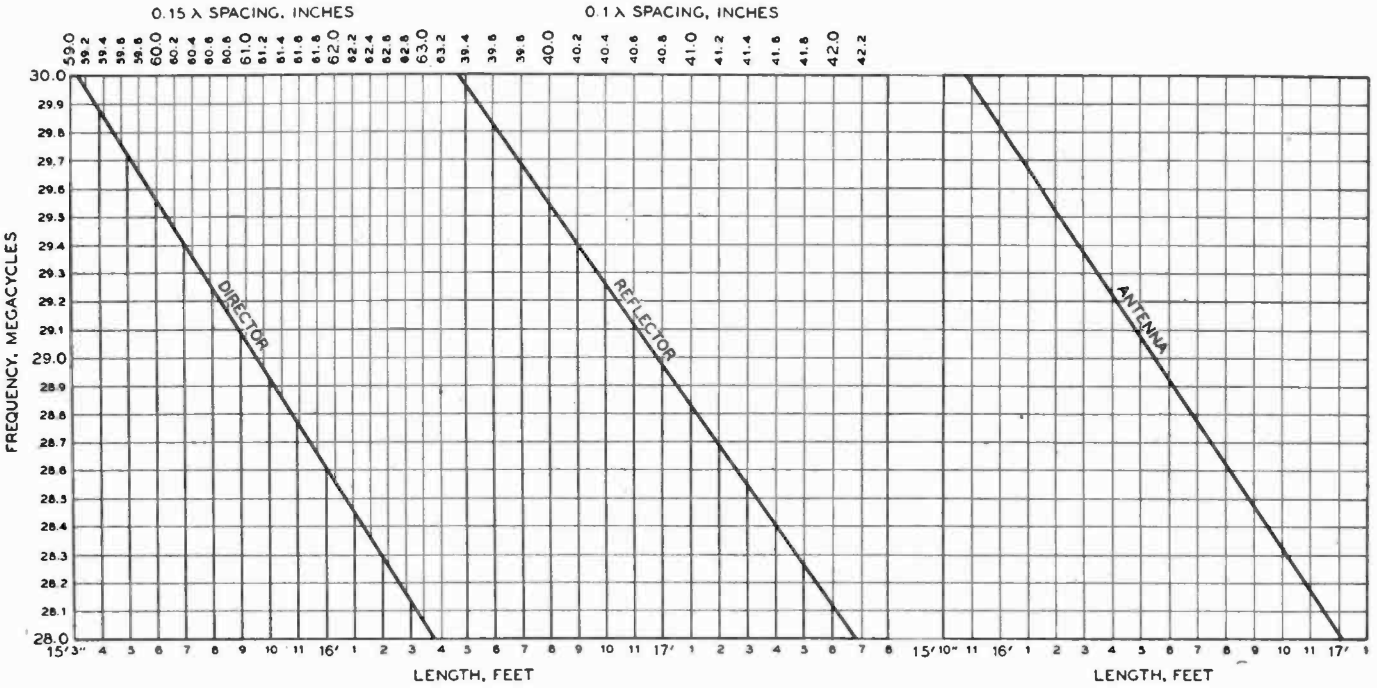


Figure 53.

DIMENSION CHART FOR BROWN THREE-ELEMENT CLOSE-SPACED ARRAY.

While it should be realized that for maximum directivity it is advisable to adjust the parasitic elements individually in each installation, many amateurs seem reluctant to prune the elements and prefer to put up their array "ready cut" with the assurance that the dimensions will be sufficiently accurate to give good results. For the benefit of these amateurs the accompanying chart is given. The chart can be used for determining dimensions of a 20-meter array by dividing the frequency by 2 and multiplying the dimensions by the same factor. The director and reflector lengths apply only when 0.15 wavelength spacing is used for the director and 0.1 wavelength spacing for the reflector.

chase tapered copper plated steel tubing elements designed especially for the purpose at only slightly greater expense. In fact, several kits are available complete with rotating mechanism and direction indicator for those who desire to purchase the whole "works" ready to put up.

The radiation resistance of a close-spaced three-element array is quite low, in the vicinity of 10 ohms. Likewise the Q is high, which means that the array is selective as to frequency. This is perhaps the only important disadvantage of the array; it works much better on the exact frequency for which it was cut, the gain and discrimination falling off considerably a few per cent either side of resonance.

Because of the high Q and close spacing, it is desirable to use tubing of sufficient diameter that it doesn't whip about appreciably in the wind, as any change in spacing will produce considerable detuning effect.

The self-supporting elements are usually supported on husky standoff insulators mounted on a wooded cross arm of the type illustrated in figure 54. The voltage at these points is relatively low, but large insulators are used for reasons of mechanical strength. The length of each parasitic element is usually made adjustable by means of at least one sliding telescopic joint on either side of center.

The optimum length for the parasitic elements for a given frequency can best be determined by setting the array temporarily as high above the ground as can be reached conveniently from a ladder or fence. Then, with a local amateur to give you a check (his receiver must have an "R" meter) adjust the parasitic elements for the best gain. After this point has been found, shorten the director 1% and lengthen the reflector 1%. This improves the discrimination slightly without reducing the gain appreciably, and makes the array tune more broadly.

Feed Methods

The problem of feeding a three-element unidirectional array is complicated not only by the problem of rotating, but also by the low radiation resistance. Special low impedance, flexible coaxial cable with built-in quarter-wave matching section for impedances of this order (10-14 ohms) is available for the purpose, and can be used where the line length is not unduly long. Such cable is simply attached to the center of the driven element, which is split for this type of feed in the same manner as a doublet antenna.

For long line lengths, an open wire line is advisable in the interest of low losses. This type line may be delta matched to the driven element the same as for a delta matched doublet, except that the points of attachment to the driven element will not be the same as for a simple dipole. The feeder wires are simply fanned out until standing waves are at a minimum. This type of feed does not permit quite as good dis-

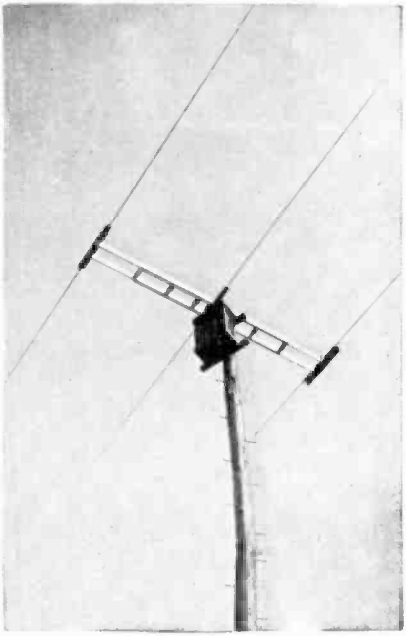


Figure 54.

TYPICAL INSTALLATION OF 3 ELEMENT CLOSE-SPACE ARRAY

This particular 14-Mc. unidirectional array uses 0.15 wavelength spacing for both director and reflector.

crimination, as there is a slight amount of radiation from the fanned out portion of the line, and the director and reflector have little effect on this radiation.

Flexible coaxial line may be allowed to dangle against the supporting tower or guy wires or most anything without harm, but an open line must be kept from touching anything or twisting on itself and shorting out. This problem is often solved by the incorporation of slip rings and brushes. Not only does this avoid whipping feeders, but permits continuous rotation. Neither voltage nor current is high for a given power at an impedance of 400 to 600 ohms, and there will be little loss in slip rings working at this impedence if they are carefully constructed.

Rotolink Feed

The Smith "Rotolink" method of feed for a close-spaced three-element array is illustrated in figure 55. The system allows continuous rotation, has no wiping contacts, and uses an open-wire line in order to keep line losses low even for long line lengths.

Two one-turn links of ¼-inch copper tubing are placed around the shaft that supports and drives the wood superstructure, and are separated by approximately 1 inch. The upper ring is fastened by means of standoff insulators either to the shaft or to the superstructure, so that it rotates with the array. The lower ring is supported by means of insulators fastened to the top of the supporting tower, or pole.

Each ring is 7 inches in diameter, with a gap of ¾ to 1 inch. The ends of the upper ring connect to the driven element by means of a section of low impedance line which matches the radiation resistance of the driven element. This requires a short line of 10-12 ohms surge impedance. This impedance can be readily obtained by twisting together two lengths of Bassett rubber-covered 28-ohm flexible concentric cable, and paralleling the two by *cross connecting* them as in figure 55.

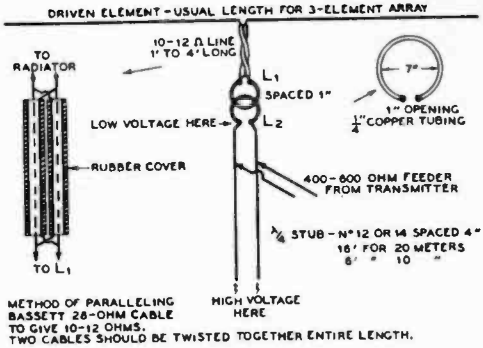


Figure 55.
ROTOLINK FEED OF THREE ELEMENT ARRAY.
Inductive coupling by means of one turn links around the supporting shaft permits continuous rotation without sliding contacts.

Connecting the two centers together and two outsides together would cut the surge impedance in half; but by connecting the *inner* conductor of each cable to the *outer* conductor of the other, the surge impedence is reduced still further, because the two outside conductors then are of opposite polarity and phase, and act as two close-spaced Q bars separated by a rubber dielectric. This brings the surge impedance down to the desired value of 10-12 ohms.

The ends of the lower ring are connected to a quarter-wave stub which is run down the side of the supporting pole or tower. The exact length of the stub, to the point at which it attaches to the gap in the lower ring, is given in the diagram. The upper end of the stub should be fanned for a distance of about 1 foot from the point of attachment to the lower ring. In other words, the line is spaced 1 inch when it leaves the ring, and is gradually fanned out to 4 inches. The voltage at the bottom of the stub will be quite high, and good insulation should be used (the less insulation the better). If more than 500 watts power is used, it is advisable to space the bottom half of the stub 6 inches instead of 4 inches, thus lengthening the leakage path of the spreaders where the voltage is highest.

After the spacing between L_1 and L_2 is adjusted to the closest value which will permit complete rotation without their touching at any point, merely slide the feed line up and down the stub until standing waves on the line are at a minimum.

W8JK ROTARY ARRAY

The Kraus "Flat-Top Beam" is often used as a rotary antenna because of its ability to work on two bands when tuned feeders are used. A single-section 14-Mc. flat-top beam can be used as a two-section 28-Mc. array of the same type. Because the antenna must be fed current on the low-frequency band and voltage on the high-frequency band, an untuned line is not practicable. Therefore a tuned line consisting of no. 12 or no. 14 wire spaced 6 inches is advised for two-band operation.

The problem of the open line whipping about is simplified by the fact that the array is bidirectional, thus requiring only 180 degree rotation instead of 360 degree rotation.

17-foot self-supporting rods are a standard size and therefore a two-band flat-top beam for 10 and 20 meters is usually made with 34-foot elements, four 17-foot rods being utilized. The spacing is not critical, 7 or 8 feet being common.

Further details are covered earlier in this chapter under *Flat-Top Beam.* The same considerations apply for a rotatable array as for a stationary one.

ROTATING MECHANISMS

There are many solutions to the mechanical problem of rotating an array of either of the two types described. The most common system consists of a tower or else a pole of the "telephone" variety atop which is an assembly consisting of bearings and driveshaft assembly, the latter supporting a superstructure of wood, which in turn supports the radiating elements.

A simple rotating and drive mechanism for a 10-meter array can be made from a grinding head or saw mandrel mounted vertically atop the pole or tower. A 20-meter array will require something stronger, an automobile rear axle and housing from a junk dealer serving nicely after being operated on a bit if the tower or pole will support the weight. The "rear end" of a small car such as an Austin is to be preferred to heavier ones.

If a custom made assembly is desired, suitable gears and bearings and pulleys may be obtained from the *Boston Gear Works* at reasonable prices.

Another system that has found favor calls for the whole tower's being mounted on a thrust bearing, the entire mast turning inside a large, guyed bearing near the top of the mast.

The cheapest method of rotating the array from the operating position is by means of ropes and pulleys, but motor drive is highly desirable if one can afford such an installation. Sometimes the motor is placed atop the pole; sometimes it is placed part way down or at the bottom.

The drive motor must be geared down so that the array turns at a speed of from 1 to 2 r.p.m. The motor and gear reduction assembly from a large oscillating fan can be used to rotate most any array, as the torque developed by a small motor is quite high with a gear ratio giving a speed of 1 r.p.m. The oscillating gear shaft on most oscillating fans turns at about 6 r.p.m. and this can easily be stepped down to 1 or 2 r.p.m. by means of a large and a small pulley or a bicycle sprocket and chain.

Two Selsyn type motors make the nicest control system, but any small reversible motor is almost as satisfactory. If the feed line to the array is not designed for continuous rotation, an automatic stop should be provided to prevent damage to the feeders.

If pulleys and belt drive are used, the tension of the belt can be adjusted so that it slips on the pulley when the array hits the "stop", thus preventing damage to both feeders and motor.

DIRECTION INDICATOR

Some means must be provided whereby the operator can tell from the operating position the direction in which the array is "aimed". A simple but highly effective indicating device requiring only three wires between array and operator can be constructed as follows:

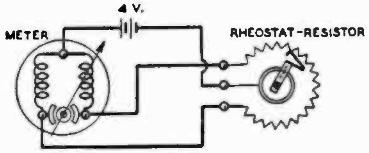


Figure 56.

GASOLINE GAUGE DIRECTION INDICATOR.

The type gasoline gauge required can be purchased reasonably at most any junk yard. It gives an accurate indication of the direction in which the array is pointed after once calibrated.

From an automobile junk yard, procure a panel type gasoline gauge from a car of '26 to '28 vintage, complete with the potentiometer that goes in the gas tank. Be sure to get the type having *three* contacts on it. It is preferable that both meter and resistor be from the same make car. The La Salle ('27 and '28 model) is one of the several makes of this era having this type gas gauge.

The three-contact meter is a balanced coil affair, and gives a highly accurate indication that is not affected appreciably by battery deterioration.

File open the case to the resistor unit from the tank and take out the brush and resistor-rheostat affair. Bend the resistor into a complete circle and shorten the brush arm to turn inside it. The resistors are originally built to turn 270 degrees and usually are in the vicinity of 150 ohms.

Attach the reassembled unit to your mast in any way you see fit. Adjust the brush so that it contacts the resistor in the direction from center that your antenna points. Then calibrate your meter to match these cut and tried points. To calibrate, just remove the meter face and turn it over. Paint on any calibration you want.

The meter will work best on 3 to 4½ volts. An ordinary "C" battery will serve nicely, as the current drain is only 20 or 30 ma.

In case the meter doesn't allow enough scale to satisfy you, mount the works in an old alarm clock case—or something similar—and paint the glass black except through where the scale will be read. Glue onto the original needle a small broom straw, previously dipped in ink, and you can have as much scale as you like. Be sure to allow a little overlap of the straw at the bottom of the needle for counterbalance, as this type meter has no counterbalance spring.

U. H. F. ANTENNAS

(See Also Chapter 16)

Antenna Requirements

The only difference between the antennas for ultra-high-frequency operation as compared with those for operation in other bands is in their physical size. The fundamental principles are unchanged.

Many types of antenna systems can be used for u.h.f. communication. Simple nondirective half-wave vertical antennas are popular for general transmission and reception in all directions. Point-to-point communication is most economically accomplished by means of directional antennas which confine the energy to a narrow beam in the desired direction. If the power is concentrated into a narrow beam, the *apparent* power of the transmitter is increased a great many times.

The useful portion of a signal in the u.h.f. region for short-range communication is that which is radiated in a direction *parallel to the surface of the earth*. A vertical antenna transmits a wave of low angle radiation and is effective for this reason, not because the radiation is vertically polarized.

Horizontal antennas can be used for receiving, with some reduction in noise.

At points close to a transmitter using a vertical antenna, signals will be louder on a vertical receiving antenna. However, at distances far enough from the transmitter that the signal begins to get weak, the transmitted wave has no specific polarization and will appear approximately equal in signal strength on either a vertical or horizontal receiving antenna.

When used for transmitting, horizontal antennas radiate off the ends (in line with the wire) at too high a vertical angle to be effective for quasi-optical u.h.f. work. In fact, even the broadside radiation will be mostly at excessively high angles unless the antenna is far removed from earth (10 or more wavelengths). However, by using several horizontal elements in an array which concentrates the radiation at low angles, results as good or better than with vertically polarized arrays of the same type will be obtained.

The antenna system for either transmitting or receiving should be as high above earth as possible and clear of nearby objects. Transmission lines, consisting of concentric lines or spaced two-wire lines, can be used to couple the antenna system to the transmitter or receiver. Nonresonant transmission lines are more efficient at these frequencies than those of the resonant type.

Open lines should preferably be spaced closer than is common for longer wavelengths, as 6 inches is an appreciable fraction of a wavelength at 2½ and 5 meters. Radiation from the line will be minimized if 2-inch spacing is used rather than the more common 6-inch spacing.

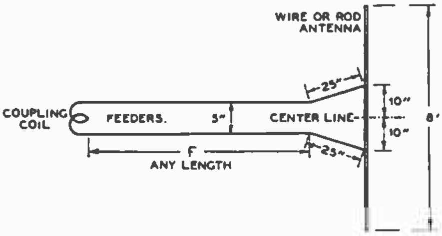


Figure 57.

5-METER MATCHED-IMPEDANCE ANTENNA.

For 2½ meters divide all dimensions by 2. For feed line use no. 18 spaced 2 inches on both bands.

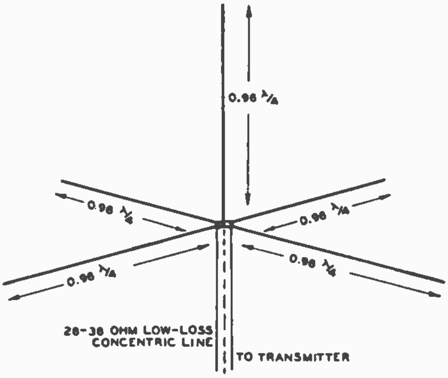


Figure 58.

LOW ANGLE RADIATOR FOR GENERAL COVERAGE U.H.F. WORK.

With this type of radiator there can be no distortion of the radiation pattern by radiation of the feed system.

It is possible to construct quite elaborate u.h.f. directive arrays in a small space; even multi-element beams are compact enough to permit rotation. For this reason, it is more common to employ directional 5-meter arrays to obtain a strong transmitted signal than to resort to high power. Any of the arrays described in the section on directive antenna arrays can be used on 5 meters or 2½ meters, though those with sharp, low angle vertical directivity will give the best results. Of the simpler types of arrays, those with their dipole elements vertical give the lower angle of radiation, and are to be preferred. When a multi-element stacked dipole curtain is used, little difference is noticed between vertical and horizontal orientation.

Effect of Feed System on Radiation

A vertical radiator for general coverage u.h.f. use should be made either ¼ or ½ wavelength long. Longer antennas do not have their maximum radiation at right angles to the line of the radiator

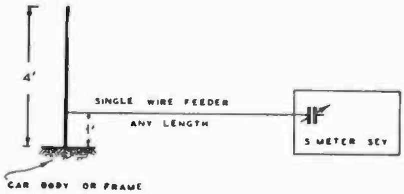


Figure 59.

SIMPLE 5-METER AUTO ANTENNA.

For 2½ meters divide dimensions by 2. Feeder should be kept at least 1 inch from car body.

(unless co-phased) and therefore are not practicable for use where greatest possible radiation parallel to the earth is desired.

Unfortunately a feed system which is not perfectly balanced and does some radiating not only robs the antenna itself of that much power, but *distorts the radiation pattern of the antenna.* As a result, the pattern of a vertical radiator may be so altered that the radiation is bent upwards slightly and the amount of power leaving the antenna *parallel to the earth* is greatly reduced. A vertical half-wave radiator fed at the bottom by a quarter-wave stub is a good example of this; the slight radiation from the matching section due to the phase unbalance resulting from the "floating" feeders decreases the power radiated parallel to the earth by nearly 10 db.

The only cure is a feed system which does not disturb the radiation pattern of the antenna. Such a system is illustrated in figure 58. The four horizontal quarter-wave radials act as a perfect earth for the quarter-wave vertical radiator, which is fed by means of a concentric line coming up "out of the ground."

In actual practice the antenna would consist of a quarter-wave rod mounted by means of insulators atop a pole or pipe mast. Elaborate insulation is not required, as the voltage at the lower end of the quarter-wave radiator is very low. Self-supporting quarter-wave rods would be extended out as in the illustration and connected together. As the point of connection is effectively at ground potential, no insulation is required; the horizontal rods may be bolted directly to the supporting pole or mast, even if of metal. The concentric line should be of the low loss type especially designed for u.h.f. use. The outside connects to the junction of the radials and the inside to the bottom end of the vertical radiator.

MOBILE U.H.F. ANTENNAS

For 2¼- and 5-meter mobile work, the b.c.l. "whip" or "fishpole" auto antennas are highly satisfactory. Either a quarter wavelength may be used as a Marconi against the car body, or a half wavelength may be used as a vertical dipole. The latter, while delivering a stronger signal, must be very well insulated at the base.

The Marconi type may be fed either with a single wire feeder tapped 28% up from the base or by means of coaxial or twisted-pair line. Coaxial line constructed of copper tubing, with ceramic or polystyrene centering spacers holding the inner conductor, has the lowest loss. If single-wire feed is used, the Marconi antenna need not be insulated at the base. If coaxial line is used, a base insulator is necessary. However, the voltage at the base of a Marconi is quite low, and the insulation provided on commercially available b.c.l. fishpoles is adequate.

The coaxial line is connected across the base insulator; no tuning provision need be provided. If the radiator is of the telescoping type, the length may be adjusted for maximum field strength.

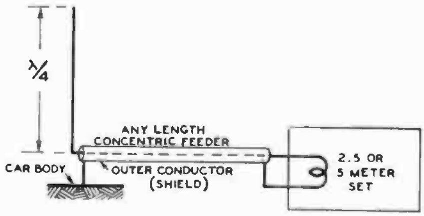


Figure 60.

CONCENTRIC LINE FED U.H.F. AUTO ANTENNA.

Coaxial line may be coupled to the transmitter or receiver by means of a one- or two-turn link.

The losses in twisted-pair and *rubber-insulated* coaxial lines are relatively high at 5 meters; but because only a short length is ordinarily required in a mobile installation, such a line is quite often used when the feeder must be run conveniently and inconspicuously.

COMPACT ANTENNAS

Oftentimes on the lower frequency bands it is necessary because of space restrictions to use a compromise antenna, an antenna that has been folded or otherwise physically shortened to take up less room than required for a conventional antenna of that frequency. Naturally a constricted antenna will not have as high efficiency, but by going about the problem scientifically it is possible to reduce the size of an antenna with very little sacrifice in efficiency.

Difficulty in getting up enough antenna is confined primarily to the 80- and 160-meter bands, but some amateurs are so cramped for space or are so hampered by a disapproving landlord that it is impossible to get a 40-meter doublet high enough in the air to give low angle radiation. For dx work, requiring a low vertical angle of radiation, a horizontal antenna should be at least a half wavelength above *effective earth*. In the average backyard this means 70- or 75-foot poles for 40 meters. As mentioned above these are not always feasible.

If you are so handicapped, the u.h.f. antenna illustrated in figure 58 can be used with surprisingly good results for 40-meter dx. Because the four horizontal radials act as a highly effective ground, the antenna does not display the loss in efficiency common to vertical radiators over average soil. The vertical element may be of thin-walled steel conduit mounted on the peak of the roof or atop a 15-foot pole placed in the yard. A 34-foot length of such tubing rising 50 feet or so in the air is much less obtrusive than a pair of 70-foot poles. Any guy wires supporting the vertical element should be well broken up with insulators.

Oftentimes it is possible to get the necessary height for a horizontal antenna on 40, 80, or 160 meters, but not the necessary linear span. As the major portion of the radiation from a dipole is from the center half of the dipole, the ends may be bent downward with little effect upon the efficiency and radiation pattern. As much as ⅛ wavelength at each end of a half-wave dipole may be bent or allowed to hang down if it is necessary in order to get the antenna to fit the span between poles. For the sake of electrical symmetry, it is desirable that the radiator be bent the same amount at each end.

As an example, suppose we would like to string a 130-foot dipole (for 80-meter operation) between two 50-foot poles 90 feet apart. We have 40 feet too much wire; so we shall bend down 20 feet at each end of the dipole. Each bent portion (20 feet) is less than the height of the poles; so there will be no difficulty on that score. The total bent portion (40 feet) is less than half the total length of the radiators; so the efficiency will still be high.

Multi-Wire Doublets on Half-Frequency

If we bend down the ends of a half-wave dipole until the bent portion at each end is an eighth wavelength long, leaving the flat top a quarter wavelength long, we have an antenna of the type just discussed. If we carry the bending process further and bend the ends not only downwards but back in towards the center, we have something that resembles a multi-wire doublet designed for the next higher frequency band. Thus we see that a multi-wire half-wave doublet antenna (page 479) can be used as a *folded* antenna on *half* frequency. The feed line is no longer an untuned feeder, but rather a zepp feed system feeding both ends of the antenna at once. This is possible because the two ends of a dipole are of opposite polarity and phase.

A folded antenna of this type, instead of having very high radiation resistance like a multi-wire doublet system, will have rather low radiation resistance. However it is still sufficiently high to give good radiation efficiency. The folding of the antenna does not cancel the radiation because the current is so much greater in the main portion of the antenna than in the ends which are bent in toward the center, and also because the currents in the parallel wires are less than 180 degrees out of phase.

Loading Coils

An old and still popular method of increasing the electrical length of a wire is by means of a *loading coil.* The customary procedure is to place a loading coil at the current loop (center of a dipole or ground lead of a Marconi) and vary the inductance by means of taps until the desired lengthening effect is obtained.

However, the most desirable place for a loading coil is *not* at the *current loop* but towards the end (voltage loop) of the radiator. If the coil were placed at the extreme end of the antenna, it would have little loading effect, as there would be no current flowing through it. So the coil is placed about 1/20 wavelength from the end (or ends in the case of a dipole) instead of at the current loop. Thus we see that while a Marconi will still require only one loading coil, a dipole will require two for end loading.

As an example of the desirability of end loading, let's look at a vertical Marconi as used in broadcast work. It has been found that an eighth wavelength vertical radiator loaded to an electrical quarter wavelength by means of a loading coil at the bottom or current loop has a radiation resistance of only 4 or 5 ohms instead of the usual 36 ohms attributed to a quarter-wavelength vertical Marconi.

If we move the loading coil up nearly to the top of the radiator and add more turns to the coil to compensate for the decreased current flowing through the coil, we find that the antenna now has a radiation resistance of around 20 or 25 ohms. In both cases the physical height of the radiator is an eighth wavelength; merely by moving the position of the loading coil we have increased the radiation resistance about five times.

The exact position of the coil is not critical; approximately 1/20th wavelength from the far end of a Marconi is a good place for the coil. As previously mentioned, the coil must have considerably more turns to effect resonance than if it were placed at the current loop.

As it is difficult to make adjustments to the coil when it is placed towards the far end of the antenna, the loading coil for an end loaded Marconi is usually wound with somewhat more than the required turns and resonance found by means of a series condenser in the ground lead. This eliminates the necessity for taking the coil down several times to get precisely the right amount of inductance for resonance at the operating frequency. The series condenser also allows one to adjust the antenna for maximum efficiency over the entire band.

The loading coil will be exposed to the weather and hence this should be taken into consideration. No. 14 outside house wire scramble wound on a 1-foot diameter and held in place with tire tape will serve nicely. The exact amount of wire required is difficult to calculate, but it will usually be somewhat more than the amount the radiator (including ground lead) lacks being a quarter wavelength.

The Multee Antenna

An antenna that works well on both 75 and 160 meters and is sufficiently compact to permit erection on the aver-

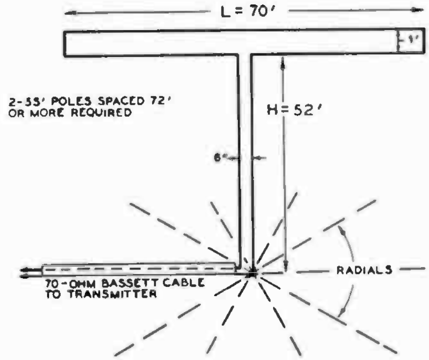


Figure 61.

MULTEE TWO-BAND ANTENNA.

This compact antenna can be used with excellent results on both 75 and 160 meters. On 160 meters the efficiency compares favorably with that obtained from a 122-foot vertical radiator.

age city lot is the Smith *Multee* antenna illustrated in figure 61.

On 160 meters the antenna is nearly as efficient as a 122-foot vertical radiator. Practically all the radiating on this band is done by the vertical portion.

In the average amateur Marconi installation a good portion of the radiation is from the ground lead, which often runs 20 or 30 feet before it finally reaches actual ground. As this wire is usually close to the earth, it is not a very effective radiator. In the antenna of figure 61, the heavy current portion starts immediately skyward where it can do some effective radiating, without first running considerable distance to the transmitter and back.

Essentially the antenna (as a 160-meter Marconi) evolves from a vertical 122-foot two-wire radiator, fed in just one wire in order to increase further the terminal radiation resistance. The top portion does little radiating; so we squash it down as in the diagram with no ill effects except to lower the terminal radiation resistance slightly to a value of around 70 ohms, which matches the concentric feed line.

The earth below a vertical radiator must be of good conductivity not only to provide a low resistance ground connection, but also to provide a good reflecting surface for the waves radiated downward toward the ground. As the current loop of a Marconi is right at the ground rather than a quarter wavelength above earth, the radials shown in the diagram need not extend out as far to provide a reflecting surface as would be the case for an antenna where most of the radiation was from the center rather than from the lower end.

Thus, while a large number of radials is still desirable (the more the better) they need not extend out the 0.3 wavelength that broadcast stations have found advisable for half-wave radiators. 50-foot radials will be satisfactory, and there is little point in increasing their length to more than 100 feet. 20 radials 50 feet in length or 10 radials about 100 feet in length of no. 16 or larger copper wire buried just below the surface of the soil (about 6 inches) will do an excellent job. While an ordinary water-pipe ground system with no radials may be used, a system of radials will provide a worthwhile increase in field strength.

The length L can be cut down by making H correspondingly greater. If L is shortened a foot, H should be increased by the same distance. Thus if L is made 65 feet, H should be 57 feet. In no case, however, should H be made less than 52 feet if best efficiency is desired. Likewise, L should not be made less than about 60 feet if the antenna is to be used on 75 meters, for reasons which soon will be apparent.

On 75 meters the *flat top* does the radiating rather than the vertical portion. The radiating portion is a half-wave doublet folded back on itself, fed by means of a quarter-wave (Q) linear transformer. The operation will be more clear if L and H are both made 61 feet for the purpose of this discussion. We have a 122-foot radiator with ends folded back on themselves to take up 61 feet, the ends being fed by means of a 600-ohm Q section 61 feet long. Thus the (approximately) 6000-ohm antenna impedance is transformed by the 600-ohm matching section to a value approaching

70 ohms, the surge impedance of the concentric cable. Because the impedance at that point is low, it does not upset the symmetry of the system to leave the outer conductor of the far end of the cable grounded to the midpoint of the radials.

Because this antenna works equally well on both 75 and 160 meters with no changes or alterations whatsoever, care must be taken when operating on 160 meters to see that no 75-meter harmonic is radiated. It is advisable to use a push-pull output stage and moderately high "C" in the output tank to minimize generation of harmonics. If a check reveals appreciable second harmonic radiation, a harmonic suppression trap should be incorporated (see *harmonic suppression*).

RECEIVING ANTENNAS

A receiving antenna should feed as much signal and as little noise—both man-made and atmospheric—to the receiver as possible. Placing the antenna as high as possible and away from house wiring, etc. will provide *physical* discrimination if a transmission line is used which has no signal pickup. Using a *resonant* antenna will provide *frequency* discrimination, attenuating signals and noise on frequencies removed from the resonant frequency of the antenna. Using a directional antenna will provide *directional* discrimination, attenuating signals and noise reaching the antenna from directions removed from that of the station transmitting the desired signal.

The ideal antenna has these three kinds of discrimination: physical, frequency and directional, which will thus deliver the most signal and the least amount of noise to the input circuit of the receiver. Such an antenna connected to a mediocre receiver will give better results than will the best receiver made working on a mediocre antenna.

All of the transmitting antennas previously described are suitable for receiving. A good transmitting antenna meets all three of the desirable requirements set forth above. For this reason, an amateur is seldom justified in erecting a separate antenna system for the purpose of receiving. A d.p.d.t. relay designed for r.f. use, working off the send-receive switch or the communications switch on the receiver, can be used to throw whatever transmitting antenna is being used at the time to the receiver input terminals.

Fortunately, the antenna that delivers the best signal into a certain locality will also be best for receiving from that locality, and conversely the antenna which provides the best received signal will be best for transmitting to the same locality. In fact, a rotary antenna can be aimed at a station for maximum gain when transmitting by the simple expedient of rotating the array for maximum received signal.

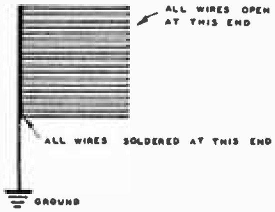
As most man-made noise is essentially vertically polarized, an antenna or array with horizontal polarization will give minimum noise pickup from that source. For this reason, an array with horizontal polarization is advisable when it is to be used not only for transmission but also for reception.

The problem of noise pickup is most important because it is the signal-to-noise ratio that limits the signals capable of being received satisfactorily. No amount of receiver amplification will make a signal readable if the noise reaching the receiver is as loud as the signal. Peak-limiting devices will improve reception when trouble is experienced from *short-pulse* popping noises such as auto ignition interference. But no electrical device in the receiver is of avail against the steady buzzing, frying noises present in most urban districts.

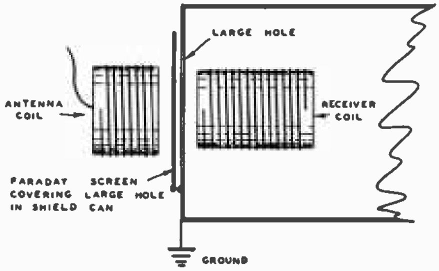
For the latter type of interference, caused by power leaks, defective neon signs, etc., a recently developed modification of an old principle is oftentimes of considerable help. A noise antenna, a short piece of wire placed so as to pick up as much of the interfering noise and as little of the desired signal as possible, is fed to the input of the receiver *out of phase* with the energy received from the main antenna. By proper adjustment of coupling and experimentation with the length and placement of the noise antenna, it is sometimes possible to eliminate the offending noise completely. The system of noise bucking is described on page 105 and in greater detail in the RADIO NOISE REDUCTION HANDBOOK.

Stray Pickup

More care has to be taken in coupling a transmission line to a receiver than to a transmitter. The whole antenna system, antenna and transmission line, may tend to act as a Marconi antenna to ground by virtue of capacity coupling. When transmitting, this effect merely lowers the maximum discrimination of a directive array with but little effect on the power gain; with a nondirectional antenna, nothing will even be noticed when there is a very slight amount of Marconi effect. But if the effect is present when *receiving* there is little point in using an antenna removed as far as possible from noise sources because the transmission line itself will pick up the noise.



FARADAY SCREEN



SIDE VIEW OF SCREEN ASSEMBLY

Figure 62.

Faraday Electrostatic Shield

There are two simple ways of avoiding the Marconi effect. The first method calls for a *Faraday screen* between the antenna coil of the receiver and the input grid circuit, and grounded. This eliminates all capacity coupling. This type of electrostatic screen can be constructed by winding a large number of turns of very small insulated wire on a piece of cardboard which has first been treated with insulating varnish. The wire is wound on, then another coating of varnish is applied.

After it has dried, *one edge* is trimmed with tin snips or heavy shears and the wires are soldered together along the opposite edge. The screen is placed between the two coils and grounded. If properly made, it has little effect on the inductive coupling as there are no closed loops.

Balancing Coils

The second method calls for a center-tapped antenna coil with the center tap grounded. If the coil is not easily accessible, a small center-tapped coil of from 5 to 30 turns is connected across the antenna input to the receiver and the center tap grounded. While not critical, the best number of turns depends upon the type of transmission line, the frequency and the turns on the antenna coil in the receiver. For this reason, the correct number of turns can best be determined by experiment.

The center tap must be at the *exact* electrical center of the coil. The coil may be scramble wound and made self-supporting by means of adhesive tape. It should be borne in mind that a twisted-pair or open two-wire line will work *correctly* only if the receiver has provision for balanced (doublet) input. This is especially true of the latter type of line. If one side of the input or antenna coil is grounded inside the receiver, the ground connection must be broken and moved to the center of the coil or an external balancing coil used.

Impedance Matching

Another thing to take into consideration is the impedance of the input circuit of the receiver. If the receiver has high impedance input, it will not give maximum performance when a twisted-pair line is used. If it has low impedance input, it will not give maximum performance with an open-line. Most receivers are designed with 200-to-300 ohm (medium impedance) input and will work well with either type line. However, the performance can sometimes be improved by incorporating an impedance matching transformer even when the receiver has medium impedance (300 ohms) input.

A 30-to-100 ohm twisted pair of coaxial cable can be matched to a receiver having 300-ohm input simply by using a balancing coil as already described and tapping the cable down on the coil far enough to give maximum signal input.

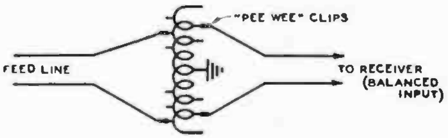


Figure 63.

"AUTOTRANSFORMER" IMPEDANCE MATCHING COIL.

Any two-wire line can be matched to any receiver having balanced input by means of this coupling transformer. The best points at which to tap must be determined by experiment. Both antenna and receiver wires should always be tapped the same number of turns each side of center (ground). A 20- or 25-turn coil wound on a 1-inch form will usually be found optimum. The coil should be tapped every two turns, and at the exact center.

The optimum number of turns for the receiver input connection will vary with frequency and with different receivers, and hence it is necessary to determine the best number by experiment for each receiver and each band.

SUPPORTING THE ANTENNA

The foregoing portion of this chapter has been concerned primarily with the *electrical* characteristics and considerations of antennas and arrays. The actual construction of these antennas is just as important. Some of the physical aspects and mechanical problems incident to the actual erection of antennas and arrays will, therefore, be discussed.

Up to 60 feet, there is little point in using mast-type antenna supports unless guy wires must either be eliminated or kept to a minimum. While a little harder to erect because of their floppy nature, fabricated wood poles of the type to be described will be just as satisfactory as more rigid types, *provided* many guy wires are used.

Rather expensive when purchased through the regular channels, 40- and 50-foot telephone poles can *sometimes* be obtained quite reasonably. In the latter case, they are hard to beat inasmuch as they require no guying if set in the ground six feet (standard depth) and the resultant pull in any lateral direction is not in excess of a hundred pounds or so.

For heights of 80 to 100 feet, either three-sided or four-sided lattice type masts are most practicable. They *can* be made self-supporting, but a few guys will enable one to use a smaller cross section without danger from high winds. The torque exerted on the base of a high self-supporting mast is terrific during a 40- or 50-mile wind.

Guy Wires

Guy wires should never be pulled taut; a *small* amount of slack is desirable

Galvanized wire, somewhat heavier than seems sufficient for the job, should be used. The heavier wire is a little harder to handle, but costs only a little more and takes longer to rust through. Care should be taken to make sure that no kinks exist when the pole or tower is ready for erection as the wire will be greatly weakened at such points if a kink is pulled tight, even though it is later straightened.

If "dead men" are used for the guy wire terminations, the wire or rod reaching from the dead men to the surface should be of nonrusting material such as brass or given a heavy coating of asphalt or other protective substance to prevent destructive action by the damp soil. Galvanized iron wire will last only a short time when buried in moist soil.

Only strain-type (compression) insulators should be used for guy wires. Regular ones might be sufficiently strong for the job, but it is not worth taking chances, and egg-type strain insulators are no more expensive.

Only a brass or bronze pulley should be used for the halyard, as a nice high pole with a rusted pulley is truly a sad affair. The bearing of the pulley should be given a few drops of heavy machine oil before the pole or tower is raised. The halyard itself should be of good material, preferably waterproofed. Hemp rope of good quality is better than window sash cord from several standpoints and is less expensive. Soaking it thoroughly in engine oil of medium viscosity and then wiping it off with a rag will not only extend its life but minimize shrinkage in wet weather. Because of the difficulty in replacing a broken halyard (procedure described later), it is a good idea to replace them periodically, without waiting for them to show excessive wear or deterioration.

Screw eyes should not be used in connections where appreciable tension will occur. The bite of the threads is not sufficient to withstand much loading. They should be used only to hold guy wires and such *in position*; the wires should always be wrapped around the mast or pole. Nails will serve just as well, and are cheaper.

Trees as Supports

Often a tall tree can be called upon to support one end of an antenna, but one should not attempt to attach anything to the top as the swaying of the top of the tree during a heavy wind will complicate matters.

If a tree is utilized for support, provision should be made for keeping the antenna taut without submitting it to the possibility of being severed during a heavy wind. This can be done by the simple expedient of using a pulley and halyard with weights attached to the lower end of the halyard to keep the antenna taut. Only sufficient weight to avoid excessive sag in the antenna should be tied to the halyard as the continual swaying of the tree submits the pulley and halyard to considerable wear.

Galvanized iron pipe or steel tube conduit is often used as a vertical radiator and is quite satisfactory for the purpose. However, when used for supporting antennas, it should be remembered that the grounded supporting poles will distort the field pattern unless spaced some distance from the radiating portion of the antenna.

Painting

The life of a wood mast or pole can be increased several hundred per cent by protecting it from the elements with a coat or two of paint. And, of course, the appearance is greatly enhanced. The wood should first be given a primer coat of flat white outside house paint, which can be thinned down a bit to advantage with second-grade linseed oil. For the second coat, which should not be applied until the first is thoroughly dry, *aluminum paint* is not only the best from a preservative standpoint but looks very well. This type of paint when purchased in quantities is considerably cheaper than might be gathered from the price asked for quarter-pint cans.

Portions of posts or poles below the surface of the soil can be protected from termites and moisture by painting with creosote. While not so strong initially, redwood will deteriorate much more slowly when buried than will the white woods such as pine.

Antenna Wire

The antenna or array itself presents no especial problem. A few considerations should be borne in mind, however. For instance, soft-drawn copper should not be used as even a short span will stretch several per cent after whipping around in the wind a few weeks, thus affecting the resonant frequency. Enameled-copper wire as ordinarily available at radio stores is usually soft drawn, but by tying one end to some object such as a telephone pole and the other to the frame of an auto, a few husky tugs can be given and the wire, after stretching a bit, is equivalent to hard drawn.

Where a long span of wire is required, or where heavy insulators in the center of the span result in considerable tension, copper-clad steel wire is somewhat better than hard-drawn copper. It is a bit more expensive though the cost is far from prohibitive. The use of such wire, in conjunction with strain insulators, is advisable where the antenna would endanger persons or property should it break.

For transmission lines, steel core wire will prove awkward to handle, and hard-drawn copper should therefore be used. If the line is long, the strain can be eased by supporting it at several points.

The use of copper tubing for antennas is not only expensive but unjustifiable. Though it was a fad at one time, there is no excuse for using anything larger than no. 10 copper or copper-clad wire for any power up to one kilowatt. In fact, no. 12 will do the trick just as well and passes the underwriter's rules if copper-clad steel is used. For powers of less than 100 watts, the underwriter's rules permit no. 14 wire of solid copper. This size is practically as efficient as larger wire, but will not stand the pull that no. 12 or no. 10 will, and the underwriter's rules call for the latter for powers in excess of 100 watts if solid copper conductor is used.

More important from an electrical standpoint than the actual size of wire used is the soldering of joints, especially at current loops in an antenna of low radiation resistance. In fact, it is good practice to solder *all* joints, thus insuring quiet operation when the antenna is used for receiving.

Insulation

A question that often arises is that of insulation. It depends, of course, upon the r.f. voltage at the point at which the insulator is placed. The r.f. voltage, in turn, depends upon the distance from a current node and the radiation resistance of the antenna. Radiators having low radiation resistance have very high voltage at the voltage loops; consequently, better than usual insulation is advisable at those points.

Open-wire lines operated as nonresonant lines have little voltage across them; hence, the most inexpensive ceramic types are sufficiently good electrically. With tuned lines, the voltage depends upon the amplitude of the standing waves. If they are very great, the voltage will reach high values at the voltage loops, and the best spacers available are none too good. ⅜-inch Lucite rod, which can be purchased for 18c per foot, permits lightweight spreaders having excellent electrical properties. At the current loops the voltage is quite low and most anything will suffice.

When insulators are subject to very high r.f. voltages, they should be cleaned occasionally if in the vicinity of sea water or smoke. Salt scum and soot are not readily dislodged by rain, and when the coating becomes heavy enough, the efficiency of the insulators is greatly impaired.

If a very pretentious installation is to be made, it is wise to check up on both underwriter's rules and local ordinances which might be applicable. If you live anywhere near an airport and are contemplating a tall pole, it is best to investigate possible regulations and ordinances pertaining to towers in the district before starting construction.

EIGHTEEN

Test and Measuring Equipment

THERE are certain pieces of test equipment that should be a part of every radio station and laboratory, in order to insure proper operation of radio receivers, transmitters, amplifiers and antenna systems, and to diagnose trouble when it occurs. Other pieces of test equipment, while very handy and undoubtedly desirable, are not absolutely necessary and may be considered somewhat of a luxury. Every amateur should possess a simple volt-ohmmeter, absorption wavemeter and monitor. The last can be designed and calibrated to act as a frequency meter. How much additional test equipment an amateur is justified in acquiring depends upon the condition of his pocketbook, the amount of money otherwise invested in his station and his ingenuity and resourcefulness. Some amateurs can diagnose trouble and determine whether their equipment is operating properly by means of a single meter, a few resistors and various parts from the junk box, though the job would undoubtedly be facilitated by a more extensive array of test equipment. Other amateurs, particularly those less technically inclined, will find more need for various special-purpose test instruments when trouble hunting or tuning up a transmitter; in fact, they will be helpless without such instruments.

Virtually everything in the way of test equipment of use to the amateur is described in this chapter. The units have been designed with simplicity and economy in mind, but not at the expense of reasonable accuracy or versatility.

ABSORPTION-TYPE WAVEMETER

The wavelength of any oscillator, doubler or amplifier stage can be roughly determined with the aid of a simple absorption wavemeter. It is particularly useful for determining the correct harmonic from a harmonic crystal oscillator or frequency doubler or quadrupler. It consists of a simple tuned circuit which is coupled to the tank circuit under measurement. The wavemeter absorbs a small amount of energy from the transmitter tank circuit; this produces a change in reading of the milliammeter in the plate or grid circuit. A sharp rise or dip in the milliammeter current reading will take place when the wavemeter is tuned to the same wavelength or frequency as that of the circuit under measurement.

The coil socket is bolted to the back mounting flange of the 140-$\mu\mu$fd. midget variable condenser. One coil covers from 8 to 30 meters, another from 30 to 95 meters. The coil turns should be held in place with duco cement.

The wavemeter can be calibrated by holding it near the secondary coil of an ordinary regenerative receiver which tunes to the known amateur bands. As the wavemeter condenser is rotated

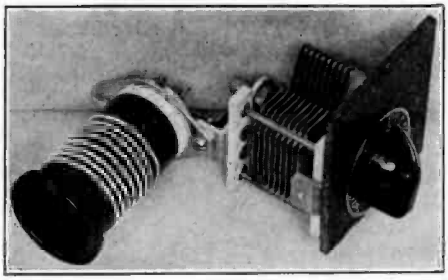


Figure 1.

SIMPLE ABSORPTION TYPE WAVEMETER.

This instrument is highly useful for identifying harmonics. Two plug-in coils cover from 8 to 95 meters. The meter is merely a calibrated tank circuit.

through its range, a point will be found where the receiver is pulled out of oscillation, as indicated by a sharp click in the headphones of the receiver. This point is then marked on the scale of the wavemeter dial. This calibration is sufficiently accurate to insure transmitter operation in the 10-meter band rather than 13-meter operation, which can be easily mistaken for 10-meter output when tuning a transmitter.

The wavemeter can also be calibrated by holding it near the plate coil of a crystal oscillator. A change in oscillator plate current or even a cessation of oscillation will occur when the wavemeter is tuned to the same frequency as that of the oscillator.

One can either make a continuous calibration curve for the two coils or make notes of the dial settings for the various amateur bands.

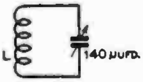


Figure 2.

ABSORPTION WAVEMETER CIRCUIT.

Nothing could be simpler than the circuit of an absorption type wavemeter. For the range of from 8 to 30 meters, L should consist of 8 turns 1" long on a 1¼"-diameter form. For 30 to 95 meters, L should consist of 27 turns 1" long on a 1¼" diameter form.

BAND EDGE FREQUENCY SPOTTER

The FCC rule regarding frequency measurement of amateur transmitters says in effect that amateurs cannot rely on the frequency marked on a crystal by its manufacturer as a suitable method of frequency checking in any case. Neither can they, if edge-of-band operation is contemplated, rely upon the dial readings of the station receiver for frequency measurement. Some independent method of accurately determining frequency is required. Such an instrument is diagrammed in figure 5 and pictured in figures 3 and 4.

The unit consists essentially of a 50-kilocycle oscillator and a tuned harmonic amplifier fed from a voltage-regulated power supply. It provides 50-kc. points of usable and adjustable strength on all the amateur bands up to and including 30 Mc. For that matter it also gives usable calibration points every 50 kc. on the frequencies in between the amateur bands should they be needed for some special purpose. These 50-kc. marker points give the edges of all the amateur bands, phone and c.w., except the low-frequency edge of the 160-meter c.w. band (1715 kc.). When and if the 160-meter band is changed to 1750 to 2050 kc. in accordance with the Havana agreement the unit will provide points at both ends of this band as well.

The 50-Kilocycle Oscillator

A 6K8 tube is used as a combined 50-kilocycle oscillator and electron-coupled doubler to 100 kc.

The oscillator coil is a Meissner 456-kilocycle beat-oscillator unit with the mica trimmer removed. By loading this comparatively high-frequency coil to the low frequency of 50 kc., the oscillator tuned circuit becomes quite high C. The stability with respect to tube and circuit temperature variations and plate voltage variations is greatly improved by the high oscillator lumped capacity. Actually, the capacity required to tune this oscillator coil to 50 kilocycles is very close to 0.00625 microfarads. This capacity is obtained through the use of a .006-μfd. fixed condenser of the silver-plated mica type in parallel with a .0002-μfd. condenser of the same type and a 100-$\mu\mu$fd. midget variable. It is important that the identical coil as shown in the Buyer's Guide be used (and that the mica trimmer thereon be removed) if the values of capacity shown are to hit 50 kilocycles. It is also important that zero coefficient fixed condensers be used for lump capacity.

The 100-$\mu\mu$fd. midget trimmer condenser is brought through the chassis and allows the frequency of the oscillator to be tuned about one-half kilocycle either side of the operating frequency of 50 kilocycles. This adjustment will ordinarily compensate for any small variations in coil inductances and in circuit capacity. If, however, it is impossible to tune this circuit to 50 kc. by a variation in the capacity of this condenser, the addition or subtraction of .00005 μfd. from the fixed value of .00625 will usually allow it to be accomplished.

The oscillator coil, as it comes from the manufacturer, is not a single tapped unit but rather a two-winding affair with four leads brought out from the coils. It will then be necessary to series these two coils as shown in the manufacturer's diagram as the connection for an electron-coupled oscillator. The cathode of the oscillator-mixer tube is then connected to the tap. The actual connections to the coil are as follows: blue wire, ground; green wire, grid; red and black connect together and go to cathode.

The Harmonic Amplifier

The output circuit of this stage consists of a tapped coil which is resonated by a 100-$\mu\mu$fd. midget variable. With the whole coil in the circuit the output can be peaked at any frequency from about 7500 kc. down to about 3500 kc. Nevertheless, there is ample output with this coil in the circuit down through the broadcast band. It is not necessary to resonate the output circuit at these low frequencies; there is more than ample output for all measurements and for calibration.

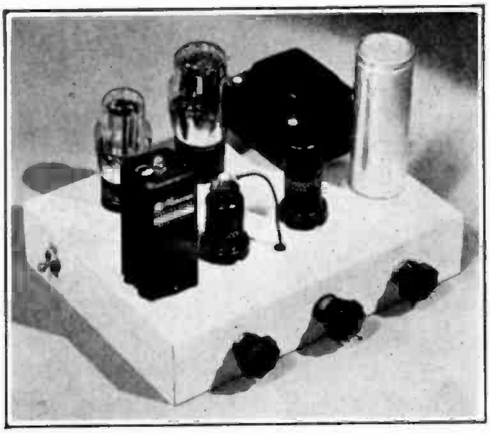


Figure 3.

FRONT VIEW OF THE FREQUENCY SPOTTER.

The control to the left of the front panel is the trimmer on the 50-kilocycle oscillator. The right-hand control is the harmonic amplifier coil switch and the center control is the trimmer condenser across this coil.

With the switch in the second position all but 9 turns of the inductance are shorted and the coil will resonate at any frequency from about 7000 kc. down through 18,000 kc. This tap peaks in the middle of the dial for strong signals on the 14-Mc. band. With the switch on the last tap, with only four turns in the circuit, the circuit peaks up in the 28-Mc. band and for a considerable distance either side of it.

Coupling of the output circuit to the external load is accomplished by means of a .000025-μfd. mica condenser which connects between the plate of the 6V6 and the output terminal. The decrease in the reactance of this condenser with increasing frequency tends to equalize the signal strength output of the unit over a wide range of frequency.

A simple resistance-capacity filtered power supply using an 80 rectifier is used for plate voltage to the unit. Ample filtering for the harmonic amplifier stage is attained through the use of the RC filter. The VR-150-30 voltage regulator with its associated resistors and condensers supplies very pure direct current to the 6K8 oscillator and first multiplier.

Tuning Up and Calibration

If the oscillator coil specified has been used and if the exact values of capacity specified have been placed across the coil it is only necessary to get the oscillator going on the proper frequency of 50 kilocycles; when this is once done, all other adjustments become very simple.

For tuning up the frequency spotter the only additional piece of equipment required is a calibrated broadcast receiver and a few incoming broadcast signals on frequencies that are integral multiples of 50 kc. With the oscillator operating (with the output coil on the no. 1 tap—all the coil in the circuit) run a wire from the output terminal of the spotter to the antenna post on the b.c.l. set and connect a small external antenna to the receiver.

With the trimmer condenser in the oscillator set to about mid-scale tune the b.c.l. set to the low-frequency end of the dial and pick up the first harmonic of the oscillator that can be tuned in. Mark down the frequency of this harmonic as determined from the calibration of the b.c.l. set. Then tune to the next harmonic (they will be strong and easy to identify because of their lack of modulation) and mark down its frequency as again determined from the b.c.l. set. Keep doing this until 8 or 10 points are determined. Then subtract each frequency from the next higher one all the way down the line and average the resulting differences in frequency between the harmonics. If any one of the differences falls very far out of line, recheck its frequency to see if an error has been made or to see if a harmonic has been missed.

If the average of all the differences in frequency falls very near to 50 kilocycles (say 48 to 52 kc.) the unit is ready for calibration. If not the values of padding condenser across the oscillator coil will have to be changed.

When the oscillator has been adjusted very closely to 50 kc. by the "difference-between-harmonics" method, pick out a broadcast station that is operating on some multiple of 50 kc.; one in the vicinity of 550 to 1100 kc. will be the best. Tune in this station, turn on the oscillator, and adjust the beat between the harmonic of the oscillator and the broadcast station to zero. Then find another b.c. station on a harmonic of 50 kc. and see if it also is at zero beat. If the second b.c. station is not at zero beat or within a few cycles of it, the oscillator definitely isn't on 50 kc. and the fre-

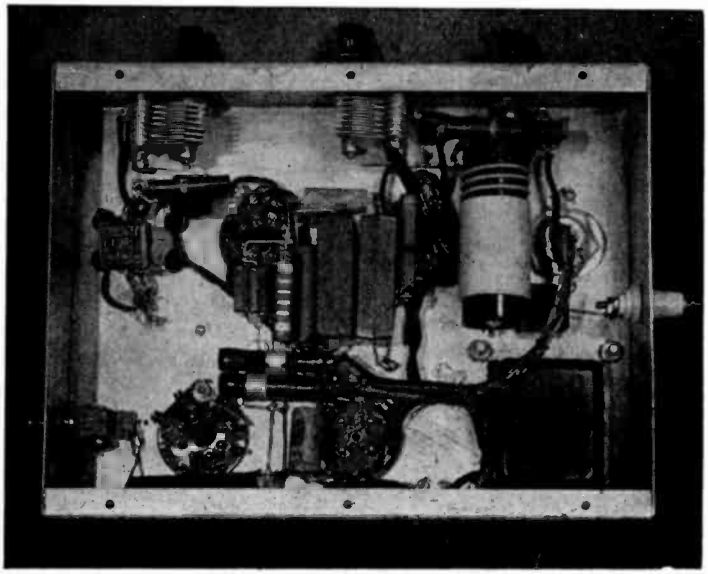
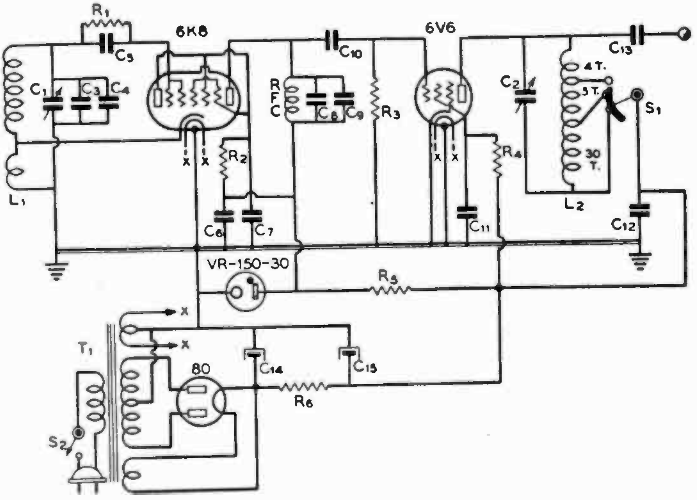


Figure 4.
BOTTOM VIEW OF THE CHASSIS SHOWING PLACEMENT OF COMPONENTS.

The tapped amplifier output coil is to the right and the r.f. choke with the two paralleled condensers across it comprising the plate circuit of the 6K8 is just to the left of the center of the chassis.

Figure 5.

WIRING DIAGRAM OF THE FREQUENCY SPOTTER.



C_1, C_2—100-μμfd. midget variable
C_3—.006-μfd. silvered mica
C_4—.0002-μfd. midget mica
C_5—.0005-μfd. midget mica
C_6, C_7—0.1-μfd. 400 volts
C_8—.001-μfd. mica
C_9—.0001-μfd. mica
C_{10}—.001-μfd. mica
C_{11}—0.1-μfd. 400 volts
C_{12}—.01-μfd. midget mica
C_{13}—25-μμfd. midget mica
C_{14}, C_{15}—8-8 μfd. 450-volt elect.
R_1—100,000 ohms, 1 watt
R_2—25,000 ohms, 2 watts
R_3—2 megohms, 1 watt
R_4—50,000 ohms, 2 watts
R_5—20,000 ohms, 10 watts
R_6—10,000 ohms, 10 watts
S_1—Shorting-type 1-pole 3-position switch
S_2—S.p.s.t. a.c. line switch
L_1—456-kc. b.f.o. coil with trimmer removed
L_2—39 turns no. 20 d.c.c. on 1"-dia. form tapped at 9 and 4 turns; last 4 turns spaced
RFC—2.1-mh., 125-ma. r.f. choke
T_1—650 v. c.t., 40 ma.; 6.3 v. 2 a.; 5 v. 2 a.

quency will have to be rechecked by the procedure given in the preceding paragraphs, fixed condensers being added or subtracted depending on whether the frequency is high or low.

If the second station is at zero beat with the harmonic, check with a few more stations on multiples of 50 kc. just to make sure all is well. As mentioned before, if the values and components given are used it will only be necessary to adjust the trimmer condenser across the oscillator tank, which is brought out to the front panel, to hit 50 kc. and hence to arrive at this stage of the adjustment.

It will now only be necessary to set the trimmer condenser so that the harmonics in the broadcast band fall exactly at zero beat with the b.c. stations and the unit will thenceforward be calibrated.

It will be found that strong, steady signals are available every 50 kilocycles throughout all the amateur bands from 160 through 10 meters. These signals can be used as band-edge markers for either the phone or c.w. bands. Or, if a receiver with substantially straight-line-frequency tuning and an accurate dial is in use, the frequency of any incoming or locally-generated signal may be determined to a good degree of accuracy by interpolating between the 50-kilocycle points with the dial.

The warm-up time of the unit is very short, a matter of only five minutes or so, due to the very high value of capacity in the 50-kilocycle oscillator tank. Once the oscillator has been set it will not drift more than a few cycles on the broadcast band (less than 100 cycles on ten meters) in many hours of continuous operation. However, each time the unit is placed into operation from a cold start it will be best to check the setting of the oscillator trimmer condenser against a broadcast station on a multiple of 50 kc. after allowing five minutes or so to warm up.

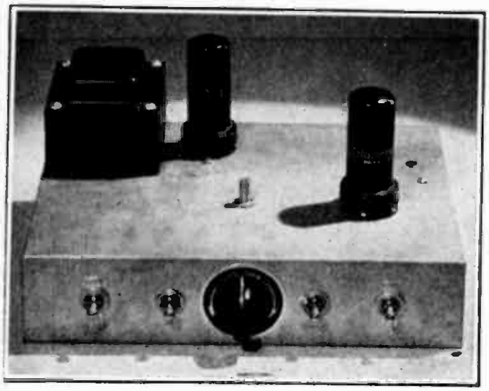
DUAL FREQUENCY CRYSTAL CALIBRATOR

At a reasonable price it is possible to purchase a crystal unit containing a crystal which will oscillate on either 100 or 1000 kc., oscillating along its length for the lower frequency and through its thickness for the higher frequency. The accuracy of the 100 kc. oscillation is very high, when installed and adjusted in a calibrator of the type to be described, thus permitting precision frequency measurement. The advantage over the 50-kc. self-controlled unit just described is that it is much simpler to get going initially and one need not allow for warm up or check it each time before taking a measurement. It has the further advantage that it can be made to oscillate with reasonable accuracy (.05%) at 1000 kc., which is of considerable help in identifying the 100 kc. points on the higher frequencies where it is sometimes difficult to determine the order of a particular 100 kc. harmonic. The only disadvantage is that the 100 kc. points are twice as far apart as the points given by the "Band Edge Spotter" previously described, and the strength of harmonics above 14 Mc. is not quite as great with the crystal calibrator, due to the lack of a separate harmonic amplifier.

Figure 6.

DUAL FREQUENCY CRYSTAL CALIBRATOR.

This instrument generates 1000 kc. harmonics up to 56 Mc. and 100 kc. harmonics up to 20 Mc., the latter with a high degree of accuracy. On the front of the chassis is the output control; the slotted shaft projecting out of the top of the chassis is a shunt trimmer across the crystal for adjusting the low frequency oscillations precisely to 100 kc.



It should be borne in mind that the accuracy of the crystal when oscillating on 1000 kc. is not supposed to be sufficient for precision measurements; it is simply for convenience in identifying the highly accurate 100 kc. points.

Construction

The only precautions to be observed in construction are to place the crystal away from any components which radiate heat, and to make the leads from the tube to the crystal as short as possible. Mounting the crystal under the chassis close to the 6F6 socket as illustrated meets these requirements. The leads to condenser C_6 should also be kept as short as possible.

The coil L_1 is one pie of a midget 125 ma. 2.1 or 2.5 mh. r.f. choke. If the crystal will not oscillate with the switch on 1000 kc. position, it may be necessary to remove a few turns from the coil. A midget solenoid b.c.l. coil may be substituted if desired.

Adjustments and Use

When completed the first thing to do is check for oscillation on both positions of S_1 to make sure the crystal will oscillate both on 1000 and 100 kc. If it does not oscillate on 1000 kc., then the mica trimmer C_1 should be varied. When this trimmer has once been adjusted so that the crystal "comes on" every time the switch is thrown, the trimmer never need be touched again.

The 100 kc. frequency should then be precisely adjusted by means of the 25-$\mu\mu$fd. air trimmer C_6 until harmonics of the 100 kc. oscillator zero beat *exactly* with broadcast stations on multiples of 100 kc. Zero beat can most accurately be determined if the receiver has a tuning eye or "R" meter. The trimmer is first adjusted as close as possible by ear and then further adjusted until the "flutter" of the indicator is reduced to as low

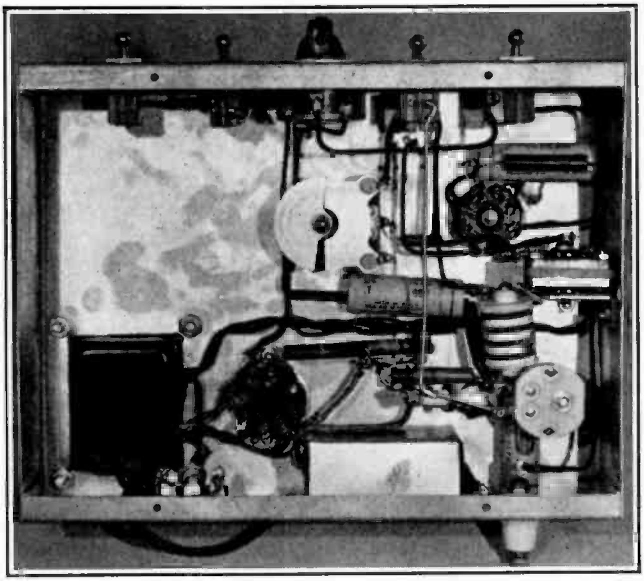


Figure 7.

UNDER-CHASSIS VIEW OF THE CRYSTAL CALIBRATOR.

The crystal unit is mounted close to the 6F6 sockets. Power supply components are to the lower left.

a frequency as possible. The adjustment should preferably be checked against three or four broadcast stations and an average taken if there is any deviation for the different stations. No modulation should be applied to the oscillator during this adjustment.

The calibration when thus obtained will hold over a long period of time, and it is not necessary to check the frequency against broadcast stations before taking a measurement so long as the room temperature does not vary too much from the temperature at which the instrument was originally calibrated.

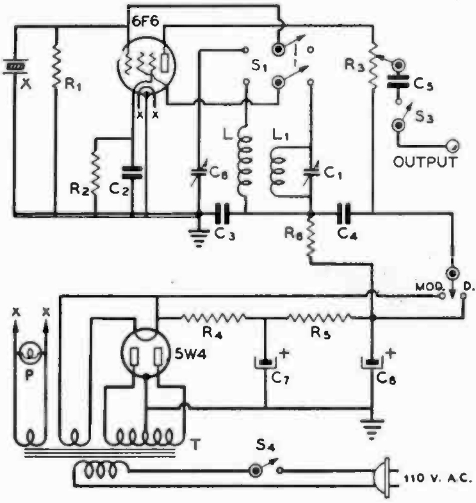
Modulation is accomplished by applying unfiltered r.a.c. to the output circuit of the oscillator, and can be cut in or out by means of the s.p.d.t. toggle switch indicated. The modulation facilitates

Figure 8.

WIRING DIAGRAM OF CRYSTAL CALIBRATOR.

(as recommended by Bliley Electric Co.)

X—100 and 1000 kc. crystal calibrator unit
R_1—5 meg., ½ watt
R_2—500 ohms, 1 watt
R_3—0.5 meg. potentiometer
R_4—10,000 ohms, 1 watt
R_5—20,000 ohms, 1 watt
C_1—25 - 100 - µµfd. mica trimmer
C_2, C_3, C_4—0.1-µfd. tubular
C_5—.001-µfd. mica
C_6—25-µµfd. midget variable
C_7, C_8—Dual 4-µfd. 450-volt electrolytic
T—320 v. each side of c.t., 40 ma. and fil. windings.
S_1—D.p.d.t. toggle switch
S_2—S.p.d.t. toggle switch
S_3—S.p.s.t. toggle switch
S_4—S.p.s.t. toggle switch
L—R.F.C., exactly 8 mh.
L_1—Pie wound 2.1 or 2.5 mh, 125 ma. r.f. choke with all sections except one removed.



spotting of the harmonics by making it easier to pick them out from among stray carriers.

Care should be taken with any 50 kc. or 100 kc. oscillator when making measurements on 14 Mc. or above if the receiver used does not have good image rejection. The appearance of images will result in spurious carriers and false readings.

DELUXE FREQUENCY STANDARD

A device of somewhat more usefulness than the crystal calibrator just described but requiring more components is illustrated in figures 9 to 12. Essentially it is a crystal calibrator with integral multivibrators permitting not only 100 kc. points, but 10 kc. points and 1 kc. a.f. signal generator as well. The crystal is of the precision type, having a very low temperature coefficient. Mounted in the same holder with the crystal is a 100 kc. tank coil designed for optimum performance of the unit. The crystal is not of the dual frequency type, and is used because of its lower temperature coefficient and precision mounting. For most work a crystal of the less expensive type used in the calibrator of figure 8 will suffice, but where the greatest possible accuracy is desired the precision, low coefficient type is preferable.

Figure 9.

VERSATILE, SELF-CONTAINED FREQUENCY STANDARD.

Outputs are provided on 100, 10, and 1 kc. at the jacks on the right, and any stage may be switched off by means of the toggle switches along the bottom. The audio gain control (lower center) regulates the level of the 1000-cycle output. The correction control (left) permits variation of the crystal frequency plus or minus 8 cycles on the fundamental.

The multivibrator, a type of relaxation oscillator none too familiar to most amateurs may be regarded simply as a *frequency divider* and as such performs a function opposite to that of the more familiar frequency multipliers (doublers, triplers, quadruplers, etc.) found in amateur transmitters.

Operating alone, the multivibrator has little value. Its oscillations are highly unstable and ragged, as may be observed by listening to one of its harmonics on a selective receiver. It can, however, be controlled by a stable crystal oscillator, even when the latter is operating on a harmonic of the multivibrator fundamental, and in this controlled state the roughness of the output disappears and the multivibrator locks into step. In the controlled state, the multivibrator emits a signal on its own fundamental frequency (determined by the values of resistance and capacitance in its circuit), this being a subharmonic of the crystal frequency and possessing the same order of accuracy as the crystal oscillator. It is possible to synchronize a given multivibrator on more than one submultiple of the controlling frequency and the desired output frequency must be selected by adjustment of one of the grid resistors, made variable for the purpose, as will be pointed out later.

The multivibrator output is unusually rich in harmonics, a property which suits it ideally to the production of standard frequency points at high radio frequencies. At the same time, most multivibrators are operated at fundamentals which are audio frequencies and these are highly useful where accuracy of frequency rather than purity of wave form is desired.

Multivibrators have been synchronized on 1/40 the controlling frequency, but for maximum stability and controls, the frequency division is seldom carried out in a single multivibrator stage beyond 1/10 the controlling frequency. A 10-kc. multivibrator controlled by a 100-kc.

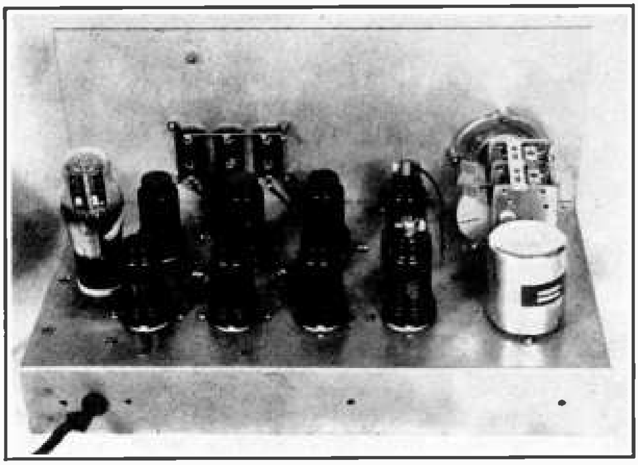


Figure 10.

INTERIOR VIEW OF THE DE LUXE STANDARD.

This inside view of the unit, shows the special crystal unit, oscillator, multivibrator, amplifier, and rectifier tubes. These may be identified with the layout diagram, figure 12.

standard oscillator provides crystal-controlled output on 10,000 cycles and its harmonics appear as spot frequencies equally spaced between each two adjacent 100-kc. points. The 100-kc. oscillator-10-kc. multivibrator combination is common in most complete standards. Multivibrator stages operating on lower frequencies than 10 kc. are employed primarily as generators of accurate audio frequencies since their harmonics are too closely spaced for convenience in radio measurements.

The portable frequency standard shown on these pages employs a highly stable 100-kc. crystal oscillator and two multivibrators, one operating on 10 kc.; the other on 1 kc. Outputs are provided at 100 kc.; 10 kc., and 1 kc. Amplifiers are placed between each stage for the purpose of isolation and building up the output voltage from the driving stage. If desired the standard can be simplified by omitting the 1 kc. multivibrator and its amplifier.

The tank condenser, C_2, is a split stator, 350-$\mu\mu$fd.-per-section broadcast midget employed here as the correction control. This condenser permits variation of the crystal frequency over the narrow range of plus or minus 8 cycles at 100 kc. (plus or minus 400 cycles at 5000 kc.). The crystal frequency drift due to temperature is less than 3 cycles per Mc. per °C.

The multivibrators are separately controlled by s.p.s.t. toggle switches, S_2 and S_3 respectively, which short out one grid resistor in the *off* position. This arrangement allows plate current to be drawn constantly and contributes to the stability of the crystal oscillator.

The heaters of all the tubes are wired in series *in the order shown*. No shielded leads are employed in the customary positions (output connections, etc.) since the small capacity between conductor and shield has been found to by-pass some of the useful higher r.f. harmonics. For the same reason, all output leads are kept away from the chassis and other grounded parts and large jack holes are cut in the front panel.

A liberal number of large holes are punched in the back of the case to permit ventilation, since the nine tubes in the unit generate considerable heat that must be carried away from the crystal.

Calibration and Use

After all wiring has been carefully checked and the tubes and crystal unit inserted, the frequency standard must be corrected and adjusted. For this purpose a good receiver covering either the 80- or 160-meter band and tunable to 5000 kc. or over the broadcast band must be warmed up and disconnected from its regular antenna to prevent pick-

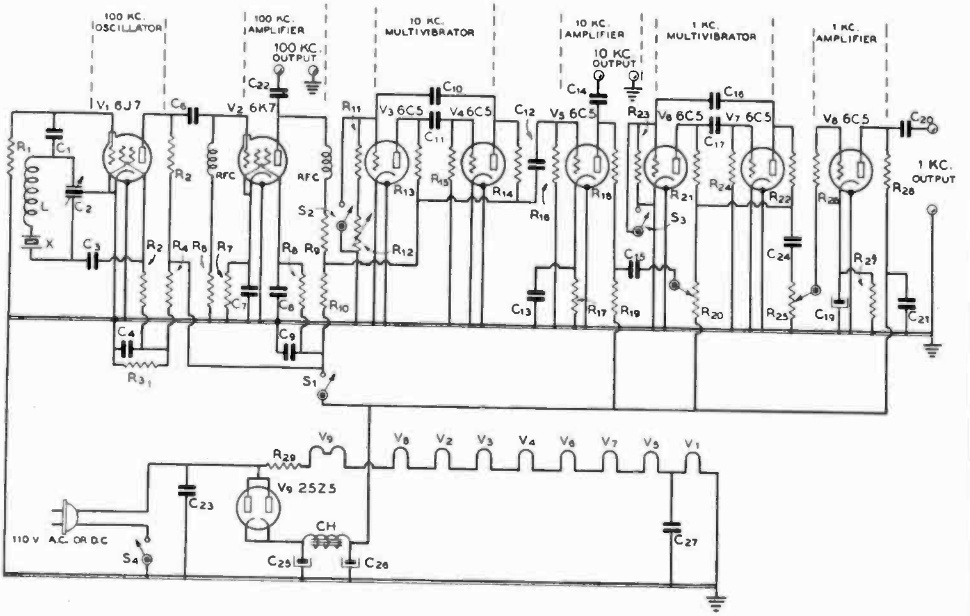


Figure 11.

SCHEMATIC OF THE FREQUENCY STANDARD WITH A.C.-D.C. POWER SUPPLY.

X, L—Bliley SOC100 crystal unit
C_1—0.01-µfd. 200-volt tubular
C_2—350-µµfd. per section broadcast midget variable
C_3—0.01-µfd. 200-volt tubular
C_4—0.1-µfd. 200-volt tubular
C_5—0.1-µfd. 200-volt tubular
C_6—.001-µfd. mica
C_7—0.1-µfd. 200-volt tubular
C_8—0.1-µfd. 200-volt tubular
C_9—0.1-µfd. 200-volt tubular
C_{10}—.002-µfd mica
C_{11}—.002-µfd. mica
C_{12}—00.1-µfd. mica
C_{13}—0.1-µfd. 200-volt tubular
C_{14}—0-1-µfd. 200-volt tubular
C_{15}—.001-µfd. mica
C_{16}—.002-µfd. mica
C_{17}—.002-µfd mica
C_{18}—.001-µfd. mica
C_{19}—10-µfd. 50-volt electrolytic
C_{20}—0.1-µfd. 200-volt tubular
C_{21}—0.1-µfd. 200-volt tubular
C_{22}—0.1-µfd. 200-volt tubular
C_{23}—0.1-µfd. 200-volt tubular
C_{21}—0.1-µfd. 200-volt tubular
C_{25}, C_{26}—40-µfd., 150-volt midget electrolytic
C_{27}—0.1-µfd. 200-volt tubular
R_1—1 megohm, ½ watt
R_2—½ megohm, ½ watt
R_3—100,000 ohms, 1 watt
R_4—0.14 megohm, 1 watt
R_5—½ megohm, ½ watt
R_6—½ megohm, ½ watt
R_7—1500 ohms, ½ watt
R_8—300 ohms, ½ watt
R_9—50,000 ohms, ½ watt
R_{10}—50,000 ohms, ½ watt
R_{11}—2500 ohms, ½ watt
R_{12}—5000-ohm wirewound potentiometer
R_{13}—20,000 ohms, 1 watt
R_{14}—200,000 ohms, 1 watt
R_{15}—25,000 ohms, ½ watt
R_{16}—½ megohm, ½ watt
R_{17}—2500 ohms, ½ watt
R_{18}—50,000 ohms, ½ watt
R_{19}—50,000 ohms, ½ watt
R_{20}—10,000-ohm wirewound potentiometer
R_{21}—250,000 ohms, 1 watt
R_{22}—20,000 ohms, 1 watt
R_{23}—150,000 ohms, ½ watt
R_{24}—150,000 ohms, ½ watt
R_{25}—½-megohm wirewound potentiometer
R_{26}—1000 ohms, ½ watt (necessary only if in a particular layout adjustment of R_{25} causes 1-kc. multivibrator frequency to jump)
R_{27}—2500 ohms, ½ watt
R_{28}—100,000 ohms, ½ watt
R_{29}—132-ohm filament-dropping resistor in line cord
S_1—S.p.s.t toggle switch (100-kc. on-off switch)
S_2—S.p.s.t. toggle switch (10-kc. on-off switch)
S_3—S.p.s.t. toggle switch (1-kc. on-off switch)
S_4—S.p.s.t. toggle switch (power switch)
CH—30-henry, 50-ma. midget b.c.l. filter choke
RFC—2.5-mh. 125-ma. radio frequency choke

ing up outside signals. Either broadcast stations or the standard frequency transmissions of WWV (5000 kc.) may be used for correcting the crystal.

First, determine that the 100-kc. section is operating by switching on the power supply, switching off all but the 100-kc. section, setting the correction condenser, C_2, to half-scale and locating the 100-kc. harmonics in the receiver which must be set for *c.w.* reception in the 80- or 160-meter band, (beat oscillator switched on if the receiver is a superheterodyne). The standard is coupled to the receiver by connecting a length of wire between the ungrounded 100-kc. output jack and the receiver antenna post.

If the 100-kc. stages are found to be operating correctly, the crystal frequency may now be corrected to exactly 100 kc. by the same procedure as given for the dual frequency crystal calibrator previously described.

Synchronizing the Multivibrators

After the correction has been completed, disconnect the receiving antenna, switch on the beat oscillator of the receiver and make a note of the dial settings for the various 100-kc. harmonics in the 80- or 160-meter band. The multivibrators are synchronized with the corrected 100-kc. oscillator as follows:

With the 100-kc. section running, if the 10-kc. multivibrator is switched on (1-kc. multivibrator off), and is operating correctly, a number of somewhat weaker intermediate signals will be observed between each two 100-kc. harmonics. There will be nine such intermediate points if the multivibrator is synchronized at 10 kc. Eight intermediate points indicate that the multivibrator is locked in step at approximately 11 kc., and 10 points indicate that it is synchronized at approximately 9 kc., etc. To synchronize at the desired frequency, 10 kc., R_{12} is adjusted slowly, noting that at particular settings of this resistor the frequency of any one of the intermediate points will *suddenly jump* to a new value. (This characteristic frequency jump is an indication of correct operation — smooth variation of frequency with the adjustment of R_{12} indicates absence of control by the injected 100-kc. voltage.) Increasing R_{12} will decrease the frequency of synchronization, and vice versa. The correct setting of R_{12} will give 9 standard frequency points between any two adjacent 100-kc. points on the receiver dial. If quickly switching the 10-kc. stage on and off causes the multivibrator to jump to a different frequency, the setting of R_{12} should be reduced slightly.

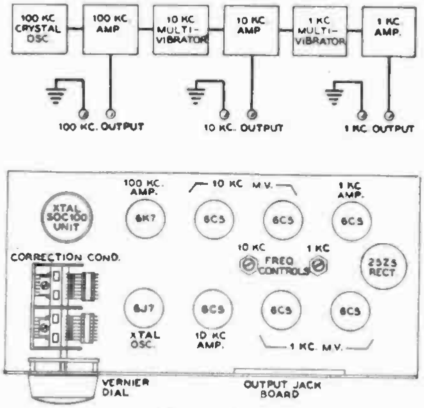


Figure 12.

BLOCK DIAGRAM AND PLAN DRAWING OF FREQUENCY STANDARD.

A simplified diagram showing how the frequency standard functions is given above, while below is shown the recommended arrangement for the various components.

The separate 10-kc. audio output may be utilized by plugging headphones, speaker or amplifier into the two 10-kc. output jacks.

The 1-kc. multivibrator is synchronized in a somewhat similar manner:

A. The 100- and 10-kc. stages are switched on with the 1-kc. stage, R_{25} set for full output, and the ungrounded 1-kc. output jack connected *directly* to the antenna post of the receiver. The other coupling lead is transferred from the 100-kc. jack to the 10-kc. output and loosely coupled to the antenna circuit. For this adjustment a selective single-signal receiver must be used with the crystal filter set for *maximum* selectivity.

B. It will be observed that several somewhat weaker signals appear between each two adjacent 10-kc. points as the receiver is tuned through a narrow range. These are harmonics of the 1-kc. multivibrator and will be 9 in number if the multivibrator is synchronized on 1 kc. In the same manner outlined in the directions for adjusting the 10-kc. multivibrator, the setting of R_{20} is varied until exactly 9 points are counted between any two 10-kc. points on the dial. When this condition exists, headphones, speaker or amplifier connected to the 1-kc. output jacks will be supplied with accurate 1000-cycle voltage.

C. In the absence of a sufficiently selective receiver, the 1-kc. stage may be adjusted by means of a dependable beat frequency audio oscillator. Output voltages from the 1-kc. stage and the beat frequency oscillator (set to 1000 cycles per second) are fed into the grid circuit of a suitable mixer tube and R_{20} is adjusted to select the proper synchronization frequency determined by zero beat with the 1-kc. signal from the beat frequency oscillator.

The frequency standard may be used directly for receiver or monitor calibration by coupling the 100-kc. output into the receiver or monitor, as described earlier, switching on both the 100- and 10-kc. stages, and tuning the receiver or monitor to locate a series of calibration points. A curve, showing the relation of dial settings to frequencies can then be prepared from the data obtained.

A frequency meter may be calibrated by coupling its output circuit into a receiver already coupled to the frequency standard. In this operation, the receiver is tuned to zero beat with successive 10- or 100-kc. points and the frequency meter adjusted to zero beat with those points. The frequency meter calibration curve would show dial settings (meter) against standard frequencies.

An oscillator, signal generator, or transmitter is set to a desired frequency by coupling its output into a receiver or monitor which is also coupled to the frequency standard. The desired frequency, as generated by the standard, is located on the receiver or monitor dial, and the oscillator or transmitter is adjusted to zero beat with this same point. If the desired frequency is intermediate to any of the standard frequency points, it may be obtained by interpolation on the dial of the receiver or monitor.

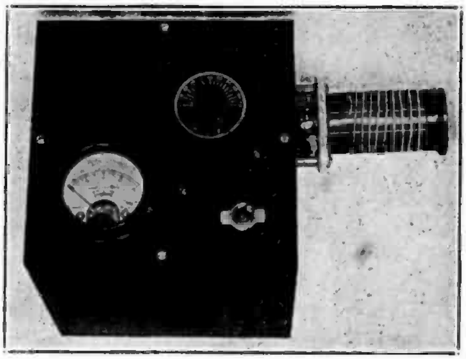


Figure 13.

SIMPLE FIELD STRENGTH METER.

This field-strength meter uses a type 30 connected as a diode; a 0-200 microammeter provides good sensitivity. The unit can be used as an absorption wave-meter if calibrated. It can also be used as a neutralizing indicator.

DIODE-TYPE FIELD-STRENGTH METER

The most practical method of tuning any antenna system, such as a half-wave antenna or a directional array, is by means of a field-strength meter. This instrument gives a direct indication of the actual field strength of a transmitted signal in the vicinity of the antenna. The device consists of a tuned circuit and a diode rectifier which is connected in series with a microammeter so that the meter will read the carrier signal strength.

A 0-200 microammeter as an indicator provides higher sensitivity than can be obtained with the more common 0-1 ma. meter ordinarily used for this purpose.

The unit is very inexpensive and requires but a single 1½-volt cell for power. Besides serving as a field-strength meter, it can be used as a neutralizing indicator or calibrated for use as an absorption wavemeter. A type 30 tube may be used. The 30 filament is rated at 2 volts, but in actual practice works well at 1½ volts. The entire unit, except coils and coil socket, is housed in a metal can 6″ square. The externally mounted coil facilitates coil changing and better adapts the unit for use as a wavemeter, no antenna or pick-up wire being necessary in this application.

For service as a field-strength meter, the coil can be coupled to a small doublet by means of two or three turns of insulated wire wound around the coil. The instrument will be most sensitive if the pickup doublet is made resonant; but such a resonant doublet may, if it is closer than two or three wavelengths, upset the operation of the antenna being adjusted.

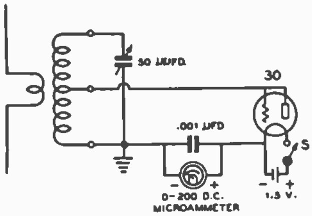


Figure 14.

WIRING DIAGRAM OF THE SIMPLE FIELD-STRENGTH METER.

COIL TABLE.

160 λ	88 turns #26 d.c.c. 1½″ diam. closewound center tap
80 λ	38 turns #22 d.c.c. 1½″ diam. closewound center tap
40 λ	24 turns #22 d.c.c. 1½″ diam. 1½″ long center tap
20 λ	10 turns #22 d.c.c. 1½″ diam. 1½″ long center tap
10 λ	6 turns #22 d.c.c. 1⅛″ diam. 1″ long center tap
5 λ	2 turns #18 enam. 1⅛″ diam. ¾″ long center tap

The meter illustrated was checked against a signal generator. With a type-30 tube in the meter, the following calibration in terms of decibels was obtained, using 12½ μa. as an arbitrary zero db reference level:

12½ μa.—0 db
25 μa.—5 db
50μa.—10 db
100 μa.—15 db
150 μa.—18 db
200 μa.—20 db

The above calibration will vary somewhat from the above for a particular type of construction, components used, and their arrangement. On the whole, however, the above will be found fairly accurate. Calibration is a simple matter, and may be done quite easily if a signal-generator is available.

Figure 15.

INTERIOR VIEW.

Few components are inside the can housing the diode-type field-strength meter. A single "little six" dry cell is strapped inside the cabinet and supplies 1½ volts to the filament of the type-30 tube, used as a diode rectifier.

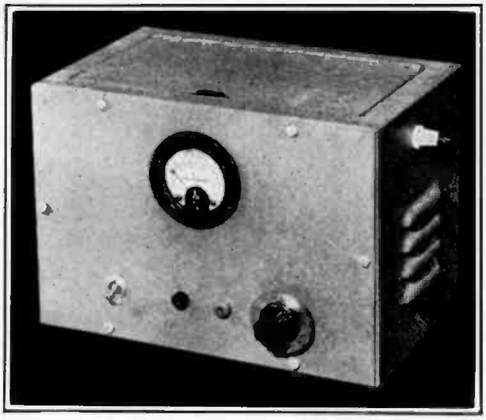


Figure 16.

HIGHLY SENSITIVE FIELD STRENGTH METER.

This device is more sensitive than the one illustrated in figures 13, 14, and 15, and also has the advantage of being usable as a simple vacuum tube voltmeter. However it requires more batteries.

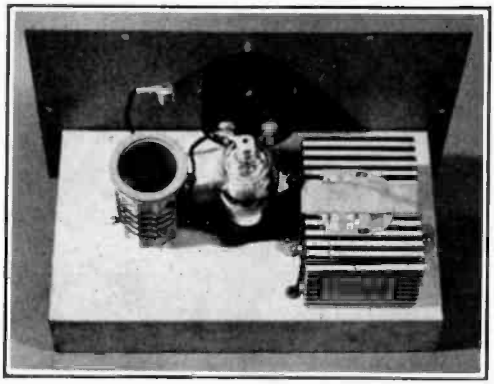


Figure 17.

REAR VIEW OF SENSITIVE FIELD STRENGTH METER.

The plate battery is mounted above the chassis, held firmly in position by means of a strap. Note the extra grid clip, which is brought out to a pin jack for v.t. voltmeter use.

HIGH-SENSITIVITY FIELD-STRENGTH METER AND SIMPLE V.T. VOLTMETER

When it is desired to make field strength readings some distance from the antenna, especially when a low-powered transmitter is used, the diode-type field meter just described does not have sufficient sensitivity. For this purpose a more sensitive device is required. The field strength meter illustrated in figure 16 and diagrammed in figure 18 is considerably more sensitive, but requires a plate battery and a more expensive tube than the diode type previously described.

A 1B4 tube, triode connected, is used as a detector. Two small batteries are required for the plate, filament and bias supplies. The plate voltage is 22½ volts, the bias about 2½ volts and the rated filament voltage, 2 volts. In normal use, the batteries shown with the unit should give a useful life of several months. As the batteries become aged, the calibration will change.

The one tuned circuit in the meter is designed to cover any two consecutive amateur bands. A single 140-$\mu\mu$fd. condenser is used across the plug-in coil, and since the minimum-to-maximum variation in capacity across the coil (the sum of the condenser capacities plus the distributed circuit capacities) is from about 35 to 150 $\mu\mu$fd., it is possible to tune through any two consecutive bands. (A capacity variation of four-to-one is necessary to tune across two consecutive bands with a single coil.)

In the unit shown, one coil is used to cover 10 and 20, another to cover 40 and 80, and still another coil to cover the 160-meter band. All coils are wound on 1½"-diameter coil forms.

The 10-20-m. coil contains 4 turns spaced to about ¾"; the 40-80-m. coil is of 15 turns closewound, and the 160-m. coil is of 50 turns, closewound. All coils are wound with no. 20 wire; the 10-20 one is wound with enamelled and the other two with d.c.c. Both of the two-band coils (10-20 and 40-80) will hit the lower-frequency band with the condenser plates almost completely meshed, and the higher frequency band with them almost separated. Enough range is left, however, so that the bands may easily be covered from one end to the other.

When the unit is first turned on, if the batteries and the tube are in good condition, the 0-1 d.c. milliammeter in the common plate and screen circuit of the 1B4 will indicate about 50 microamperes of plate current. In an r.m.s. voltage indicator (of which this meter is a special type), it is always advisable to have some no-signal plate current.

Now, to return the meter to the zero position, with this .05 ma. flow going through it, it is only necessary to turn the zero-adjustment screw until the needle points to zero with the meter in operation. Then, the fact that the meter will always point to zero when all components are in adjustment will serve as a check on the calibration and condition of the batteries. However, as soon as the meter is turned off, the pointer of the milliammeter will fall below the zero on the scale—actually it will rest upon the pin on the zero side of the meter.

If this instrument is duplicated accurately, the meter will be practically linear, and readings on the 1-ma meter can be converted to decibels by referring to figure 20. Or, if a 2-inch 1-ma. Triplett type 221 meter is used, the scale in figure 20 may be cut out and pasted directly on the meter face.

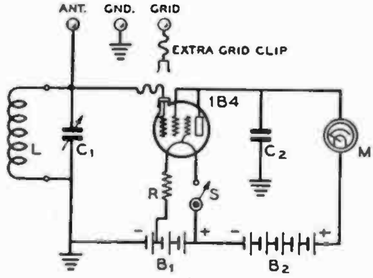


Figure 18.

WIRING DIAGRAM OF SENSITIVE FIELD STRENGTH METER.

C_1—140-μμfd. midget variable
C_2—.002-μfd. mica
R—15-ohm resistor
S—On-off switch, s.p.s.t. toggle
M—0-1 d.c. milliammeter (2" size to use chart given)
B_1—4½-volt C battery. Filament leads connected to + and —3, ground connected to —4½
B_2—22½-volt C battery
L—Coils—see text

If a short length of wire is used for pickup, it may be connected directly to the antenna post, which is a standoff insulator on the side of the cabinet, wired directly to the stator of the tuning condenser. If it is impossible to get a substantial deflection with a short length of wire, the case of the instrument should be grounded and a longer piece of wire connected to the antenna post through a 3-30 μμfd. mica trimmer used as a pickup. If the trimmer is not used, a long pickup antenna will detune the meter.

The tuning condenser C_1 can be detuned from resonance if too great a deflection is obtained. It is not necessary that the tank be tuned to resonance for field-strength measurements, though the meter will be most sensitive when C_1 is tuned to exact resonance.

If the instrument is used as a wavemeter, the calibration should be made with a short, rigid piece of wire as a pickup. The same wire should then be used whenever subsequent wavelength measurements are made. This wire or rod need not be over a few inches long, as it will receive sufficient pickup when brought near the tank circuit whose frequency is to be determined.

For simple vacuum tube voltmeter measurements it is only necessary to substitute the extra grid clip and make connections from the pin jacks to the device whose voltage is to be measured.

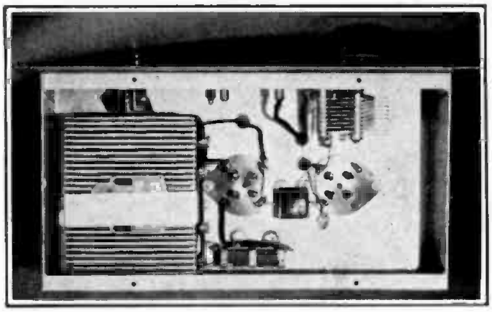


Figure 19.

UNDER-CHASSIS VIEW OF SENSITIVE F.S. METER.

The combined "A" and "C" battery is strapped under the chassis as shown here.

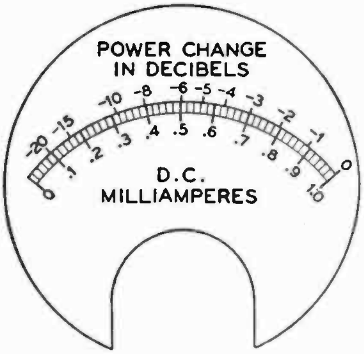


Figure 20.

REPLACEMENT METER SCALE.

This scale can be used for converting current readings to decibels, or it may be pasted directly on the face of a two-inch meter.

The meter is almost indispensable in the adjustment of certain types of antennas. Consider the tuning-up of a rotatable array of the close-spaced type. The meter is placed in a vacant lot some distance from the antenna (two or three wavelengths is usually ample distance), tuned to resonance with its small pickup antenna in place, and the array is pointed toward the f.s. meter. The reading in decibels is noted. The meter should be near enough to the array to give a reading close to full scale. Then the array is rotated and the new reading in decibels noted. The front-to-back ratio of the array is then the difference between the two readings on the meter.

If the meter reads —1 db with the array pointed toward it and —15 with the beam pointed in the other direction, the front-to-back discrimination of the array is 14 db. The meter is calibrated in negative decibels simply to facilitate accuracy of reading, since it will generally be used at readings approaching full scale. The negative numbers can always be added or subtracted just as if they were positive.

A. C. FREQUENCY METER-MONITOR

An accurate means for determining the frequency of a radio transmitter is essential when the circuit is of the self-excited oscillator type. The same device is useful for checking quartz crystal transmitters in order to make certain that the crystal frequency falls within the desired amateur band. It is also a great help in finding a station whose exact frequency is known.

The frequency meter consists of a very stable electron-coupled oscillator which is accurately calibrated. This same unit can serve as a c.w. *monitor* by adding an audio amplifier stage to the plate circuit of the electron-coupled oscillator. The oscillator can be designed to cover either the 80- or 160-meter amateur bands, and harmonics of these frequencies can then be used for measurements in the shorter wave bands.

The oscillator has a small tuning condenser shunted by a larger, bandsetting condenser; the latter is adjusted only when the frequency meter is calibrated from standard frequency transmissions or broadcast station harmonics in conjunction with a calibration oscillator. The condenser used is one particularly designed for such use. It is in reality two condensers built in a single frame, each rotor being individually adjustable. A good, finely-graduated vernier dial is essential for reading the setting of the smaller condenser for accurate determination of frequency. The instrument must be housed in a metal cabinet or can to prevent excessive pick-up from the transmitter under test. The electron-coupled oscillator functions as a beat-note detector similar to the one in a short-wave regenerative receiver.

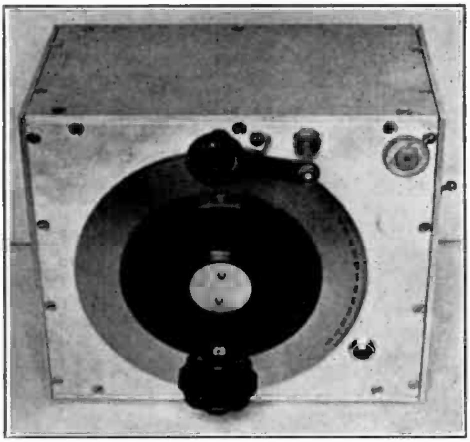
Calibration

The frequency meter may be calibrated in several ways. The simplest method is to calibrate it against signals of known frequency with the aid of a receiver. These signals may be provided by amateur stations having accurate frequency control or by a frequency standard. These signals can be tuned in on a short-wave receiver and the frequency meter tuned to the zero beat-note in the output of the radio receiver. External coupling can be provided from the frequency meter oscillator, if necessary for sufficient pickup, by connecting a

Figure 21.

HETERODYNE FREQUENCY METER.

This heterodyne frequency meter has an audio amplifier stage following the electron-coupled oscillator so that it can be used as an effective c.w. monitor. A heavy, rigid cabinet and a large, vernier dial are necessary for accuracy when it is used as a frequency meter. The pin-jack at the upper right is wired to the output circuit of the oscillator and is used to connect an external "antenna" when sufficient pickup or radiation is not otherwise obtained.



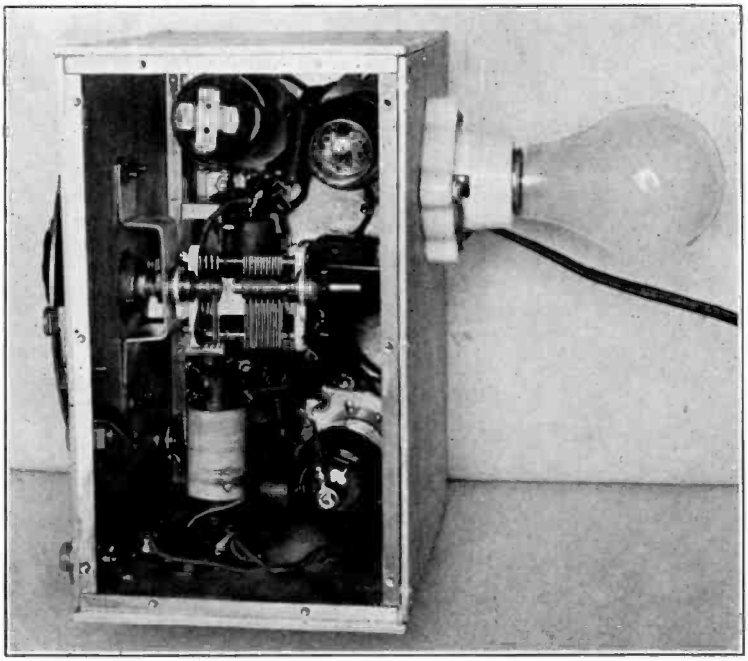


Figure 22.

LOOKING DOWN INTO THE HETERODYNE FREQUENCY METER.

A special bandspread condenser with lock nut on the bandset section is used. If desired, a line cord with built-in 320-ohm resistor, of the type used with a.c.-d.c. midgets, can be used in place of the Mazda lamp to drop the line voltage to a suitable value for the three series-connected tube heaters.

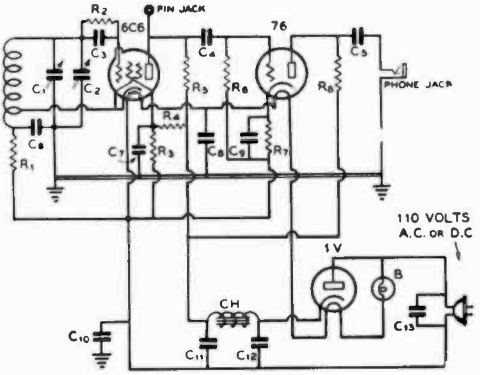


Figure 23.

WIRING DIAGRAM OF THE COMBINED FREQUENCY METER AND MONITOR.

C_1 C_2—Special band-spread condenser, 50-μμfd. and 100-μμfd. sections with individually adjustable rotors and lock nut on band-set section
C_3—100-μμfd. mica
C_4—50-μμfd. mica
C_5—0.1-μfd. tubular
C_6, C_7—.005-μfd. mica
C_8—.01-μfd. tubular
C_9, C_{10}—0.1-μfd. tubular
C_{11}, C_{12}—8-μfd. 200-v. electrolytics
C_{13}—.01-μfd. tubular
R_1—500 ohms, 1 watt
R_2—100,000 ohms ½ watt
R_3, R_4—25,000 ohms, 1 watt
R_5—100,000 ohms, 1 watt
R_6—1 meg., ½ watt
R_7, R_8—50,000 ohms, 1 watt
B—40 watt Mazda bulb
CH—30-hy. 30-ma. Choke
COIL—See text

short piece of wire to the pin-jack provided for the purpose on the front panel, and running it close to the receiver antenna lead in in order to pick up r.f. energy from the frequency meter.

If a superheterodyne is used for calibration purposes, care must be taken that the frequency meter is *not tuned to the image frequency* of the radio receiver. A calibration chart can be plotted so that a frequency range of 3,500 to 4,000 kc. is obtained. Harmonics of the oscillator can be determined accurately by multiplying the frequency readings from the chart by the number of the harmonic.

A typical calibration chart is shown in figure 26. Here it is seen that the dial reading 60 indicates frequencies of 3600, 7200, 14,400 and 28,800 kc., the latter three being the second, fourth and eighth harmonics of the generated signal

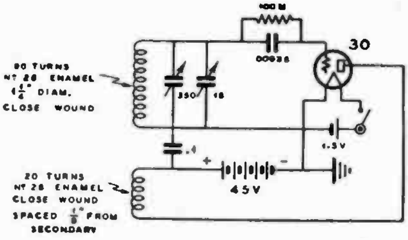


Figure 24.

CALIBRATION OSCILLATOR FOR BATTERY OPERATION.

This oscillator generates a very stable carrier over the broadcast range.

if an 80-meter coil is used. If the frequency meter has a 160-meter coil, this same reading will also show a frequency of 1,800 kc. If the frequency meter is calibrated in the range of 3,500 to 4,000 kc., it does not matter whether a 160- or 80-meter coil is used in the electron-coupled oscillator circuit.

The frequency meter can be calibrated by means of a calibration oscillator and a broadcast receiver. The calibration oscillator is tuned to zero beat in the broadcast receiver with carrier signals from broadcast stations of known frequency. The harmonics of the calibration oscillator are coupled into the frequency meter and the latter is tuned to zero beat, as heard through headphones in the output of the monitor. An example would be where the local oscillator is tuned to zero beat with a broadcast station signal

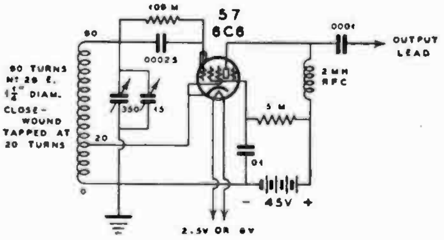


Figure 25.

CALIBRATION OSCILLATOR FOR A.C. TUBES.

With heater type tubes, battery plate supply is still used with the calibration oscillator for the sake of stability.

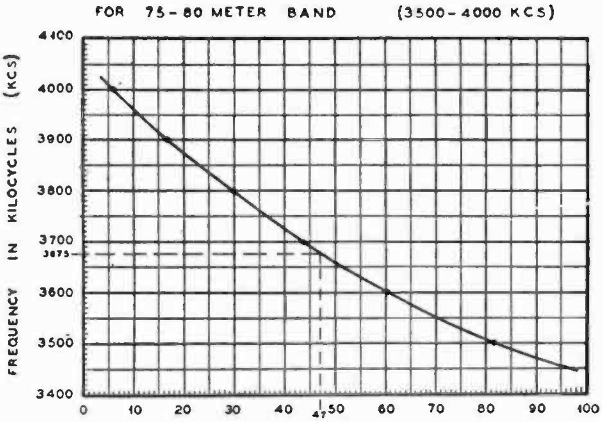


Figure 26.
TYPICAL FREQUENCY METER CURVE.
For example—say freq. meter dial reading of signal was 47; project the vertical line "47" to calibration curve, then project this point horizontally to the kc. reading which, in this case, is 3675 kcs.

of 880 kc.; the fourth harmonic of the local oscillator would be four times 880 or 3520 kc. This value can be used to obtain a calibration point on the frequency meter. Zero-beating with broadcast stations is recommended as an accurate means of calibrating frequency meters and monitors, since these stations always operate well within the allowed frequency tolerance of plus or minus twenty cycles.

Suggested circuits for calibration oscillators are shown in figures 24 and 25. Calibration oscillators can be built on small breadboards; they do not require shielding.

Before calibration is attempted, the bandsetting condenser C_2 is adjusted so that the 75-85-meter band is "centered" on the dial. If the coil specifications are followed carefully, it will be possible to cover the 3500-4000-kc. range with a little overlap at either end. The lock nut on the bandset portion of the condenser should then be tightened to insure permanency of the adjustment. The shield cover (cabinet) should be bolted in place before calibration is attempted, as its presence has an appreciable effect upon the frequency.

The calibration of the meter should be checked every few weeks, as aging of the components will affect the accuracy. Also, while the meter is sufficiently accurate for most amateur purposes, one should not put faith in it to the extent of arguing with the Grand Island monitoring station as to whether you are just in or just out of the band.

The metal cabinet in which the meter is housed *must* be rigid and well built. The one illustrated is of ⅛″ sheet aluminum and measures 7″ high x 8″ long x 5″ deep. It is held together by a generous number of angle brackets and screws.

Because only 90- or 100-volts plate supply is required for operation of the frequency meter, it is possible to dispense with a power transformer in the manner of the popular "a.c.-d.c." midgets. The three 0.3-ampere tube heaters and a 40-watt Mazda lamp are connected in series to work directly from either 110 volts a.c. or d.c. The lamp is mounted outside the cabinet to prevent heating of the components which would affect the calibration. The heat transmitted to the components inside the cabinet by the lamp is less than a power transformer mounted inside the cabinet would generate.

The meter should always be allowed to warm up a few minutes before calibrating it or taking a frequency measurement.

The oscillator coil consists of 37 turns of no. 22 d.c.c. spacewound on a ⅞″-diameter bakelite or ceramic form to cover 1½″ of winding space. It is tapped at the 9th turn (from the ground end) for the cathode connection. Duco cement should be applied to hold the turns firmly in place.

BANDSWITCHING C. W. MONITOR

A c.w. monitor is a useful adjunct to a c.w. station as a means of checking the emitted signals for chirps, excessive ripple, key clicks, tails and other undesirable characteristics. A shielded monitor enables the operator to tell from within the station how the radiated signal sounds at a distance.

The c.w. monitor illustrated in figures 27 and 28 incorporates a battery-type dual triode, one-half of which acts as an oscillating detector and the other half as an audio amplifier. To make plug-in coils unnecessary, bandswitching is employed. Three coils and a selector switch allow choice of 20-, 40- or 80-meter operation at the flip of a switch.

A standard "Little Six" 1½-volt compact dry cell and a midget 22½-volt C battery are used for power supply. The filament battery will give well over 100 hours operation before requiring replacement, and the 22½-volt plate battery will outlast several filament batteries. Both filament and plate batteries are enclosed in the cabinet, but are not fastened to the front panel as the other components are.

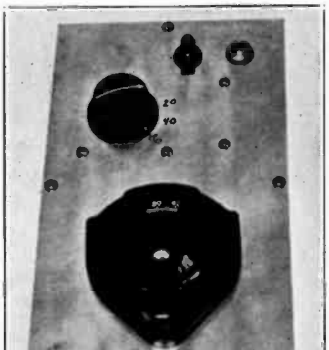


Figure 27.

BANDSWITCHING 20-40-80-METER C.W. MONITOR.

This monitor is powered by self-contained batteries. Because the drain on the batteries is low, the cost of operation per hour is very slight.

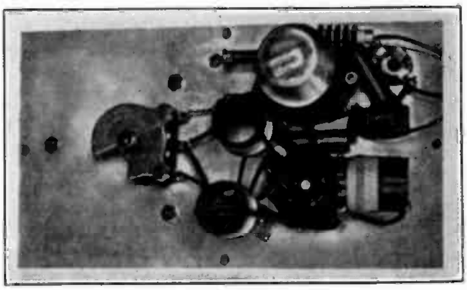


Figure 28.

BACK VIEW OF THE C.W. MONITOR.

All components except the batteries are supported by the panel.

The shield can measures 5"x5"x9" and has just enough inherent leakage to allow pickup of a comfortable signal from a nearby transmitter. To prevent excessive pickup and blocking of the detector, the a.f. plate lead to the phones contains an r.f. choke to forestall pickup by way of the phone cords. If the transmitter is of low power giving insufficient signal strength for monitoring purposes, the r.f. choke can be left out of the phone cord circuit. This will raise the signal strength noticeably.

All three coils are wound on 1½" lengths of 1-inch bakelite tubing as illustrated in figure 28. All windings are of no. 24 d.c.c. except the 80-meter grid coil, which is of no. 26 enamelled.

The 20-meter coil consists of 9 turns spaced ½" for the grid winding and 6 turns closewound for the tickler. The latter is wound at the ground end of the grid coil, with very little spacing between the windings.

The 40-meter coil consists of 22 turns spaced 1" for the grid winding and 7 turns closewound for the tickler which is wound at the ground end of the grid coil with very little spacing between the windings.

The 80-meter grid coil consists of 55 turns, closewound. The tickler is wound directly over the grid coil, near the

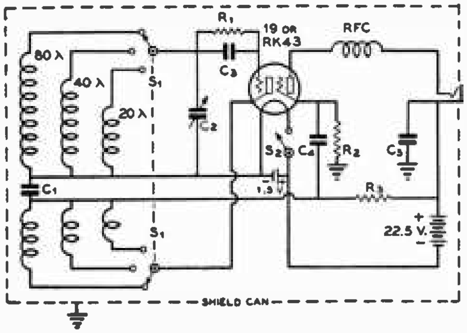


Figure 29.

Wiring diagram of the band-switching c.w. monitor. Somewhat better 20 meter operation will be had with a 45 volt plate battery (midget type).

C_1—.002-μfd. mica
C_2—50-μμfd. midget variable
C_3—100-μμfd. mica
C_4, C_5—.01-μfd. tubular
R_1—0.5 meg., ½ watt
R_2—1 meg., ½ watt
R_3—20,000 ohms, ½ watt
S_1—Two-pole three-position rotary switch
RFC—2½-mh. midget choke (omit if signal is not sufficiently strong with choke in circuit)

grounded end of the latter, and is insulated from the grid winding by a layer of paper.

It should be borne in mind that unless the polarity of the tickler coils is correct, the detector will not oscillate.

GENERAL PURPOSE PHONE TEST SET

A phone test set is quite similar to a field-strength meter, yet it lends itself to making additional measurements. It can be used as an overmodulation indicator, phone monitor, field-strength meter, neutralizing indicator and wavemeter.

Such an instrument enables the operator to check for overmodulation of a phone transmitter. When the tuned circuit of the test set is coupled to the modulated amplifier or antenna system in such a manner as to obtain half-scale deflection of the milliammeter, any flicker of the meter reading will then be an indication of overmodulation. A change in meter reading during modulation is an indication of *carrier shift*, which will produce illegal interference in adjacent radio-phone channels.

The phone test set consists of a diode rectifier connected across a tuned circuit, as shown in figure 32. A 0-1 d.c. milliammeter serves to check overmodulation, and is useful as an indicator in field-strength measurements or neutralizing adjustments in a transmitter.

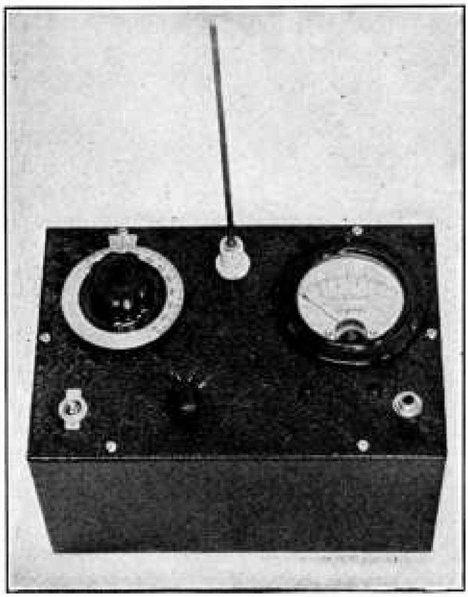
The audio volume with half to full scale meter indication is sufficient to give normal headphone response. A 5,000-ohm resistor is connected into the jack circuit for use when the test set functions as an overmodulation indicator. This resistor is in series with the diode and tends to produce a more linear rectification of the carrier wave.

For neutralizing or field-strength measurements, a short-circuiting plug or brass rod should be inserted into the phone jack to short-circuit the 5,000-ohm resistor and thereby increase the sensitivity of the meter. Neutralizing adjustments

Figure 30.

PHONE TEST SET.

This versatile instrument can be used as a phone monitor, an absorption wavemeter, field strength meter, overmodulation (carrier shift) indicator, or neutralizing indicator.



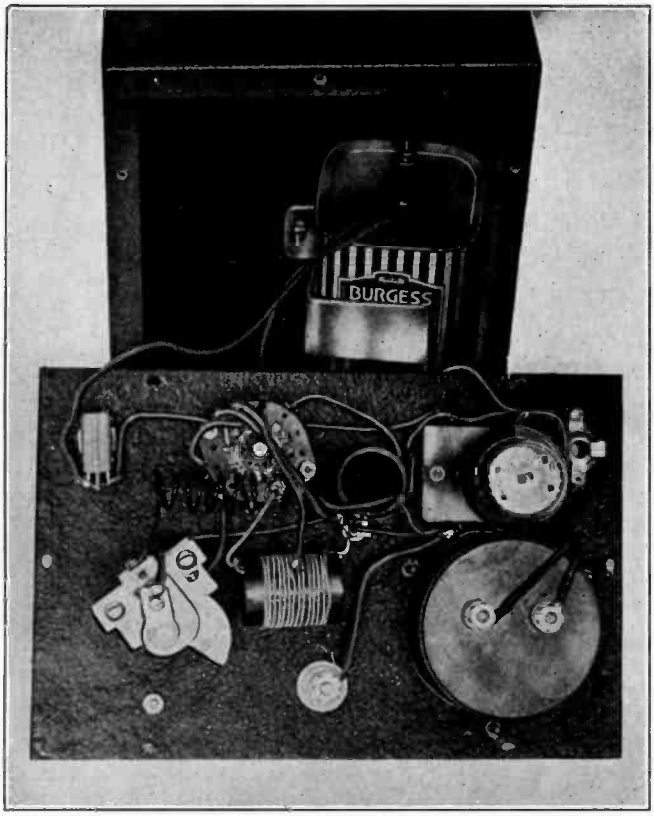


Figure 31.

INTERIOR CONSTRUCTION OF PHONE TEST SET.

All components of the general purpose phone test set are supported by the front panel; the single dry cell used for filament supply is strapped to the cabinet as illustrated.

are made by coupling the test set's tuned circuit to the transmitter stage under test (without plate voltage applied to the stage). When the stage is completely neutralized, there will be either a minimum or zero deflection of the meter needle.

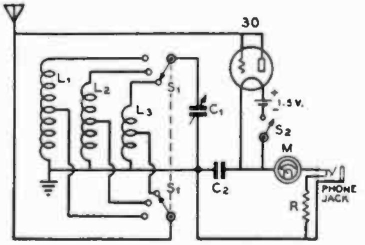
A short piece of brass rod, about 10 inches long, protrudes from the chassis as may be seen in figure 30; this rod acts as a pickup. For most purposes the signal pickup with this rod will be sufficient, but when the instrument is used or measuring field strength and there is insufficient meter deflection for an accurate reading, an auxiliary antenna consisting of several feet of insulated wire may be coupled to the pickup rod by wrapping one end of the insulated wire around the pickup rod a few times. The small amount of capacity coupling provided will be sufficient to give a higher meter reading but will not be enough to disturb the frequency of the tank circuit appreciably.

When using the instrument in the neutralization of an r.f. amplifier, a short piece of flexible wire, about 18 inches long, is clipped directly to the pickup rod. The other end of the wire is brought closer and closer to the plate lead of the stage being neutralized until a substantial deflection is obtained.

Coil Data

The use of a 140-$\mu\mu$fd. tuning condenser permits use of one coil for 5 and 10 meters, another for 20 and 40 meters and another for 80 and 160 meters.

For 5 and 10 meters the coil consists of 5 turns of no. 14 wire, ½″ diameter and spaced to occupy a length of 1 inch. This coil is self-supporting and is soldered directly to the coil switch and



WIRING DIAGRAM OF THE PHONE TEST SET.

C_1—140-µµfd. midget
C_2—.001-µfd. mica
L_1, L_2 L_3—See text
R—5000 ohms, ½ watt
S_1—Two-pole three-position rotary switch
S_2—Toggle switch
M—0-1 ma. d.c. 3" meter

tuning condenser rotor.

The 20-40-meter coil consists of 14 turns of no. 22 d.c.c. spaced to 1 inch on a 1⅛"-diameter form.

The 80-160-meter coil has 55 turns of no. 26 enamelled, closewound on a 1⅛"-diameter form.

Calibration

If the instrument illustrated is duplicated carefully, there will be no need for plotting a calibration curve or table for the individual meter in terms of decibels. The following table will be sufficiently accurate (arbitrary zero db reference level taken as .05 ma. deflection).

0.05 ma.—0 db
0.10 ma.—4½ db
0.20 ma.—8½ db
0.30 ma.—11 db
0.40 ma.—13 db
0.50 ma.—14½ db
0.60 ma.—16 db
0.70 ma.—17 db
0.80 ma.—18 db
0.90 ma.—19 db
1.00 ma.—20 db

An individual frequency calibration must be made to cover use of the instrument as an absorption wavemeter. As a wavemeter, the instrument should be used only for rough measurements, such as determining the order of a harmonic.

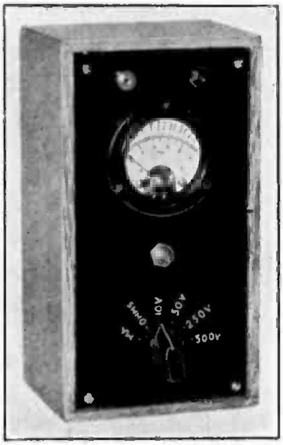


Figure 33.
SIMPLE VOLT-OHMMETER.
This volt-ohmmeter is inexpensive, easy to construct, has many uses.

A MULTIRANGE VOLT-OHMMETER

One of the most useful instruments is a simple ohmmeter for making continuity tests and for measuring the values of resistors. The same instrument can be combined into a multirange voltmeter by means of a rotary switch and a few resistors, as shown in the circuit, figure 35.

A 0-1 ma. d.c. milliammeter of the 2-inch size can be used in this test set by cutting out or reproducing the scale in figure 36 and pasting it over the existing meter scale.

The unit can be built into a small box, 4" x 8" x 3½", as shown in figures 33 and 34.

Continuity tests can be made by turning the switch to position 2; the device then acts as an ohmmeter which has a range from zero to approximately 100,000 ohms. The needle should be set to zero by means of the 1,000-ohm resistor, with the output leads short-circuited.

Resistance values may be obtained by reading the values directly on the uppermost scale. The ohmmeter proper consists only of the 0-1 d.c. milliammeter, a 4,000-ohm fixed resistor, a 1,000-ohm variable resistor and a 4.5-volt C battery. The unknown resistance is connected in series with this combination. The additional components shown in the photograph and circuit diagram are necessary only when the meter is used as a multirange voltmeter and 0-1 d.c. milliammeter.

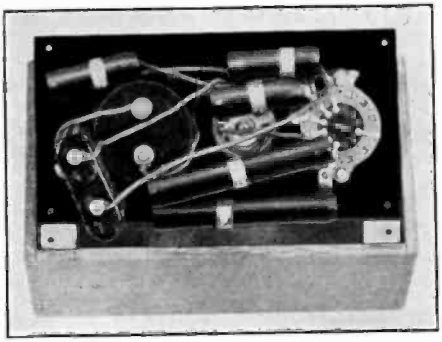


Figure 34.
INTERIOR VIEW OF OHMMETER.
Showing position of battery, rotary switch and precision (wirewound) resistors.

The accuracy of the instrument as a voltmeter will be determined by the accuracy both of the meter itself and the series resistors.

With the tap switch on position 1, the meter movement will be burned out if the pin jacks are connected to a source of voltage greater than about 1 volt. For this reason, the position of the tap switch pointer should always be checked carefully before using the instrument as a voltmeter.

When measuring a voltage the general order of which is not known, the switch should be thrown to the 500-volt position and then switched to progressively lower scales until a readable deflection is obtained.

MEDIUM- AND LOW-RANGE OHMMETER

Most ohmmeters, including the one just described, are not adapted for accurate measurement of low resistances—in the neighborhood of 100 ohms, for instance.

The ohmmeter illustrated in figure 37 was especially designed for the reasonably accurate reading of resistances all the way down to one ohm. Two scales are provided, one going in one direction and the other scale going in the other direction because of the different manner in which the milliammeter is used in each case. The low scale covers from 1 to 100 ohms and the high scale from 100 ohms to 10,000 ohms. The high scale is in reality a medium-range scale. For accurate reading of resistances over 10,000 ohms, the circuit of the ohmmeter previously described should be used.

The 1-100-ohm scale is useful for checking transformers, chokes, r.f. coils, etc. which often have a resistance of only a few ohms.

The calibration scale will depend upon the internal resistance of the particular make of 1.5-ma. meter used. The instrument can be calibrated by means of a Wheatstone bridge or a few resistors of known accuracy. The latter can be series-connected and parallel-connected to give sufficient calibration points. A hand-drawn scale can be pasted over the regu-

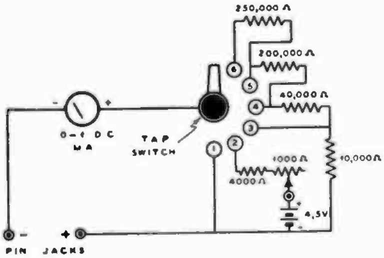


Figure 35.
VOLT-OHMMETER CIRCUIT.

Position 1 of Switch	0-1 ma.
Position 2 of Switch	0-100,000 Ohms
Position 3 of Switch	0-10 Volts
Position 4 of Switch	0-50 Volts
Position 5 of Switch	0-250 Volts
Position 6 of Switch	0-500 Volts

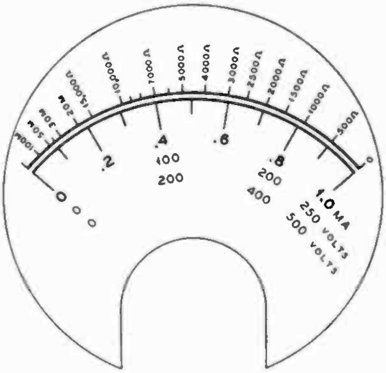


Figure 36.
REPLACEMENT SCALE FOR 2 INCH 1 MA. METER.

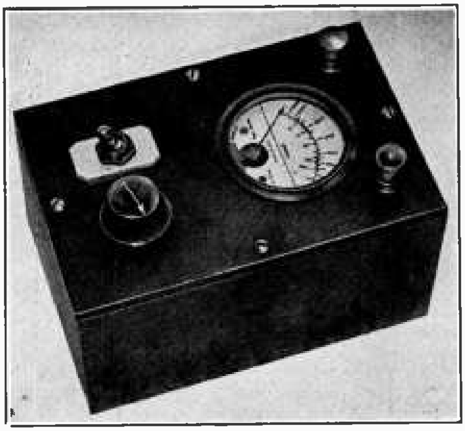


Figure 37.

LOW RANGE OHMMETER.

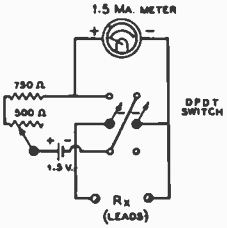
This ohmmeter is particularly useful for measuring resistances too low to be read accurately on an ohmmeter of the type illustrated in figure 35.

lar meter scale to give a direct reading in ohms.

Before calibrating the instrument or using it for measurement, the test prods should always be touched together and the zero adjuster set accurately.

Figure 38.

Diagram of the low-range ohmmeter illustrated in figure 37.



DIODE V. T. VOLTMETER

A d.c. voltmeter can be used for measuring peak a.c. voltages if a suitable rectifier and condenser are used in conjunction with the d.c. meter. The device illustrated in figure 39 and diagrammed in figure 40 can be used with any 1000-ohms-per-volt d.c. voltmeter to read peak a.c. volts. The 1-v tube acts as a peak-type diode rectifier.

Peak a.c. voltages up to 600 volts can be applied safely to the instrument. The r.m.s. value of the a.c. voltage under measurement can be determined with good accuracy by multiplying the peak value as read on the meter by 0.71.

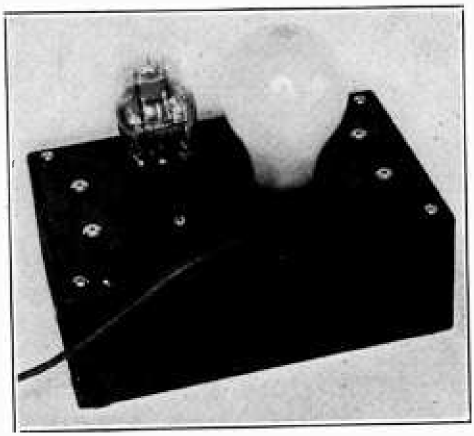


Figure 39.

DIODE METER-RECTIFIER.

This diode rectifier converts a d.c. voltmeter into an a.c. peak voltmeter.

The instrument illustrated can be used in conjunction with a d.c. voltmeter of suitable range to measure peak voltages across filter condensers and to check turns ratios of transformers, etc. It can also be used as an a.f. output meter when such a meter is required for checking a receiver or audio amplifier.

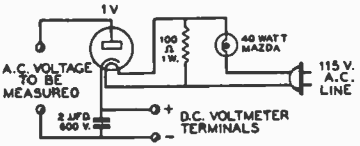


Figure 40.

WIRING DIAGRAM OF THE DIODE PEAK RECTIFIER.

A. C.-TYPE V. T. VOLTMETER

Peak value of radio- and audio-frequency voltages can be measured by means of a vacuum tube voltmeter. This device can be calibrated from a 60-cycle source, and the same calibration curve will be satisfactory for radio-frequency

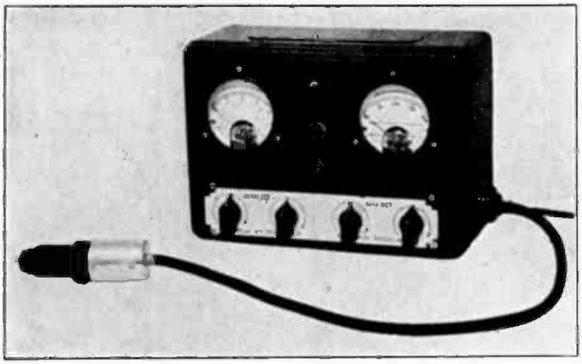
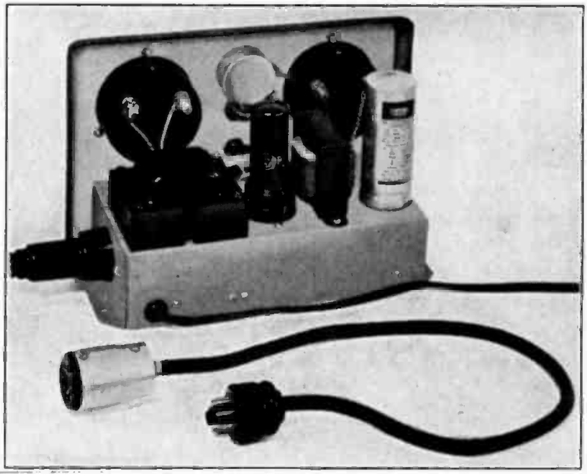


Figure 41.
PEAK V.T. VOLTMETER.
An instrument of this type is especially useful for measuring r.f. voltages, and a.c. voltages where no current can be drawn from the circuit.

Figure 42.
INTERIOR CONSTRUCTION OF V.T. VOLTMETER.



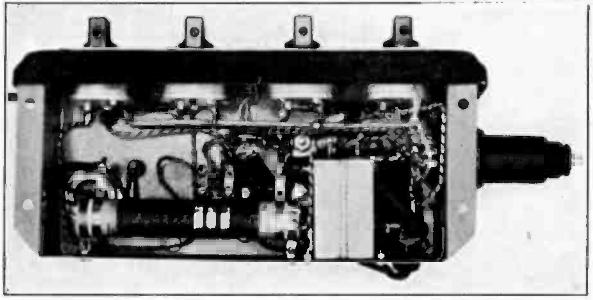


Figure 43.
UNDER-CHASSIS VIEW OF PEAK V.T. VOLTMETER.

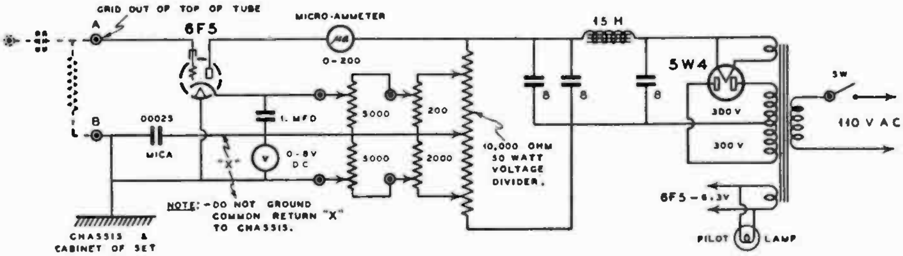


Figure 44.
WIRING DIAGRAM OF V.T. VOLTMETER AND POWER SUPPLY.

measurements except at very high frequencies. A vacuum tube voltmeter is also very useful for aligning the circuits of a radio receiver. The device has nearly infinite input resistance. It consists of a vacuum tube, operated with high grid bias. The tube acts as a rectifier or detector, and the change in plate current produced by the application of an external grid voltage is indicated by means of a microammeter. There are many types of vacuum tube voltmeters, one of which is shown in figures 41 to 44. The outstanding features of this device are: (1) a.c. operation, (2) good calibration stability, very nearly independent of moderate changes in line voltage, (3) high-μ 6F5 tube which can be plugged into the side of the metal cabinet for voltage measurements on the workbench or plugged into an extension cable for making r.f. tests where the length of grid and ground leads is of extreme importance, as in lining up r.f. amplifiers in radio receivers. A vacuum tube voltmeter is one of the few types of instruments which allows the measurement of a.v.c. voltage in receivers. This type of measurement is helpful in effecting correct receiver alignment.

A 0-200 microammeter is operated at an initial deflection of approximately 10 microamperes or it can be used as a "slide-back" type of voltmeter with practically zero initial deflection. The input voltage should be balanced out by a change in the setting of the 6F5 grid bias potentiometers. The d.c. voltmeter reading at this point is the actual peak input voltage. This type of measurement depends upon maintaining the microammeter reading at some fixed, low indication.

When this device is in operation, care must be taken to provide a d.c. path from the grid of the 6F5 to the chassis ground. If this is not done, there will be no bias on the 6F5 and the resulting high plate current will damage the microammeter. Most circuits under measurement will complete this path, which can be as high as several megohms without damage to the microammeter. The complete test set is housed in a commercially available metal cabinet of standard size.

A.F. AND R.F. POWER MEASURING DEVICE

For accurate measurement of a.f. and r.f. power a thermogalvanometer in series with a non-inductive resistor of known resistance can be used. The meter should have good accuracy, and the exact value of resistance should be known with accuracy. Suitable dummy load resistors of the "vacuum" type are available in various resistances in both 100 and 250 watt ratings. These are virtually non-inductive and may be considered as a pure resistance except at ultra high frequencies. The resistance of these units is substantially constant for all values of current up to the maximum dissipation rating, but where extreme accuracy is required a correction chart of the dissipation coefficient of resistance (supplied by the manufacturer) may be employed. This chart shows the exact resistance for different values of current through the resistor.

If a current-squared r.f. galvanometer (commonly 115 ma. full scale deflection reading 0-100) is used, it will be necessary to use a conversion chart to determine the exact value of current from the scale reading. If a thermo ammeter is used, the current reading can be taken directly from the meter.

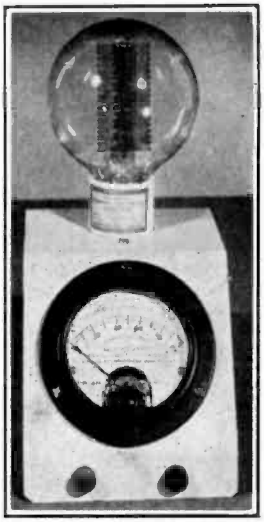


Figure 45.

R.F. AND A.F. POWER MEASURING DEVICE.

A thermogalvanometer or thermo ammeter is placed in series with a non-inductive dummy load resistor whose resistance is known accurately.

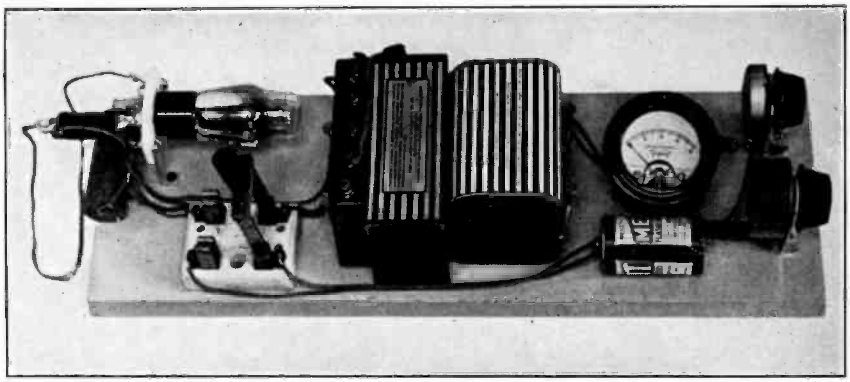


Figure 46.
BREADBOARD-CONSTRUCTED BATTERY-OPERATED V.T. VOLTMETER.
This battery-operated v.t. voltmeter is considerably less elaborate than the one illustrated in figures 41-44, but has many useful applications around an amateur station.

BATTERY-TYPE V. T. VOLTMETER

A very simple battery-operated vacuum tube voltmeter is shown in figures 46 and 47. This type of meter can be calibrated by means of a potentiometer and low-reading a.c. voltmeter connected across a transformer filament winding. The a.c. voltmeter reads r.m.s. values which may be converted arithmetically to peak values. For example, 1.2 volts r.m.s. equals 1.68 volts peak. The maximum peak voltage which can be measured by this instrument is not over 2 volts; the useful range is from about 0.5 to 1.8 peak volts.

The steady direct plate current through the meter to the 30 tube is balanced out by a bridge arrangement of resistors and a small flashlight cell. The 30-ohm rheostat R_1 has an off position and is turned on to protect the meter when the switch or the grid circuit is open. The same danger and considerations concerning an open grid circuit apply to this v.t. volt-meter as to the instrument previously described.

The range of the meter is from about 0.5 volt to 1.8 volts peak, and the accuracy is good on a.c. or on r.f. voltages (except when the frequency is in the u.h.f. region). While greatest accuracy will be obtained by calibrating the individual instrument by means of known a.c. voltages, accuracy sufficient for all practical purposes may be obtained by using the following calibration, provided of course that the instrument is an exact duplicate of the one described.

30 μa.—0.7 volts peak
60 μa.—1 volt peak
120 μa.—1.4 volts peak
200 μa.—1.8 volts peak

If it is desirable that the meter indicate peak-volts directly, and if the instrument has been accurately calibrated, a direct-reading scale may be drawn and pasted over the old one.

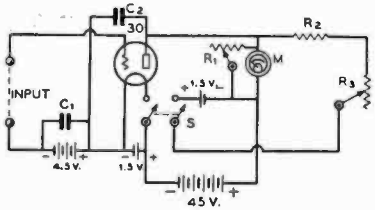


Figure 47.
WIRING DIAGRAM OF THE BATTERY-OPERATED V.T. VOLTMETER

C_1—.002-µfd. mica
C_2—1-µfd. paper tubular
R_1—30-ohm rheostat
R_2—5000 ohms, 1 watt
R_3—10,000 ohms
S—D.p.s.t. midget knife switch
M—0-200-µa. d.c. microammeter
CAUTION: Refer to text regarding possible damage to meter

BANDSWITCHING TEST OSCILLATOR

(Or Signal Generator)

A modulated test signal is required for lining up a superheterodyne receiver in order to simplify the procedure. The intermediate and tuned-radio-frequency circuits in the receiver must be properly aligned; a signal generator produces a signal similar to that of a weak radio signal, yet it is instantly available at any desired frequency.

The simple, one-tube modulated oscillator illustrated in figures 48 and 49 and diagrammed in figure 50 covers the range of 75 to 1500 kc. by means of bandswitching. Its harmonics can be used for work at still higher frequencies.

The oscillator circuit is a standard *Hartley* with a type RK-42 tube. A variable grid leak is controlled from the front panel; this gives a means for obtaining either unmodulated or self-modulated carrier signals. High values of grid leak cause a blocking grid action, and the result is a test r.f. signal modulated at some audio frequency of 500 or 1,000 cycles. This grid leak resistor at low resistance values produces an unmodulated signal which simulates that of a c.w. signal.

A signal 1.5-volt dry cell and a 22.5-v. C-battery furnish filament and plate potentials for the oscillator. The entire instrument, including the batteries, is con-

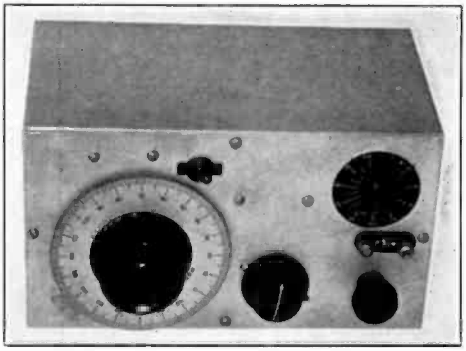


Figure 48.

TEST SIGNAL GENERATOR.

This test signal generator covers the range of from 75 kc. to 1500 kc. by means of bandswitching. It is important that the instrument be built in a metal can which shields it thoroughly.

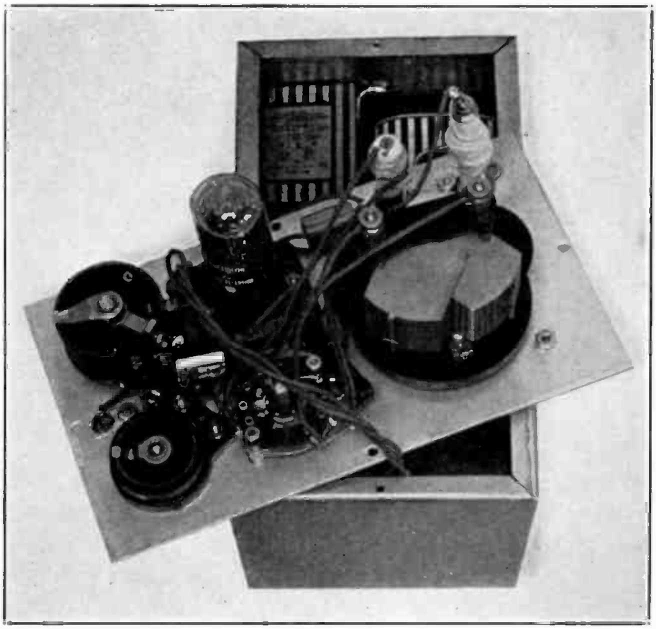


Figure 49.

INTERIOR OF THE BATTERY - POWERED TEST SIGNAL GENERATOR.

Either a pure unmodulated or a modulated carrier wave can be obtained from the instrument. A continuously variable attenuator is provided for adjusting the output signal voltage to the desired level.

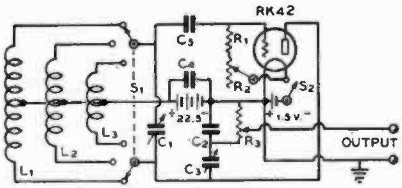


Figure 50.
WIRING DIAGRAM OF THE TEST SIGNAL GENERATOR.

C_1—.00035-or .00037-μfd. b. c. l. type condenser
C_2—.0005-μfd. mica
C_3—3-30-μμfd. mica trimmer
C_4—.01-μfd. tubular
C_5—.002-μfd. mica
R_1—5000 ohms 1 watt
R_2—5-meg. pot.
R_3—200-ohm pot.
L_1, L_2, L_3—Refer to text.

tained in a metal can measuring 5″x5″x 9″. Any 350- or 375-*μμ*fd. b.c.l. type variable condenser and dial may be used. The one used in the model illustrated is an old Remler b.c. condenser.

Level Control

A small portion of the r.f. voltage across the plate side of the tuned circuit is applied across a condenser type voltage divider consisting of a 3-30-*μμ*fd. mica trimmer and a .0005-*μ*fd. fixed mica condenser. The trimmer is set near maximum capacity to give the optimum capacity ratio, a compromise between stability and maximum available output signal voltage. Across the .0005-*μ*fd. mica condenser is a 200-ohm potentiometer, which is used as an attenuator to regulate the amplitude of the test signal. Variation in output level is obtained by this method without appreciably affecting the frequency of the oscillator. The effect of the potentiometer setting on the oscillator frequency of the oscillator. The effect of screwing the trimmer C_3 until the capacity is only about 5 *μμ*fd. However, this reduces the amplitude of the maximum test signal voltage available.

The modulated wave emitted by the oscillator is rather broad but is suitable for most receiver alignment work.

Coil Data

All three coils are jumblewound on ½″- diameter porcelain insulator rods or wooden dowels, and are center-tapped. The number of turns for the various frequency ranges follow:

75-220 kc.—1100 turns no. 34 d.s.c. about ¾″ long.
200-500 kc.—450 turns no. 32 d.s.c. about ½″ long.
500-1500 kc.—175 turns no. 26 d.c.c. about ½″ long.

Calibration

The instrument is calibrated by coupling it into a radio receiver which can be tuned to broadcast stations in the frequency range of from 550 to 1500 kc. The oscillator is tuned to zero beat with broadcast station signals of a known frequency.

The range of from 200 to 500 kc. can be calibrated in a similar manner by using the harmonics of the signal generator to produce zero beat. When a calibration scale is to be plotted, the frequency of the receiver can be divided by 2 or 3, depending upon whether the second or third harmonic of the oscillator is being used in the calibration of the long-wave range.

Operation

The long-wave ranges of this test oscillator are used to line up the i.f. circuits in superheterodyne receivers. The majority of receivers have an intermediate frequency of approximately 465 k.c. The output terminals of the test oscillator can be connected to each stage of the i.f. amplifier in the radio receiver while that stage is being lined up. The last i.f. stage should be aligned first. The signal generator produces a steady tone-modulated signal which can be heard in the output of the radio receiver. The short-wave ranges of the oscillator are useful for lining up the h.f. oscillator, first detector and r.f. stage, so as to make them track properly. More details are given in the chapter on *Receiver Theory*.

The frequency of a quartz crystal, such as that used in a single signal receiver, can be determined very closely by setting the quartz plate on, or leaning it against, the grid of the oscillator tube.

The oscillator frequency will suddenly change at resonance with the crystal, as will be heard in a broadcast receiver tuned to the second harmonic of the oscillator. This test requires a manipulation of both oscillator and broadcast receiver, but once the crystal frequency is found, the i.f. amplifier in the short-wave receiver can be lined up to this same frequency by means of the oscillator.

CATHODE-RAY OSCILLOSCOPES

Measurements of r.f. and a.f. voltage and wave form can easily be made with the aid of a cathode-ray oscilloscope. Such a device includes a vacuum tube which has two sets of deflecting plates for controlling a beam of electrons; this beam strikes a fluorescent screen on the face of the tube and traces a pattern of the signal applied to the control grid or deflection plates. The fluorescent screen in the tube produces a visual indication of the pattern of r.f. or audio voltages.

Some of the many uses of the cathode ray oscilloscope in its various forms are as follows:

Measurement of d.c. voltage or current.
Measurement of peak a.c. and r.f. voltage.
Trouble-shooting in receivers.
Adjustment of i.f. stages (including bandpass).
Measurement of audio amplifier distortion, overload and gain.
Adjustment phase-inversion circuits.
Checking of power supplies.
Checking of harmonic content.
Measurement of phase angle and phase distortion.
Measurements for dynamic tube characteristic curves.
Checking of phone signals and per cent modulation by:
  Modulation envelope
  Trapezoidal pattern
  Cat's eye pattern
Making condenser power factor tests.
Making overall frequency response tests.
Determining unknown frequencies.
Adjusting auto vibrators.
Studying surges and transients.

Cathode-ray oscilloscopes are extremely useful for measuring percentage modulation and analyzing distortion in a radiophone transmitter.

While constructional data is given for two oscilloscopes, one a simple instrument for checking modulation in a radiophone transmitter and the other a more elaborate instrument possessing greater versatility, anyone contemplating construction of an oscilloscope should invest in one of the many excellent books on the subject, available very reasonably from *Rider, RCA Manufacturing Co., Dumont* and others. Because of space limitations, a comprehensive treatise on the theory, construction and use of oscilloscopes is not within the scope of this book. This will be appreciated when it is realized that there appear books on oscilloscopes which contain over 100 pages devoted to applications of the instrument alone.

C. R. MODULATION CHECKER

A very simple oscilloscope, such as the one shown in figures 51 and 52, is entirely satisfactory for modulation checking. It consists of an RCA-913 cathode-ray tube which has a fluorescent screen approximately one inch in diameter. This tube, and a suitable power supply, are built into a small metal cabinet measuring 5"x6"x9".

A dime magnifying glass obtainable at any five-and-ten-cent store gives a trapezoidal figure comparable in size to that of a 2" cathode-ray tube. The magnifying glass is held about 2 inches from the screen of the 913 by a piece of bakelite tubing which is slipped over the 913 and allowed to project slightly beyond the magnifying glass in order to keep out external light.

Three a.f. binding posts allow connection of the scope to the modulator of any phone transmitter with 5-to 1000-watts carrier power. No external coupling condenser is required; a lead may be connected directly to the class C amplifier plate return circuit at the modulation transformer terminals. *Beware of the*

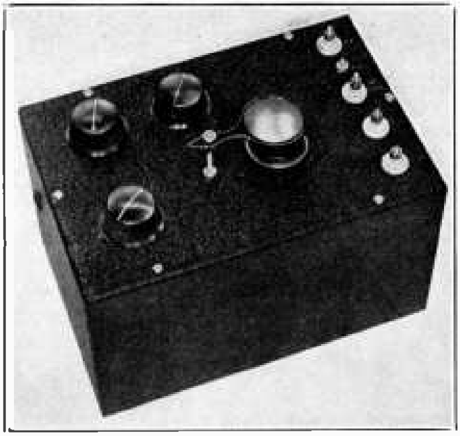


Figure 51.

CATHODE RAY MODULATION CHECKER.

This inexpensive oscilloscope is useful for obtaining trapezoidal modulation patterns. A cheap magnifying glass and tubular shade to keep out external light give a pattern comparable to that obtained with a 2-inch c.r. tube.

high voltage. Connections for a grid-modulated transmitter are similar, except that the modulation transformer connection is in the grid-return instead of the plate return circuit of the r.f. amplifier. The resistor network adapts the instrument for use on any transmitter at a moment's notice; no trouble will be experienced in getting just the right amount of audio deflecting voltage.

The network resistors R_5 and R_6 are not standard items; each is made up of 1-megohm 1-watt carbon resistors in series, R_5 requiring six such resistors and R_6 two. The 1-watt resistors are mounted on terminal strips.

When a voltage is applied to only one set of plates, a thin straight line is obtained on the face of the cathode-ray tube when the 25,000- and 50,000-ohm potentiometers are correctly adjusted.

When a modulated carrier voltage is applied to one set of plates, and the audio modulating voltage applied to the other, a *trapezoidal figure* will be produced during modulation. With 100 per cent modulation this pattern should be a straight-sided triangle, sharply pointed. Typical patterns are shown for plate and grid modulation in the accompanying sketches, figure 53.

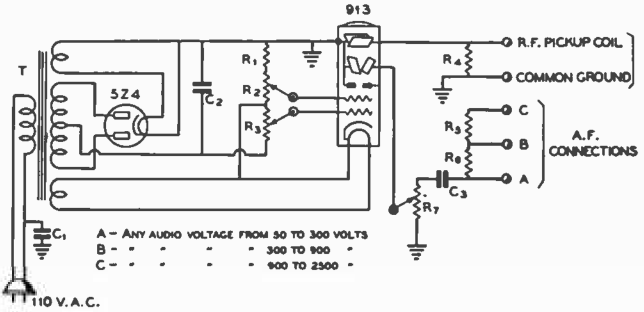
The audio- or radio-frequency voltage should have an amplitude of at least 50 volts in order to cause good deflection on the screen. The amplitude should be sufficient to give a large pattern on the face of the tube. The 25,000- and 50,000-ohm potentiometers are adjusted to give sharp definition and a reasonable amount of illumination on the screen. The r.f. voltage can be secured by coupling a few turns of wire to the center of the modulated amplifier tank coil or to the antenna coupler.

C. R. 'SCOPE WITH SWEEP CIRCUIT

Most audio-frequency measurements require a variable frequency sweep oscillator circuit which can be synchronized with the frequency of the audio voltage

Figure 52.

WIRING DIAGRAM OF THE CATHODE-RAY MODULATION CHECKER.



C_1—.01-μfd. tubular
C_2—1-μfd. 1000 volts w.v.
C_3—.01-μfd. mica, 5000 volts
R_1—150,000 ohms, 1 watt
R_2—50,000-ohm pot.
R_3—25,000-ohm pot.
R_4—5 meg., 1 watt
R_5—6 meg., 6 watts (see text)
R_6—2 meg., 2 watts (see text)
R_7—1 meg pot.
T—350 v. each side c.t., 40 ma.

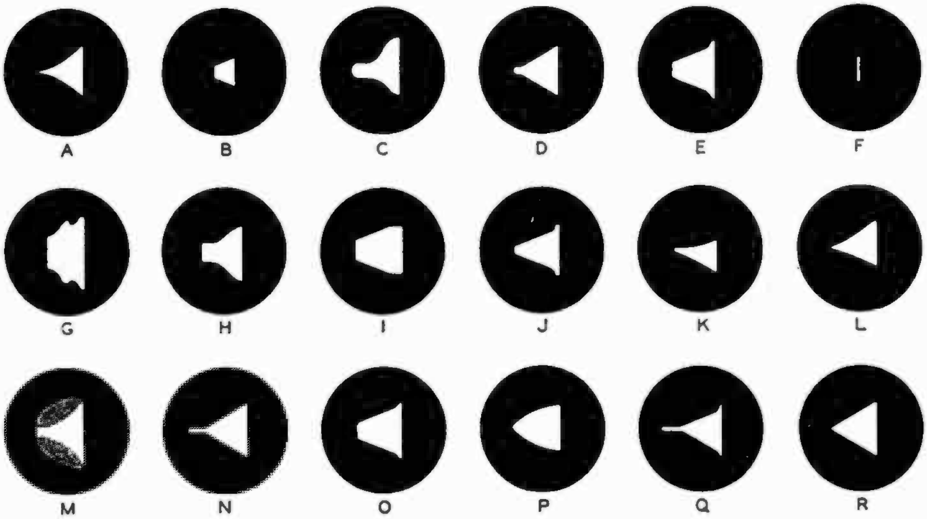


Figure 53.
OSCILLOSCOPE PATTERNS, PLATE AND GRID MODULATION.

A: Plate-Modulated. Excessive Bias or Regeneration.

B: Undistorted Plate or Grid Modulation. Less Than 100%.

C: Suppressor-Modulated 802 or RK-20 Phone with Crystal in Grid Circuit.

D: Suppressor-Modulated Phone with Separate R. F. Driver Tube, Modulated Approximately 100%.

E: Maximum Plate Modulation of 6L6, 813 or 814 Screen-Grid Tubes without Screen Modulation (or Insufficient Screen Modulation).

F: Unmodulated Carrier Signal.

G: Plate-Modulated. Regeneration and Modulator Overload or Mismatch.

H: Plate Overmodulation with Bad Mismatch of Class-B Modulator Impedance.

I: Plate-Modulated. Insufficient R. F. Grid Drive to Allow Over 50% Modulation.

J: Grid-Modulation. Excessive R. F. Grid Drive.

K: Grid- or Plate-Modulated Phone with Improper Neutralization or Detuned Final Amplifier.

L: 100% Grid Modulation, 2 Times Cut-Off Bias. Very little distortion.

M: Phase Shift Through Speech Amplifier. Approximately 60% Modulation. No Distortion in Output.

N: Plate Overmodulation. Too Much Audio Input.

O: Class-B Mismatched or Underpowered. Corners of Pattern Indicate Overmodulation. May be due to Excessive Antenna Load for Transmitter.

P: Insufficient R. F. Grid Drive or bias with Plate Modulation.

Q: Very Bad Overmodulation. Too Much Audio Input with Plate Modulation.

R: 100% Plate Modulation. No Distortion.

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being tested. For this purpose, a saw-tooth wave form is desirable; it can be obtained from a condenser-charge-and-discharge-circuit. The condenser is slowly charged, then rapidly discharged by means of a gas-filled type 885 triode which ionizes at a certain peak voltage and short-circuits the condenser in the plate circuit.

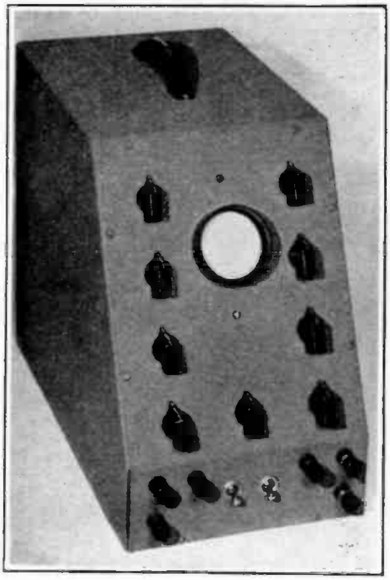
The sweep circuit oscillation can be synchronized with that of the audio-frequency signal by applying a small portion of the latter to the grid circuit of the type 885 tube. The approximate frequency of the saw-tooth oscillator is adjusted by means of the capacity in the plate circuit of the tube and the value of the resistance in series with the B-plus load from this tube. The output of this oscillator must be amplified by a high-gain audio stage in order to provide sufficient voltage to produce a sweep across the screen of the cathode-ray tube.

The oscilloscope diagrammed in figure

Figure 54.

DE LUXE CATHODE RAY OSCILLOSCOPE.

With amplifiers and linear sweep, this oscilloscope can be built at a reasonable price yet will do most anything a larger model will do. The cathode ray tube is a 2 inch RCA-902.



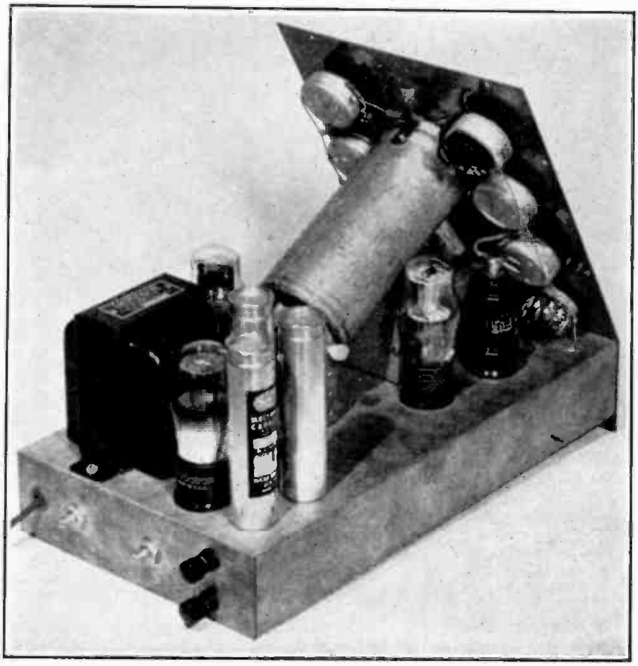


Figure 55.

INTERIOR CONSTRUCTION OF THE C.R. OSCILLOSCOPE.

The piece of heavy iron pipe shields the cathode-ray tube both inductively and electrostatically. The pipe is supported from the panel by angle brackets. Sufficient space should be allowed to rotate the power transformer to eliminate any inductive coupling remaining after the pipe shield has been installed.

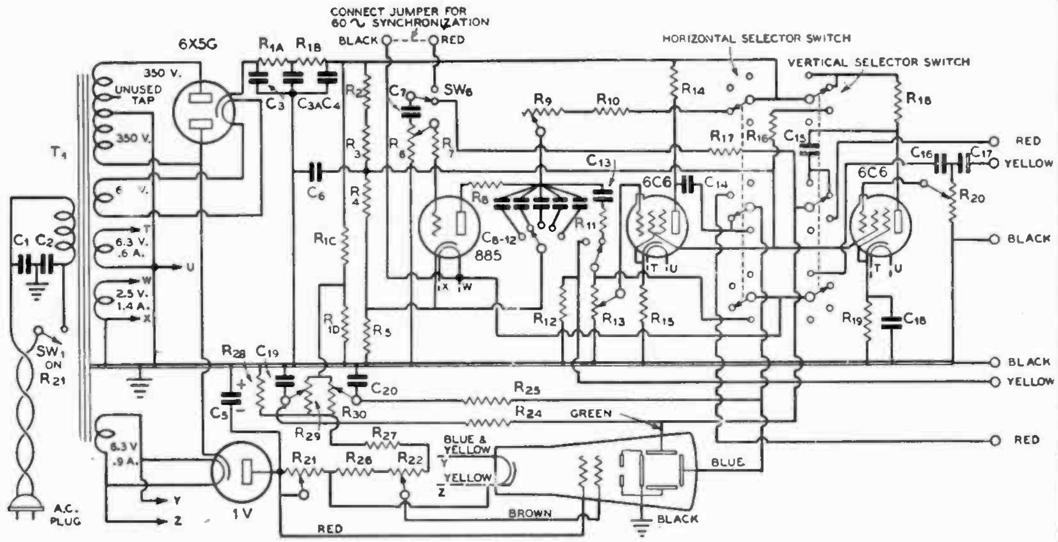


Figure 56.

VERSATILE CATHODE RAY OSCILLOSCOPE INCORPORATING DEFLECTION PLATE AMPLIFIERS, LINEAR SWEEP, AND RCA-902 TWO INCH C.R. TUBE.

R_1—5000 ohms, 1 watt

R_{1A}, R_{1B}—2500 ohms, 1 watt

R_{1C}—250,000 ohms, 1 watt

R_{1D}—50,000 ohms, ½ watt

R_2, R_3, R_4—40,000 ohms, 1 watt

R_5—1500 ohms, ½ watt

R_6—50,000-ohm potentiometer

R_7—25,000 ohms, ½ watt

R_8—200 ohms, ½ watt

R_9—5-megohm potentiometer

R_{10}—750,000 ohms, ½ watt

R_{11}, R_{12}—1 megohm, ½ watt

R_{13}—3-megohm potentiometer

R_{14}—100,000 ohms, 1 watt

R_{15}—1000 ohms, ½ watt

R_{16}—200,000 ohms, 1 watt

R_{17}—2 megohms, ½ watt

R_{18}—100,000 ohms, 1 watt

R_{19}—1000 ohms, ½ watt

R_{20}—500,000-ohm potentiometer

R_{21}—25,000-ohm potentiometer with a.c. line switch

R_{22}—50,000 ohm pot.

R_{23}—150,000 ohms, 1 watt

R_{24}—2 megohms, ½ watt

R_{25}—4 megohms, ½ watt

R_{26}—25,000 ohms, ½ watt

R_{27}—100,000 ohms, 1 watt

R_{28}—100,000 ohms, 1 watt

R_{29}, R_{30}—100,000-ohm potentiometers

C_1, C_2—0.1-μfd., 400-volt tubular

C_3, C_4, C_5—8-μfd., 450-volt electrolytics

C_{3A}—8-μfd., 450-volt electrolytic

C_6—2-μfd., 200-volt electrolytic

C_7—0.1-μfd., 400-volt tubular

C_8—0.5-μfd., 400-volt tubular

C_9—0.1-μfd., 400-volt tubular

C_{10}—.02-μfd., 400-volt tubular

C_{11}—.005-μfd., mica

C_{12}—.001-μfd., mica

C_{13}, C_{14}, C_{15}, C_{16}, C_{17}—0.1-μfd., 400-volt tubulars

C_{18}—.05-μfd., 400-volt tubular

C_{19}, C_{20}—0.1-μfd. 400-volt tubular

T_1—Cathode ray oscilloscope transformer

SW_1—Line switch on R_{21}

SW_2—5-position, single-pole switch

SW_3—S.p.d.t. toggle switch

SW_4, SW_5—3-circuit 4-position, non-shorting switch

SW_6—S.p.d.t. toggle switch

C.r. tube—RCA-902

C.r. tube mounting—Amphenol 913 plug and bracket assembly

Note: Either 6C6's or 6J7's may be used with equally good results, the 6J7's requiring less space.

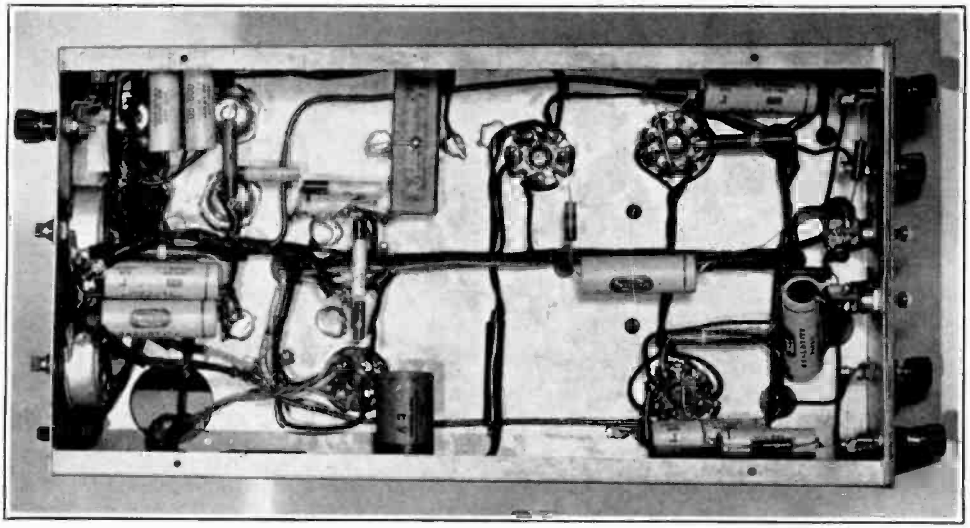


Figure 57.
SHOWING LAYOUT OF COMPONENTS MOUNTED BELOW THE CHASSIS.
The leads going to the various selector switches and potentiometers should not be cabled, though the heater and power supply leads may be cabled without harm.

56 contains vertical and horizontal deflection plate amplifiers, linear sweep and most of the adjuncts found in the most expensive oscilloscopes. The only difference is the use of a small 902 two-inch c.r. tube for the sake of economy.

In order to minimize both the inductive and electrostatic pickup of a.c. ripple by the c.r. tube, making it impossible to obtain a narrow line picture on the screen, the c.r. tube is shielded by placing it inside a piece of galvanized iron pipe just sufficiently large to take the tube, and the power transformer is rotated slightly until the best line is obtained. The method of housing the tube in the piece of iron pipe may be seen in figure 55.

It is important that the various leads to the potentiometers and switches *not* be cabled together for the sake of appearance.

Workshop Practice

WITH a few possible exceptions such as fixed air condensers and wirewound transmitting coils, it hardly pays one to attempt to build the components required for the construction of an amateur transmitter. This is especially true when the parts are of the type used in construction and replacement work on b.c.l. receivers, as mass production has made these parts very inexpensive.

Transmitters

Those who have and wish to spend the necessary time can effect considerable monetary saving in their transmitters by building them from the component parts. The necessary data are given in the construction chapter of this handbook.

To many builders, the construction is as fascinating as the operation of the finished transmitter; in fact, many amateurs get so much satisfaction out of building a well-performing piece of equipment that they spend more time constructing and rebuilding equipment than they do operating the equipment on the air.

Those who are not mechanically minded and are more interested in the pleasures of working dx and rag chewing than in experimentation and construction will find on the market many excellent transmitters which require only line voltage and an antenna. If you are one of those amateurs, you will find little to interest you in this chapter.

Receivers

There is room for argument as to whether one can save money by constructing his own communications receiver. The combined demand for these receivers by the government, amateurs, airways, short-wave listeners and others has become so great that it may be argued that there is no more point in building such a receiver than in building a regular broadcast set. Yet, many amateurs still prefer to construct their own receivers—in spite of the fact that it costs almost as much to build a receiver as to purchase an equivalent factory made job—either because they enjoy construction work and take pride in the fruits of their efforts, or because the receiver must meet certain specifications and yet cost as little as possible.

The only factory produced receiver that is sure to meet the requirements of every amateur or short-wave listener is the rather expensive de luxe type having every possible refinement. An amateur of limited means who is interested only in c.w. operation on two or three bands, for instance, can build himself at a fraction of the cost of a de luxe job a receiver that will serve his particular purpose just as well. In the receiver construction chapter are illustrated several relatively inexpensive receivers which, for the particular purpose for which they were designed, will perform as well as the costliest factory built receiver.

TYPES OF CONSTRUCTION

Breadboard

The simplest method of constructing equipment is to lay it out in breadboard fashion, which consists of screwing the various components to a board of suitable size, arranging parts so the important leads will be as short as possible.

While this type of construction is also adaptable to receivers and measuring and monitoring equipment, it is used principally for transmitter construction and remains a favorite of the c.w. amateurs using high power.

Breadboard construction requires a minimum of tools; apparatus can be constructed in this fashion with the aid of only a rule, screwdriver, ice pick, saw and soldering iron. A hand drill will also be required if it is desired to run part of the wiring underneath the breadboard. Ordinary carpenter's tools will be quite satisfactory.

Metal Chassis

Though quite a few more tools and considerably more time will be required for its construction, much neater equipment can be built by mounting the parts on sheet metal chassis instead of breadboards. This type of construction is advisable when shielding of the apparatus is necessary, as breadboard construction does not particularly lend itself to shielding. The appearance of the apparatus may be further enhanced by incorporating a front panel upon which the various controls are placed, though a front panel is not absolutely necessary.

If sufficient pains are taken with the construction and a front panel is used in conjunction with either a dust cover (cabinet) or enclosed relay rack, the apparatus can be made to resemble or even to rival factory built equipment in appearance.

Dish type construction is practically the same as metal chassis construction, the main difference lying in the manner in which the chassis is fastened to the panel. Examples of both types are shown in figure 1.

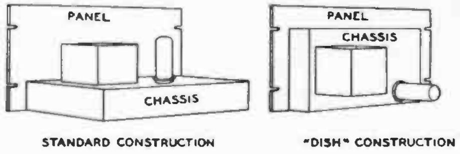


Figure 1.

Special Frameworks

For high powered r.f. stages, many amateur constructors prefer to discard the more conventional types of construction and employ instead special metal frameworks and brackets which they design specially for the parts which they intend to use. These are usually arranged to give the shortest possible r.f. leads and to fasten directly behind a relay rack panel by means of a few bolts, with the controls projecting through corresponding holes in the panel.

TOOLS

Beautiful work can be done with metal chassis and panels with the help of only a few inexpensive tools. However, the time required for construction will be greatly reduced if a fairly complete assortment of metal working tools is available. Thus, it can be seen that while an array of tools will speed up the work, excellent results may be accomplished with but few tools, if one has the time and patience.

The investment one is justified in making in tools is dependent upon several factors. If you like to tinker, there are many tools useful in radio construction that you would probably buy anyway, or perhaps already have, such as screwdrivers, hammer, saws, square, vise, files, etc. This means that the money taken for tools from your radio budget can be used to buy the more specialized tools, such as socket punches or hole saws, taps and dies, etc.

The amount of construction work one does determines whether buying a large assortment of tools is an economical move. It also determines if one should buy the less expensive type offered at surprisingly low prices by the familiar mail order houses, "five and ten" stores and chain auto-supply stores, or whether one should spend more money and get first-grade tools. The latter cost considerably more and work but little better when new, but will outlast several sets of the cheaper tools. Therefore they are a wise investment for the experimenter who does lots of construction work (if he can afford the initial cash outlay). The amateur who constructs only an occasional piece of apparatus need not be so concerned with tool life, as even the cheaper grade tools will last him several years, if they are given proper care.

The following hand tools and materials will be found very useful around the home workshop. Those marked with a double asterisk are essential. The single asterisk denotes tools next in importance, which should be bought as soon as possible after stocking up with the "must" equipment. Materials not listed but ordinarily used, such as paint, can best be purchased as required for each individual job.

1 Cheap carpenter's claw hammer
* 1 Good ball peen hammer, ¾ or 1 lb.
* 1 Hacksaw with coarse and fine blades, 10 or 12 inch.
1 Jig or scroll saw (small) with metal-cutting blades
1 Small wood saw (crosscut teeth)
* 1 Bench vise (jaws at least 3½ inch)
** 1 *Good* electric soldering iron, about 100 watts, with "radio" tip
** 1 Spool rosin-core wire solder
* 1 Spool plain wire solder
** 1 Jar soldering paste (non-corrosive)
** 1 Ea. large, medium, small and midget screwdrivers
** 1 *Good* hand drill, preferably two-speed
** 1 Pr. regular pliers, 6 inch
** 1 Pr. long nose pliers, 6 inch
** 1 Pr. cutting pliers (diagonals), 5 inch or 6 inch
* 1 Carpenter's brace, ratchet type
* 1 Square-shank countersink bit
1 Ea. Square-shank drills: ⅜, 7/16, and ½ inch
* 1 Square-shank countersink
* 1 Square-shank taper reamer, small
* 1 Square-shank taper reamer, large (the two reamers should overlap; ½ inch and ⅞ inch size will usually be suitable.
** 1 1⅛ inch tube-socket punch
* 1 ⅞ inch tube-socket punch (for electrolytic condensers)
* 1 Square-shank adjustable circle cutter for holes to 3 inch
* 1 Set small, inexpensive, open-end wrenches
1 Ea. "Spintite" wrenches, ¼ and 5/16 inch to fit standard 6-32 and 8-32 nuts used in radio work and two common sizes of Parker Kalon metal screws
* 1 Pr. tin shears, 10 or 12 inch
** 1 "Boy Scout" knife
** 1 Combination square and steel rule, 1 ft.
** 1 Yardstick or steel pushrule
1 Carpenter's plane, 8 inch or larger
* 1 Cold chisel (½ inch tip)
* 1 Wood chisel (½ inch tip)
* 1 Pr. wing dividers
** 1 Scratch awl or ice pick scribe
1 Metal punch
** 1 Center punch
* 1 Coarse mill file, flat, 12 inch
* 1 Coarse bastard file, round, ½ or ¾ inch dia.
* 6 or 8 Assorted small files: *round, half round, *triangular, *flat, square, rat-tail, etc.
** 1 doz. or more assorted round shank drills (as many as you can afford between no. 50

and ¼ or ⅜ inch, depending upon size of hand drill chuck)
1 Tap and die outfit for 6-32 and 8-32 machine screw threads
(A complete set is not necessary as other sizes will be seldom needed)
* 4 Small "C" clamps
4 Medium size "C" clamps
** 1 Combination oil stone
* Steel wool, coarse and fine
* Sandpaper and emery cloth, coarse, medium and fine
Lard oil (in squirt can)
** Light machine oil (in squirt can)
Kerosene
Duco or polystyrene cement (coil dope)
** Friction tape
* Rubber cement
Empire cloth
Alcohol
Clear lacquer ("industrial" grade)
Lacquer thinner
* File card or stiff brush
Dusting brush
Paint brushes
Sheet celluloid, Lucite, or Plexiglas
Acetone

The foregoing assortment assumes that the constructor does not want to invest in the more expensive power tools, such as drill press, grinding head, etc. If power equipment is purchased, obviously some of the hand tools and accessories listed will be superfluous.

Not listed in the table are several special-purpose radio tools which are somewhat of a luxury but are nevertheless quite handy, such as various around-the-corner screwdrivers and wrenches, special soldering iron tips, etc. These can be found in the larger radio parts stores and are usually listed in their mail order catalogs. It is not uncommon to find amateurs who have had sufficient experience as machinists to design and produce tools for special purposes.

TOOL HINTS

Of equal importance in maintaining one's supply of necessary tools and assorted materials is the assignment of each tool to one particular location. The greatest loss of time in any shop is usually incurred by searching for tools which are not in their proper place.

Amateurs in or near the larger cities will often find it profitable to visit that section of the city where may be found many large stores that deal in used machinery and tools. It is quite commonplace to find used tools of high quality in good condition at a low price.

Soldering Irons

A prerequisite to a good soldering job is a good iron. If one can afford two irons, a 150-watt size for heavy work and a smaller 75-watt size for light work and getting into tight places are highly desirable. However, a single 100-watt iron will do nicely for most purposes.

Do not get a high wattage iron that is relatively small physically. Such an iron must be used continuously to keep it from becoming too hot. When such an iron is left plugged in and is not used for several minutes, the iron will become so hot that it will curdle the solder adhering to the tip, making frequent filing and retinning necessary. An aluminum rest which presents considerable surface to the air and to the iron will prevent an iron from becoming overheated when not in actual use. Such a heat-dissipating rest for the iron can be made from an old aluminum automobile piston by sawing it off diametrically at the wrist pin.

For occasional extremely heavy work, a ten-cent store, gas-heated iron will be found very useful. This type of iron is merely a heavy copper tip fastened to a steel rod which has a wooden handle. Since the mass of the tip is great, it will hold heat for a long time, and is just the thing for working on large, heavy guage subpanels, and on antennas where no current is available for an electric iron nearby. If heated sufficiently they can be carried for considerable distance before becoming too cold for satisfactory soldering work.

Wood Saws

There are many types of wood saws on the market, but for amateur construction work those listed above are usually sufficient. Saws will work much better and last much longer if properly cared for. Keep the blades in good shape by smearing them with a thin film of vaseline after they are used. A rusty saw will not do good work. When it becomes necessary, as it does from time to time, to have them sharpened, let a good joiner do the work; it is a job for an expert, usually available in local hardware stores.

Metal Saws

The hacksaw has become an almost universally standardized tool for the amateur workshop. The replaceable blades are obtainable with varying numbers of teeth. The coarse blades, having 14 or 18 teeth per inch can be used for bakelite or ebonite; for most metals, a medium tooth blade with about 22 teeth per inch is desirable; and for very thin sheets a blade having 32 teeth per inch is best. Ordinarily, the harder the metal, the finer the blade that should be used.

When replacing saw blades, keep in mind that hacksaw blades should be put in place with the teeth pointing *towards* the tip of the saw, while jig or scroll saw blades should have the teeth *towards the handle*, in order to keep the work pressed on the cutting bench.

Files

When using a file the handle should be grasped firmly in the right hand, with the thumb on top, and the left hand should rest on the tip to guide it. The pressure should be eased off the left hand and transferred on to the right hand as the file proceeds across the work. The return stroke should be made with a minimum amount of pressure, or better, with the file raised from the work. The file should be cleaned often, both during and after work, in order to remove the filings which stick to the teeth. These may scratch the work if allowed to remain. A "file card" is inexpensive and will remove the burrs quickly.

To Resharpen Old Files

Wash the files in warm potash water to remove the grease and dirt, then wash in warm water and dry by heat. Put one and one-half pints warm water in a wooden vessel, put in the files, add three ounces blue vitriol finely powdered, and three ounces borax. Mix well and turn the files so that every one may come in contact with the mixture. Add ten and one-half ounces sulphuric acid and one-half ounce cider vinegar. Remove the files after a short time, dry, rub with olive oil, wrap in porous paper. Coarse files should be kept in the mixture for a longer time than fine ones.

File Lubricant

When filing aluminum, dural, etc., the file should be oiled or rubbed in chalk, but will cut slower than with no lubricant. However, the file will last much longer.

Screwdrivers

Screwdrivers call for little comment. The tips are important if the screw heads are to remain undamaged, however. They should fit the heads properly, not too loose, not too tight. They can be sharpened with a fine file, taking care that tip is parallel and the end square. If filed too thin, they will be weak; if filed at an angle, they will tend to jump out of the sawcut and damage the screw.

Screw Lubricant

Put hard soap on lag screws, wood screws or any screw for wood. It will surprise you how much easier they will turn in. The soap also will prevent or at least reduce splitting.

Power Drills and Drilling

Although most of us do not so consider it, a twist drill is nothing more than a modified jackknife. It has a cutting edge, an angle of clearance and an angle of rake, just as has a jackknife (or a lathe tool). The technique to be followed in drilling is, therefore, a func-

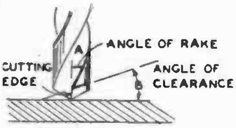


FIGURE 2

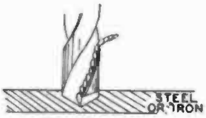


FIGURE 3

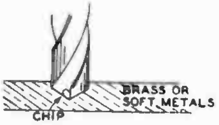
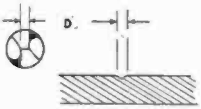


FIGURE 4



FIGURES 5 & 6

tion of the type of material worked on, as well as the speed and accuracy desired. In figure 2 is shown in heavy lines one of the cuttting edges of a drill normally used on steel. The angle B, between the cutting edge and the piece being worked on, is the angle of clearance. This determines to some extent how heavy a cut may be taken. Figure 3 shows the drill in action. Note that as the drill proceeds, the chip cut out is about the cutting edge. This has the effect of pushing the drill farther into the material. This is determined by the angle of rake, angle A, and the hardness of the material. If the material is hard at the point of cutting, the resistance to downward motion here is great enough to overcome that generated by the angle of rake.

Figures 2 and 3 show the shape of the cutting edge for steel or iron. This shape is best for these materials. The shavings which come out of the hole around the drill should be spiral and continuous as shown in figure 3. For softer metals, especially brass, the drill should have no angle of rake (or lip, as the forward projecting cutting edge is called). This is shown in figure 4. The shavings for this drill will be small chips. If this shape drill is not used, the drill will feed into the metal very rapidly and will usually jam. The result is a stalled motor, a belt off its pulley or a broken drill. The latter is usually the case.

As the tip of a drill is not a point, but a straight line perpendicular to its major axis, a drill will usually waltz all over the piece before it starts to drill unless a guide hole is punched at the point you wish to drill. The maximum diameter of this hole should be at least equal to the width of the drill tip. This is designated as D in figures 5 and 6, the latter showing a cross section of the center-punch mark. With drills of over ¼-inch diameter, this method of starting the drill is usually impractical as the diameter of the center-punch hole is prohibitively large. This difficulty is avoided by first drilling a smaller guide hole which can be started with a center-punch hole.

A great deal could be said about drilling speeds and feeds, but it would be of little value to the average person. Just remember that in drilling steel or iron,

NUMBERED DRILL SIZES

Drill Number	Diameter (in.)	Clears Screw	Correct for Tapping Steel or Brass †
1	.228	—	—
2	.221	12-24	—
3	.213	—	14-24
4	.209	12-20	—
5	.205	—	—
6	.204	—	—
7	.201	—	—
8	.199	—	—
9	.196	—	—
10*	.193	10-32	—
11	.191	10-24	—
12*	.189	—	—
13	.185	—	—
14	.182	—	—
15	.180	—	—
16	.177	—	12-24
17	.173	—	—
18*	.169	8-32	—
19	.166	—	12-20
20	.161	—	—
21*	.159	—	10-32
22	.157	—	—
23	.154	—	—
24	.152	—	—
25*	.149	—	10-24
26	.147	—	—
27	.144	—	—
28*	.140	6-32	—
29*	.136	—	8-32
30	.128	—	—
31	.120	—	—
32	.116	—	—
33*	.113	4-36 4-40	—
34	.111	—	—
35*	.110	—	6-32
36	.106	—	—
37	.104	—	—
38	.102	—	—
39*	.100	3-48	—
40	.098	—	—
41	.096	—	—
42*	.093	—	4-36 4-40
43	.089	2-56	—
44	.086	—	—
45*	.082	—	3-48

† Use next size larger drill for tapping bakelite and similar composition materials (plastics, etc.).

* Sizes most commonly used in radio construction.

the drill point should be well lubricated with a medium grade of machine oil. The weight of oil commonly used in oiling lawn mowers is about correct. This serves a double function for most machinists. The first, of course, is lubrication. The second is to keep the work cool. The oil flows from hot points to cold ones more quickly than heat flows from the hot points of the drill to the cooler ones. But, for amateur use, the oil assumes a third role, that of a temperature indicator. The oil should never evaporate visibly to form a cloud around the work (this vapor looks like steam).

Another indicator is that you should be able to hold the end of the drill in your hand with no discomfort immediately after you have finished the hole. These considerations are based on the assumption that most hams use the average carbon drill, and not one of the more expensive type designed to operate at high temperatures. Most tool steel will start to lose its hardness at a little over 100 degrees C. At 600 degrees, it is as soft as mild steel, and must be heat treated and tempered again. That means that most hams would have to grind the softened portion off and then attempt to regrind the cutting edges.

Brass should always be drilled with no lubricant. For one thing, the brass slides readily against steel. Bronze is in the same class. Witness the large number of bronze bearings in current use. Almost all of the zinc alloys may so be treated. If a lubricant is used, it usually only makes the particles cling together and thus clog up the drill point. Aluminum is sometimes lubricated with kerosene.

The drill speed (number of revolutions per minute of the drill) and the drilling feed (rate at which the drill is pushed into the work) are interdependent. The safe, simple way to determine them is to watch the temperature. If the drill is running too hot, decrease the feed. If it still runs too hot, decrease the speed. In drilling, it is a safe practice never to feed the drill in a distance greater than the diameter of the drill without backing it off until the work is clear. This permits you to examine the point and permits the drill to clear itself of particles which may be clogging it at the point of cutting. This looks like a waste of time, but actually will be a time saver. You won't have to stop to replace broken and softened drills.

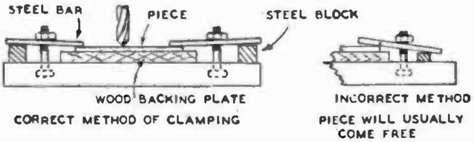


FIGURE 7

Danger

Most drill presses are equipped with some means of clamping the work. It is always wise to use these, unless the piece is large and the holes are small. A piece, especially of sheet steel, which gets jammed on the drill and tears out of the operator's hands, is a dangerous weapon. With small pieces, it is always best to clamp them in a tool maker's vise. Larger pieces may be clamped as shown in figure 7.

When working with sheet steel (as you usually are on chassis construction), if the piece is large, you may hold it safely by hand. Wear gloves and hold the work *firmly* with both hands. The drill feed may be easily arranged to operate by foot for these operations. Figure 8 shows how this is done. The spring shown is a screen door spring. The distance A from the hinge determines the ratio between foot motion and drill

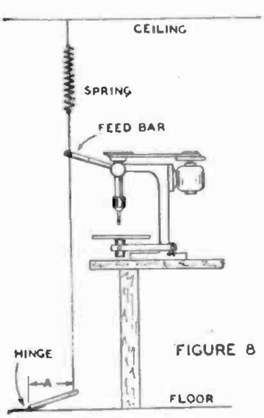


FIGURE 8

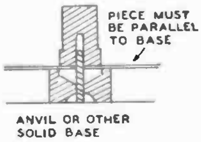


FIGURE 9

feed. The illustration is otherwise self-explanatory. For any hams interested in cutting operations other than drilling, the same principles as set forth here apply.

CONSTRUCTION PRACTICE

Chassis Layout

The chassis should first be covered with a layer of heavy wrapping paper, which is drawn tightly down on all sides and fastened with scotch tape. This allows any number of measurement lines and hole centers to be spotted in the correct positions without making any marks on the chassis itself. Place on it the parts to be mounted and play a game of chess with them, trying different arrangements until all the grid and plate leads are made as short as possible, tubes are clear of coil fields, r.f. chokes are in safe positions, etc. Remember, especially if you are going to use a panel, that a good mechanical layout can often accompany sound electrical design, but that the electrical design should be given first consideration. All too often parts are grouped to give a symmetrical panel irrespective of the arrangement behind. When a satisfactory arrangement has been reached, the mounting holes may be marked. The same procedure must now be followed for the underside, always being careful to see that there are no clashes between the two (that no top mounting screws come down into the middle of a paper condenser on the underside, etc.).

When all the holes have been spotted, they should be center-punched *through* the paper into the chassis. Don't forget to spot holes for leads which must also come through the chassis. For transformers which have lugs on the bottoms, the clearance holes may be spotted by dressing the transformer on a piece of paper to obtain impressions, which may then be transferred to the chassis. I.f. transformers with flexible leads out the bottom can use a ⅜-inch hole under the center of the can to accommodate the leads.

Punching

In cutting socket holes, one can use either a fly-cutter or socket punches. These punches are easy to operate and only a few precautions are necessary. The guide pin should fit snugly in the guide hole. This increases the accuracy of location of the socket. If this is not of great importance, one may well use a drill of 1/32" larger diameter than the guide pin. Some of the punches will operate without guides holes, but the latter always make the punching operation simpler and easier. The only other precaution is to be sure the work is properly lined up before applying the hammer. If this is not done, the punch may slide sideways when you strike and thus not only shear the chassis but also take off part of the die. This is easily avoided by always making sure that the piece is parallel to the faces of the punch, the die and the base. (Figure 9.) The latter should be an anvil or other solid base of heavy material.

A new type of punch by *Greenlee* forces socket holes through the chassis by means of a screw turned with a wrench. It is noiseless, and works much more easily and accurately than most others. It requires the use of a ⅜-inch center hole to accommodate the screw.

Transformer Cutouts

Cutouts for transformers and chokes are not so simply handled. There are devices on the market for this, but they have not yet come into common use. After marking off the part to be cut, drill about a ¼" hole on each of the inside corners and tangential to the edges. After burring the holes, clamp the piece and a block of cast iron or steel in the vise. Then, take your burring chisel and insert it in one of the corner holes. Cut out the metal by hitting the chisel with a hammer. The blows should be light and numerous. The chisel acts against the block in the same way that the two blades of a pair of scissors work against each other. This same process is repeated for the other sides. A file is used to trim up the completed cutout.

Removing Burrs

In both drilling and punching, a burr is usually left on the work. There are three simple ways of removing these. Perhaps the best is to take a chisel (be sure it is one for use on metal, as the ones for wood are not much harder than the average chassis steel) and set it so that its bottom face is parallel to the piece (in other words, has zero angle of clearance). Then gently tap it with a hammer. This usually will make a clean job with a little practice. If one has access to a counterbore, this will also do a nice job. But few of us can find one to work with. A countersink will work, although it bevels the edges. A drill of several sizes larger is a much used arrangement. The third method is by filing off the burr, which does a good job but scratches the adjacent metal surfaces badly. Any of these methods will work, but the first is quicker and does a neater job.

Mounting Components

There are two methods in general use for the fastening of transformers, chokes, and similar pieces of apparatus to chassis or breadboards. The first, using nuts and screws, is the amateur method from 'way-back. It is a good one, and can never be superseded entirely; but it is slow, and the commercial manufacturing practice of using self-tapping screws is gaining favor. For the mounting of small parts such as resistors and condensers, tie strips are very useful to gain rigidity. They also contribute materially to the appearance of finished apparatus.

Grommets of the proper size placed in all chassis holes through which wires are to be passed will give a neater appearing job and will also reduce the possibility of short circuits.

Soldering

Making a properly strong, low-resistance solder joint does not mean just dropping a blob of solder on the two parts to be joined and then hoping that they'll stick. There are several definite rules to follow, and they *must* be observed if you intend to have apparatus that will "go" every time.

All parts to be soldered must be absolutely clean. The importance of this rule cannot be over emphasized. Parts should not be touched with the hands after they have been cleaned, because there is enough oil on them to prevent the solder from flowing properly. To clean a wire, lug, or whatever it may be, take your pocket knife and scrape it thoroughly, until fresh metal is laid bare. It is not enough to make a few streaks; scrape until the part to be soldered is bright.

Make a good mechanical joint before applying any solder. Solder is intended primarily to make a good *electrical* connection; mechanical rigidity should be obtained by bending the wire into a small hook at the end and nipping it firmly around the other part, so that it will hold well even before the solder is applied.

Keep your iron properly tinned. The film of oxidized copper and dirt which forms on the tip of an untinned iron is an excellent heat insulator. It is impossible to get the work hot enough to take the solder properly if the iron is dirty. To tin your iron, file it, while hot, on one side until a full surface of clean metal is exposed. Immediately apply rosin core solder until a thin layer flows completely over the exposed surface. Repeat for the other faces. Then take a clean rag and wipe off all excess solder and rosin. The iron should also be wiped frequently while the actual construction is going on; it helps prevent pitting the tip.

Apply the solder to the work, not to the iron. The iron should be held against parts to be joined until they are thoroughly heated. The solder should then be applied against the parts, and the iron should be held in place until the solder flows smoothly and envelopes the work. If it acts like water on a greasy plate, and forms a ball, the work is not sufficiently clean.

The completed joint must be held perfectly still until the solder has had time to solidify. If the work is moved before the solder has become *completely* solid, a "cold" joint will result. This can be identified immediately, because the solder will have a dull "white" appearance rather than one of shiny "silver." Such joints tend to be of high resistance, and will very likely have a bad effect upon a circuit. The cure is simple: Merely reheat the joint and do the job correctly.

Wipe away all surplus flux when the joint has cooled, especially if you are using a paste type flux. If you use paste, be sure it is non-corrosive, and use it with plain (not rosin core) solder.

Finishes

There are a number of ways of finishing the chassis. Perhaps the best for steel is plating. Cadmium plating was once popular, but since one of the automobile manufacturers is reputed to have a corner on this material, it has been difficult to obtain. Chromium plating is pretty, but is expensive and hard to solder to. Copper plating tarnishes, but can be covered with colorless lacquer to prevent tarnishing.

An attractive dull gloss finish, almost velvety, can be put on aluminum by sandblasting it with a very weak blast and fine particles and then lacquering it. Soaking the aluminum in a solution of lye produces somewhat the same effect as a fine grain sand blast.

There are also several brands of dull gloss black enamels on the market which adhere well to metals and make a nice appearance. Air-drying crackle finishes are sometimes successful, but a baked job is usually far better. Crackle finishes, properly applied, are very durable and are pleasing to the eye. If you live in a large community, there is probably an enamelling concern which can crackle your work for you at a reasonable cost. A very attractive finish for panels especially is to spray a crackle finish with aluminum paint. In any painting operation (or plating, either, for that matter), the work should be very thoroughly cleaned of all greases and oils.

To color brass a steel blue, dissolve three drams antimony sulphite and four ounces calcined soda in one and one-half pints of water. To this add five and one-half drams kermes. Filter and mix this solution with five and one-half drams tartar, eleven drams sodium hyposulphate and one and one-half pints water. Polished sheet brass placed in the warm mixture will assume a steel blue color.

To give brass a dull finish, mix one part (by weight) of iron rust, one part white arsenic and twelve parts hydrochloric acid. Clean the brass thoroughly and apply with a brush until the desired color is obtained, after which it should be oiled, dried and later lacquered.

To protect brass from tarnish, thoroughly cleanse and remove the last trace of grease by the use of potash and water. The brass must be carefully rinsed with water and dried; but in doing it, care must be taken not to handle any portion with the bare hands nor anything else that is greasy. The preservative varnish is made by mixing two parts of shellac to nine parts of alcohol. Put on with a brush as thinly and smoothly as possible.

Drilling Glass

This is done very readily with a common drill by using a mixture of turpentine and camphor. When the point of the drill has come through, it should be taken out and the hole worked through with the point of a three-cornered file, having the edges ground sharp. Use the corners of the file, scraping the glass rather than using the file as a reamer. Great care must be taken not to crack the glass or flake off parts of it in finishing the hole after the point of the drill has come through. Use the mixture freely during the drilling and scraping. The above mixture will be found very useful in drilling hard cast iron.

Etching Solution

Add three parts nitric acid to one part muriatic acid. Cover the piece to be etched with beeswax. This can be done by heating the piece in a gas or alcohol flame and rubbing the wax over the surface. Use a sharp steel point or hard lead pencil point as a stylus. A pointed glass dropper can be used to put the solution at the place needed. After the solution foams for two or three minutes, remove with blotting paper and put oil on the piece and then heat and remove the wax.

Annealing Brass or Copper

Brass or copper when worked will become hard and, if hammered to any great extent, will split. To prevent cracking or splitting, the piece must be heated to a dull red heat and plunged into cold water; this will soften it so it can be worked easily. Be careful not to heat brass too hot or it will fall to pieces.

To Clean Copper

Prepare a strong soda or potash lye solution by adding about a pound of lye to a pail of boiling water. Dip the metal or apply this solution with a brush, scrubbing well. Then rinse or wash with plain hot water and finally with cold water.

Polish for Bakelite and Crackle Finish

Mix two parts benzine with one part mineral oil and apply with cloth. Wipe off with dry cloth. This is not a messy polish and does not leave an oily surface.

Chromium Polish

So much chromium is now being used in radio sets and panels that it is well to know that this finish may be polished. The only materials required are absorbent cotton or soft cloth, alcohol and ordinary lampblack.

A wad of cotton or the cloth is moistened in the alcohol and pressed into the lampblack. The chromium is then polished by rubbing the lampblack adhering to the cotton briskly over its surface. The mixture dries almost instantly and may be wiped off with another wad of cotton.

The alcohol serves merely to moisten the lampblack to a paste and make it stick to the cotton. The mixture cleans and polishes very quickly and cannot scratch the chromium surface. It polishes nickel-work just as effectively as it does chromium. Care should be taken to see that the lampblack does not contain any hard, gritty particles which might produce heavy scratches during the polishing.

TWENTY

Radio Therapy

RADIO-FREQUENCY energy can be applied to various parts of the human anatomy in order to produce a localized fever or temperature. The increase in temperature is effective for increasing circulation and for destroying certain kinds of germ diseases. The radio frequencies involved in radio therapy normally range from 6 to 16 meters in wavelength, although there has not yet been an accepted standard of frequencies for the treatment of any particular ailment.

The muscular cartilage, fatty and bone tissues all respond differently to applied radio waves. Some of these tissues are dielectrics while others are conductors, yet most of them have an intermediate characteristic, that of leaky dielectric shunted by a capacitance. The radio energy is dissipated in the form of a dielectric loss which increases the temperature of that portion of the body under treatment. This form of treatment is known as *radio therapy,* and the apparatus used for administering the radio-frequency current is called a *diathermy machine.*

A diathermy machine consists of an oscillator with a maximum output of from 100 to 400 watts. The load impedance connected across the oscillator varies greatly; this requires special design of the oscillator circuit. The variation in load impedance is caused by the variation in size and in spacing between the electrodes required for various forms of treatment.

Treatment

The correct application of radio therapy depends upon the ailment and should, therefore, *be under the supervision of a skilled physician.* The diathermy machine usually has a means of controlling the power output and often has a frequency control in the form of plug-in coils. The radio energy is normally applied by means of a pair of rubber-covered metal electrodes which are placed on opposite sides of the portion of the body under treatment.

Radio therapy is used to kill certain bacteria in the body, much in the same manner as artificially-induced typhoid fever. Because careless use of radio therapy can and has caused extremely serious damage, self-treatment or the treatment of others by means of a home-built diathermy machine should *never* be attempted except under the supervision of a competent practitioner.

A circuit for an excellent portable diathermy machine is shown in figure 3. This circuit has certain features not found in most commercially-made portable machines. The oscillator circuit proper is a push-pull *Hartley* system in which the grid excitation is more constant than in most u.h.f. oscillator circuits for various load impedances.

This machine, illustrated in figures 1 and 2, is similar to the portable machines used by doctors for treating a patient in his own home. Such machines are or-

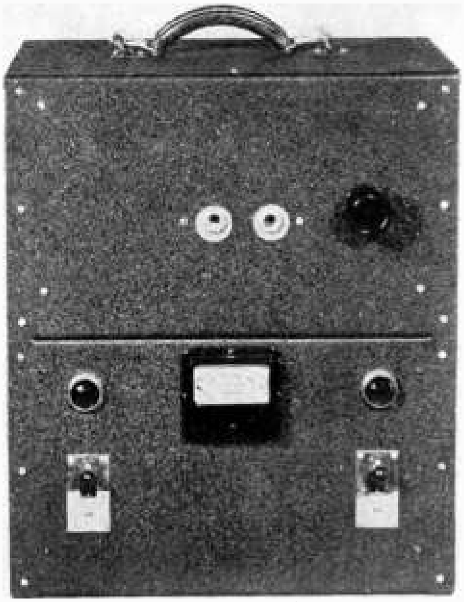


Figure 1.

FRONT VIEW OF 200-WATT PORTABLE DIATHERMY MACHINE.

This machine is of the type used for home treatment of diseases by radio therapy. It works on 15 meters, has sufficient output for most purposes, and produces a minimum of radio interference.

dinarily used only with standard type heating pads, no provision being made for electric cautery or "inductotherm" treatment. The latter calls for an insulated conductor to be coiled around the afflicted member or part of the body. The more common method of treatment with applicator pads is just as effective in most cases and usually is more convenient.

Construction

The oscillator and pad circuit are placed on the upper deck and the power supply on the lower deck of a two-deck metal chassis which is fitted with a ventilated cover having a handle. The latter item puts the machine in the category of "portable," as the machine is light enough to be carried easily by one person.

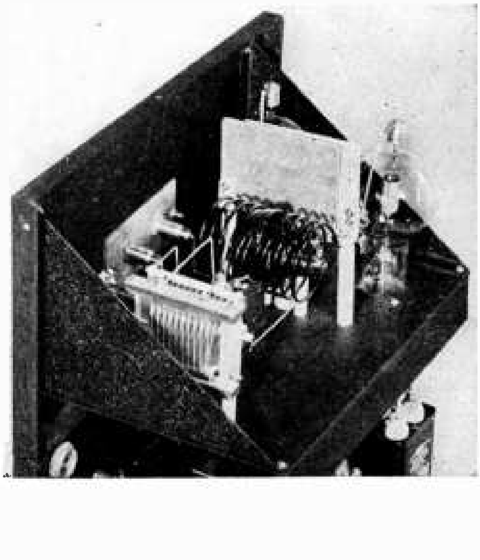
The oscillator is fixed-tuned to a wavelength of approximately 15 meters by the two plates which constitute C_1. The pads are resonated by the series condenser C_4, adjustment of this condenser providing a simple but entirely satisfactory method of regulating the output.

The layout of the power supply components is not critical; they may be arranged in any way which will permit inclusion of all of them on the lower deck. The r.f. components should be laid out approximately as illustrated in figure 2. Both the oscillator coil and the two plates constituting the tank condenser C_1 are supported on two ceramic pillars spaced 4½ inches. These plates, measuring 4¼ by 3½ inches high, overlap approximately 3¾ inches of their length, and are separated by approximately 3/16 inch, the exact spacing being finally adjusted until the wavelength of the machine is approximately 15 meters. In no case, however, should the plates be spaced closer than ⅛ inch; otherwise arcing may occur between them when there is no load on the machine.

Figure 2.

BACK VIEW OF 200-WATT DIATHERMY WITH COVER REMOVED.

All power supply components including overload relay are mounted on the lower deck. All r.f. components are mounted on the upper deck.



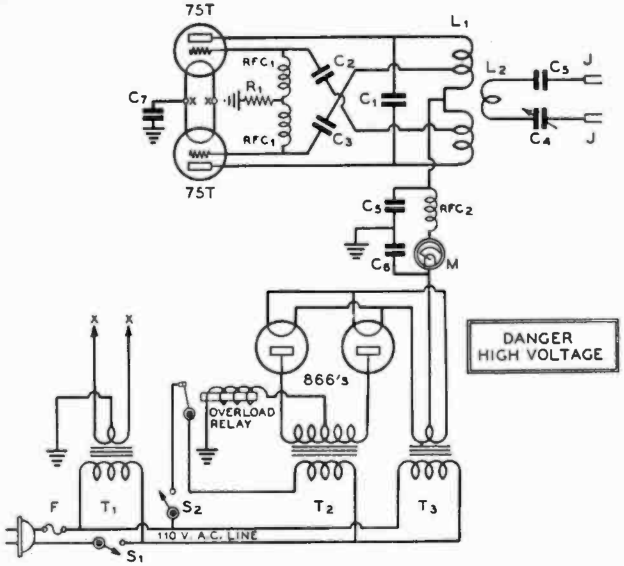


Figure 3.

WIRING DIAGRAM OF THE 200-WATT PORTABLE DIATHERMY.

C_1—Two aluminum plates mounted on ceramic pillars (see text)

C_2, C_3—.0005 µfd. 5000 v. mica

C_4—100 µµfd., 3000 v. spacing

C_5—.001 µfd. 2500 v. mica

C_6—0.5 µfd. 2000 v. oil condenser

C_7—.001 µfd. 1000 v. mica

R_1—7500 ohms, 50 watts

RFC_1—High frequency r.f. choke (see text)

RFC_2—1 or 2.5 mh. 500 ma. r.f. choke

T_1—5¼ v., 13 amp.

T_2—1200 v. each side c.t., 350 ma.

T_3—2½ v. 10 amp., 7500 v. insulation

M—0-500 ma. d.c.

Overload Relay: Adjustable 300-500 ma. type

L_1—8 turns no. 8 or no. 10 enamelled 2½" dia., wound with two halves spaced 1 inch and coil spaced to 3¼ inches

L_2—3 or 4 turns same wire same diameter inserted between two halves of L_1. Slip "spaghetti" over wire for insulation

The pads are coupled by means of a 3 or 4 turn coil which can be "folded" into the center of the oscillator coil, the latter being wound in two sections separated sufficiently to make room for the coupling coil. The coupling coil is covered with "spaghetti" to prevent shorted turns and prevent high voltage being impressed upon the coupling coil by contact with the oscillator coil.

The oscillator coil consists of 8 turns, with a gap of approximately 1 inch in the center and the whole coil spaced to approximately 3¼ inches. Both the oscillator coil and coupling coil are 2½ inches in diameter and wound with no. 10 or no. 8 enamelled wire. The coupling coil is supported from two ceramic pillars, the position of the coil with respect to the oscillator coil being adjusted by bending the wire until the desired degree of loading is obtained. The coupling is increased until the plate current to the oscillator measures approximately 350 ma. when the pads are applied to the body and C_4 is tuned to exact resonance. The coupling need not be touched after this adjustment is once made, all further adjustment of the output being made by means of C_4.

The condenser C_5 is merely a blocking condenser and has no effect upon the circuit except to protect the patient in the event of structural failure of the pillars supporting the coils or a flashover between coils. As direct current cannot pass through either C_4 or C_5, the patient is thus protected from the high voltage plate supply under all contingencies, the rubber insulation on the pads affording further protection.

The grid taps on each tank coil are made exactly the same distance from each side of center. If one tube heats more than the other, the taps have not been made symmetrically. To adjust the taps to their proper position, disconnect the pads from their circuit, place a 0-100 ma. milliammeter in series with the grounded end of the grid leak R_1, and move the taps out towards the ends of the coil in one inch steps until the grid current reads approximately 65 ma. This should be done with the pads removed from the machine (entirely disconnected) and the overload relay shorted out. The correct points will be approximately ⅓ to ½ the distance from the center to the ends of the coil. The taps may first be placed approximately ¼ the distance from the center to the ends and then moved outwardly from there until the specified grid current is obtained.

When the pads are connected and applied to a patient, the grid current will fall off considerably; hence it is necessary to adjust the excitation taps (with the tubes unloaded) for as much grid current as the tubes will stand safely.

A grid meter can be permanently incorporated in this diathermy machine, if desired. It is absolutely necessary, however, only for the initial adjustment.

The grid condensers C_2 and C_3 should be spaced at least one inch from the chassis and each other. The bakelite in which these condensers are encased is not an especially good dielectric at 15 meters, and the condensers will heat considerably if they are placed so as to have appreciable capacity to each other or to ground. This is necessary because the r.f. voltage on these condensers is rather high.

The high r.f. voltage at these points also necessitates extra good r.f. chokes for RFC_1. The usual 2½-mh. 125-ma chokes ordinarily used for grid chokes are not particularly effective, and will usually burn up after a short time. Most any "all-band" choke is none too effective at 15 meters when high r.f. voltages are involved. Hence it is desirable to use at RFC_1 chokes which are especially designed for work at frequencies of this order. Either National R-154-U chokes or Ohmite Z-2 chokes will prove satisfactory, most other chokes having a tendency to burn out the "pie" at the hot end of the choke. The latter effect can be avoided to an extent by using "tapered pie" chokes, with the smaller pies connected to the grids. Use of the grid chokes specified, however, will eliminate all possibility of trouble from burned chokes. Very little r.f. voltage is impressed upon the plate choke RFC_2; hence any type choke will be satisfactory here.

The jacks on the front panel (for the pad cords) should have at least a half inch clearance, and be mounted on Victron, hard rubber, Mycalex, or Lucite. Ordinary bakelite will break down, as it has a poor power factor at this frequency.

A red ink "warning" marker should be drawn on the scale of the plate meter at the point of 300 ma., to make certain that this value of plate current will not be exceeded. The plate meter is the only essential meter in the machine, although some physicians insist upon an r.f. meter in the pad circuit. Neither plate current nor r.f. output are more than an approximate index of the degree of heating; they are not relied upon except as a relative check when the pads are in any *given position* on a *certain patient.* When the pads are placed in different positions, the r.f. meter may read either higher or lower for a given heating effect. The actual temperature of that portion of the patient's body under treatment is the only safe barometer of the amount of heating effect being supplied.

The small filter condenser (0.5 μfd.) provides sufficient filtration to prevent the oscillator tubes from going out of oscillation instantaneously 120 times per second. "Hash" on the lower frequencies including the broadcast band will result from such momentary cessation of oscillation. The ripple voltage will still be quite high, with the small filter, but interference on frequencies other than the operating frequency will be eliminated.

It is not advisable to use higher capacity; otherwise the plate voltage will rise to excessive values when the pads are not loaded and when the plate current is relatively low. This, in turn, results in excessive grid current. The grid current normally tends to rise anyway when an oscillator is not loaded.

Overload Relay

The overload relay is of the type that can be adjusted to trip anywhere from 300 to 500 ma. After the excitation taps are fixed and the position of the coupling coil is tentatively adjusted, the overload relay can then be set to trip at 325 ma. This will protect the tubes from excessive plate current, and from severe damage that would otherwise result should the tubes go out of oscillation for any reason. When the tubes are not oscillating with plate voltage applied, the plate current is not only high enough to damage the tubes immediately, but enough to ruin the meter and overload the power supply components.

If during treatment the relay is continually "kicking out" when adjusted to trip at 325 ma., it indicates that the loading is too heavy, and that the coupling should be backed off a bit.

High-Frequency Interference

Diathermy machines are essentially radio transmitters and they can cause serious interference to radio reception.

If this diathermy machine causes interference to nearby amateurs on the 5-, 10- and 20-meter bands, the cure lies in the installation of a heavy duty *choke-input filter*, consisting of a 30-henry 350-ma. swinging choke and a 4-μfd. 2000-volt condenser. This permits a high degree of filtering without sacrificing voltage regulation. The interference will then be confined to a very narrow range of frequencies. If a choke input filter is used, a higher voltage plate transformer will be required (1500 v.).

Rectifier Time Delay

In order to prolong the life of rectifier and oscillator tubes, it is important that they be permitted to warm up for a period of 20 or 30 seconds before plate voltage is applied. Switch SW_2 should never be thrown to the *on* position, until switch SW_1 has first been turned on. This means that switch SW_2 is turned on last, and turned off first.

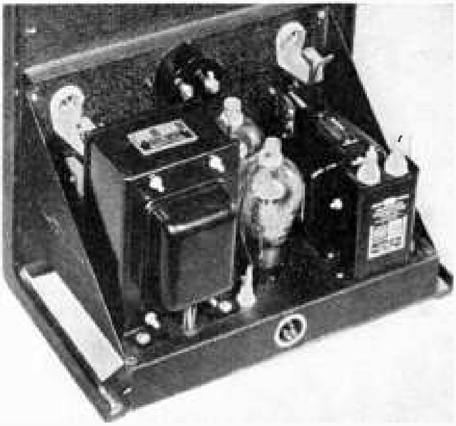


Figure 4.

ILLUSTRATING ARRANGEMENT OF POWER SUPPLY COMPONENTS.

All power supply components are mounted on the lower deck. In this view, the top deck has been removed in order to show the power supply components.

If desired, a time delay relay may be used to protect the rectifiers, thus making a fool-proof arrangement.

Heating Pads

The applicator pads are a standard item, available from most medical supply houses and some electrical and radio supply houses. In ordering pads it is necessary to specify the approximate frequency on which the machine is to operate; otherwise the length of the cords may be too short to permit resonance even with the series condenser entirely meshed. If the cord pads are too *long* (as evidenced by resonance being obtained with the plates of the condenser C_4 entirely *un*meshed) they can be cut off 6 inches at a time until they resonate satisfactorily; but if they are too short nothing can be done about it.

Information as to the availability of the heating pads may be obtained by writing the publishers and enclosing a stamped, self-addressed envelope.

TWENTY-ONE

Radio Mathematics and Calculations

INTO this chapter have been grouped various charts and methods of computation for types of calculation which will be required in more advanced amateur work. The decibel, logarithms, calculation of gain and loss, calculation of inductance, and determination of frequency of resonance will be discussed.

The Decibel

The decibel unit as used in radio engineering and virtually universal in all power and energy measurements is actually a unit of amplification expressed as a common logarithm of a power or energy ratio. One decibel is 1/10th of a bel. One bel or 10 decibels indicate an amplification by 10, the common logarithm of 10 being 1. Similarly, 2 bels or 20 db mean amplification by 100; 30 db mean amplification by 1,000, and so on. The power ratio for one decibel is expressed as

$$\frac{P_1}{P_2} = 10^{0.1} \qquad (1)$$

where P_1 is the power input; P_2, the power output. The number of decibels represents a power gain or loss, depending upon whether the relation P_1/P_2 is greater or less than 1.

Expressions for various power ratios are now commonly employed in communication engineering at audio and at radio frequencies. To express a ratio between any two amounts of power, it is convenient to use a logarithmic scale. A table of logarithms facilitates making conversions in positive or negative directions between the number of decibels and the corresponding power, voltage and current ratios.

Logarithmic Table

The table of logarithms presented here does not differ essentially from any other similar table except that no proportional parts are given and the figures are stated to only three decimal places; this arrangement does not permit great accuracy but has been found to be satisfactory for all practical radio purposes. A complete exposition on logarithms is outside the scope of this HANDBOOK; however, the very essentials together with the practical use of the tables and their application to decibels are given herewith. The following discussion is not concerned with the study of logarithms other than their direct employment to decibels.

The logarithm of a number usually consists of two parts: a whole number called the *characteristic* and a decimal called the *mantissa*. The characteristic is the integral portion to the *left* of the decimal point (see examples below), and the mantissa is the value placed to the *right*. The mantissa is all that appears in the table of logarithms.

In the logarithm, the mantissa is independent of the position of the decimal point, while the characteristic is dependent only on the position of the number with the relation to the decimal point. Thus, in the following examples:

	Number		Logarithm
(a)	4021.	=	3.604
(b)	402.1	=	2.604
(c)	40.21	=	1.604
(d)	4.021	=	0.604
(e)	.4021	=	—1.604
(f)	.04021	=	—2.604

it will be seen that the characteristic is equal, algebraically, to the number of digits *minus one* to the left of the decimal point.

In (a) the characteristic is 3, in (b) 2, in (d) 0, in (e) —1, in (f) —2. The following should be remembered: (1) that for a number greater than 1, the characteristic is *one less* than the number of digits to the left of the decimal point; (2) that for a number wholly a decimal, the characteristic is *negative* and is numerically *one greater* than the number of ciphers immediately following the decimal point. Notice (e) and (f) in the above examples.

To find a common logarithm of any number, proceed as directed herewith. Suppose the number to be 5576. First, determine the characteristic. An inspection will show that this number will be three. The figure is placed to the *left* of a decimal point. The mantissa is now found by referring to the logarithm table. Proceed selecting the first two numbers which are 55, then glance down the N column until coming to these figures. Advance to the right until coming in line with the column headed 7; the number will be 746. (Note that the column headed 7 corresponds to the *third* figure in the number 5576). Place the mantissa 746 to the *right* of the decimal point making the number now read 3.746. This is the logarithm of 5576. *Important:* do not consider the last figure, 6, in the number 5576 when looking for the mantissa in the accompanying three-place tables; in fact, disregard all digits beyond the first three when determining the mantissa. (*Interpolation,* to find the true log of 5576, cannot be accurately done from 3-place values.) However, be doubly sure to include *all* figures when ascertaining the magnitude of the *characteristic.*

Practical application of logarithms to decibels will follow. Other methods of using logarithms will be discussed as the subject develops.

Power Levels

In the design of radio devices and amplifying equipment, the standard power level of six milliwatts (.006 w.) is the arbitrary reference level of zero decibels. All power levels above the reference level are designated as plus quantities, and below as minus. The figure is always prefixed by a plus (+) or minus (—) sign indicating the direction in which the quantity is to be read.

Power to Decibels

The power output (watts) of any amplifier may be converted into decibels by the following formula, assuming that the input and output impedances are equal:

$$N_{db} = 10 \text{ Log}_{10} \frac{P_1}{P_2} \qquad (2)$$

where N_{db} is the desired power level in decibels; P_1, the output of the amplifier, and P_2, the reference level of 6 milliwatts. The subnumeral, 10, affixed to the logarithm indicates that the log is to be extracted from a log table using 10 as the base, such as the one given here.

Substitute values for the letters in the above formula as in the following:

An amplifier using 2A5 tube should be able to deliver an undistorted output of three watts. How much is this in decibels?

Solution by formula (2)

$$\frac{P_1}{P_2} = \frac{3}{.006} = 500$$

$$10 \times \text{Log } 500 = 10 \times 2.69$$

therefore $10 \times 2.69 = 26.9$ decibels.

Substituting other values for those shown allows any output power to be converted into decibels *provided* that the decibel equivalent is *above* the zero reference level or the power is *not less* than 6 milliwatts.

To solve almost all problems to which the solution will be given in minus decibels, an understanding of *algebraic addition is required.* To add algebraically, it is necessary to observe the plus and minus signs of expressions. (Do not confuse these signs with decibels.) In the succeeding illustrations notice that the result is obtained sometimes by addition and at other times by subtraction.

(a)	(b)	(c)	(d)
+2	—4	—4	+4
—4	—2	+2	+2
—2	—6	—2	+6

The terms used in (c) are those that apply to decibel calculations.

When the solution to a problem involving logarithms will be in minus decibels (when the power level under consideration is less than 6 milliwatts), note particularly that the characteristic of this logarithm will be prefixed by a minus sign (—). Note also that this sign affects *only* the characteristic; the mantissa remains positive. The mantissa *always* remains positive, regardless of whether the solution of the problem results in a positive or a negative characteristic.

A prefix —1 to a logarithm means that the first significant figure of the number which it represents will be the *first* place to the *right* of the decimal point; —2 means that it will occupy the second place to the right while the first will be filled by a cipher; —3, the third place with two ciphers filling the first and second, and so on.

To multiply a logarithm with a *minus* characteristic and a positive mantissa by

THREE-PLACE LOGARITHMS

N	0	1	2	3	4	5	6	7	8	9
00	000	000	000	000	000	000	000	000	000	000
10	000	004	008	012	017	021	025	029	033	037
11	041	045	049	053	056	060	064	068	071	075
12	079	082	086	089	093	096	100	103	107	110
13	113	117	120	123	127	130	133	136	139	143
14	146	149	152	155	158	161	164	167	170	173
15	176	179	181	184	187	190	193	195	198	201
16	204	206	209	212	214	217	220	222	225	227
17	230	233	235	238	240	243	245	248	250	252
18	255	257	260	262	264	267	269	271	274	276
19	278	281	283	285	287	290	292	294	296	298
20	301	303	305	307	309	311	313	316	318	320
21	322	324	326	328	330	332	334	336	338	340
22	342	344	346	348	350	352	354	356	358	359
23	361	363	365	367	368	371	372	374	376	378
24	380	382	383	385	387	389	390	392	394	396
25	397	399	401	403	404	406	408	409	411	413
26	415	416	418	420	421	423	424	426	428	429
27	431	433	434	436	437	439	440	442	444	445
28	447	448	450	451	453	454	456	457	459	460
29	462	463	465	466	468	469	471	472	474	475
30	477	478	480	481	482	484	485	487	488	490
31	491	492	494	495	496	498	499	501	502	503
32	505	506	507	509	510	511	513	514	515	517
33	518	519	521	522	523	525	526	527	528	530
34	531	532	534	535	536	537	539	540	541	542
35	544	545	546	547	549	550	551	552	553	555
36	556	557	558	559	561	562	563	564	565	567
37	568	569	570	571	572	574	575	576	577	578
38	579	580	582	583	584	585	586	587	588	589
39	591	592	593	594	595	596	597	598	599	601
40	602	603	604	605	606	607	608	609	610	611
41	612	613	614	616	617	618	619	620	621	622
42	623	624	625	626	627	628	629	630	631	632
43	633	634	635	636	637	638	639	640	641	642
44	643	644	645	646	647	648	649	650	651	652
45	653	654	655	656	657	658	659	659	660	661
46	662	663	664	665	666	667	668	669	670	671
47	672	673	673	674	675	676	677	678	679	680
48	681	682	683	683	684	685	686	687	688	689
49	690	691	692	692	693	694	695	696	697	698
50	699	699	700	701	702	703	704	705	705	706
51	707	708	709	710	711	712	713	713	715	715
52	716	716	717	718	719	720	721	722	722	723
53	724	725	725	726	727	728	729	730	730	731
54	732	733	734	734	735	736	737	738	738	739
N	0	1	2	3	4	5	6	7	8	9

THREE-PLACE LOGARITHMS

N	0	1	2	3	4	5	6	7	8	9
55	740	741	741	742	743	744	745	746	747	747
56	748	749	749	750	751	752	752	753	754	755
57	755	756	757	758	758	759	760	761	761	762
58	763	764	764	765	766	767	767	768	769	770
59	770	771	772	773	773	774	775	776	776	777
60	778	778	779	780	781	781	782	783	783	784
61	785	786	786	787	788	788	789	790	791	791
62	792	793	793	794	795	795	796	797	798	798
63	799	800	800	801	802	802	803	804	804	805
64	806	806	807	808	809	810	810	811	811	812
65	813	813	814	814	815	816	816	817	818	818
66	819	820	820	821	822	822	823	824	824	825
67	826	826	827	828	828	829	829	830	831	831
68	832	833	833	834	835	835	836	837	837	838
69	838	839	840	840	841	842	842	843	843	844
70	845	845	846	847	848	848	849	849	850	850
71	851	851	852	853	853	854	854	855	856	856
72	857	857	858	859	859	860	860	861	861	862
73	863	863	864	865	865	866	866	867	868	868
74	869	869	870	871	871	872	872	873	873	874
75	875	875	876	876	877	877	878	879	879	880
76	880	881	882	882	883	883	884	884	885	885
77	886	887	887	888	888	889	889	890	891	891
78	892	892	893	893	894	894	895	896	896	897
79	897	898	898	899	899	900	900	901	902	902
80	903	903	904	904	905	905	906	906	907	907
81	908	909	909	910	910	911	911	912	912	913
82	913	914	914	915	915	916	917	917	918	918
83	919	919	920	920	921	921	922	922	923	923
84	924	924	925	925	926	926	927	927	928	928
85	929	929	930	930	931	932	932	933	933	934
86	934	935	935	936	936	937	937	938	938	939
87	939	940	940	941	941	942	942	943	943	944
88	944	945	945	946	946	946	947	947	948	948
89	949	949	950	950	951	951	952	952	953	953
90	954	954	955	955	956	956	957	957	958	958
91	959	959	960	960	960	961	961	962	962	963
92	963	964	964	965	965	966	966	967	967	968
93	968	968	969	969	970	970	971	971	972	972
94	973	973	974	974	975	975	975	976	976	977
95	977	978	978	979	979	980	980	980	981	981
96	982	982	983	983	984	984	985	985	985	986
97	986	987	987	988	988	989	989	989	990	990
98	991	991	992	992	993	993	993	994	994	995
99	995	996	996	996	997	997	998	998	999	999
00	000	004	008	012	017	021	025	029	033	037
N	0	1	2	3	4	5	6	7	8	9

another number, each part must be considered separately, multiplied by the number (10 or 20 for decibel calculations), and then the products added algebraically. Thus, in the following illustration:

A preamplifier for a microphone is feeding 1.5 milliwatts into the line going to the regular speech amplifier. What is this power level expressed in decibels? Solution by formula (2):

$$\frac{P_1}{P_2} = \frac{.0015}{.006} = .25$$

Log .25 = —1.397 (from table). Therefore, 10 × —1.397 = (10 × —1 = —10) + (10 × .397 = 3.97); adding the products *algebraically* gives —6.03 db.

By substituting other values for those in the above example, any output power *below* 6 milliwatts (zero reference level) can be converted into decibels.

Determining Db Gain or Loss

In using amplifiers, it is a prime requisite to be able to indicate gain or loss in *decibels.* To determine the gain or loss in db employ the following formula:

$$\text{(gain) } N_{db} = 10 \text{ Log } \frac{P_0}{P_1} \qquad (3)$$

$$\text{(loss) } N_{db} = 10 \text{ Log } \frac{P_1}{P_0} \qquad (4)$$

where N_{db} is the number of db gained or lost; P_1, the input power, and P_0, the output power.

Applying, for example, formula (3): Suppose that an intermediate amplifier is being driven by an input power of 0.2 watt and after amplification, the output is found to be 6 watts.

$$\frac{P_0}{P_1} = \frac{6}{.2} = 30$$

$$\text{Log } 30 = 1.48$$

Therefore 10 × 1.48 = 14.8 db power gain.

DB	POWER RATIO
0	1.00
1	1.26
2	1.58
3	2.00
4	2.51
5	3.16
6	3.98
7	5.01
8	6.31
9	7.94
10	10.00
20	100
30	1,000
40	10,000
50	100,000
60	1,000,000
70	10,000,000
80	100,000,000

Amplifier Ratings

The technical specifications or rating on power amplifiers should contain the following information: the overall gain in decibels, the power output in watts, the value of the input and output impedances, the input signal level in db, the input signal voltage and the power output level in decibels.

If the specifications on an amplifier include only the input and output signal levels in db, it then is necessary to calculate how much these values represent in power. The methods employed to determine power levels are not similar to those used in previous calculations. Caution should, therefore, be taken in reading the following explanations, with particular care and attention being paid to the minor arithmetical operations.

The Antilogarithm

To determine a power level from some given decibel value, it is necessary to invert the logarithmic process formerly employed in converting power to decibels. Here, instead of looking for the log of a number, it is now necessary to find the *antilogarithm* or number corresponding to a given logarithm.

In deriving a number corresponding to a logarithm, it is important that these simple rules be committed to memory: (1) that the figures that form the original number from a corresponding logarithm depend entirely upon the mantissa or decimal part of the log (2) that the characteristic serves only to indicate where to place the decimal point of the original number, (3) that, if the original number was a whole number, the decimal point would be placed to the extreme right.

The procedure of finding the number corresponding to a logarithm is explained by the following: Suppose the logarithm to be 3.574. First search in the table under any column from 0 to 9 for the numbers of the mantissa 574. If the exact number cannot be found, look for the next *lowest* figure which is nearest to, but less than, the given mantissa. After the mantissa has been located, simply glance immediately to the left to the N column and there will be read the number, 37. This number comprises the first two figures of the number corresponding to the antilog. The third figure of the number will appear at the head of the column in which the mantissa was found. In this instance the number heading the column will be 5. If the figures have been arranged as they have been found, the number will now be 375.

Now, since the characteristic is 3, there must be four figures to the *left* of the decimal point; therefore by annexing a cipher, the number becomes 3750; this is the number that corresponds to the logarithm 3.574. If the characteristic were 2 instead of 3, the number would be 375. If the logarithm were —3.574 or —1.574, the antilogs or corresponding numbers would be .00375 and .375 respectively. After a little experience, a person can obtain the number corresponding to a logarithm in a very few seconds.

Converting Decibels to Power

It is always convenient to be able to convert a decibel value to a power equivalent. The formula used for converting decibels into watts is similar in many respects to equation (2), the only difference being that the factor P_1 corresponding to the power level is not known. Usually the formula for converting decibels into power is written as:

$$N_{db} = 10 \text{ Log } \frac{P_1}{.006} \quad (5)$$

It is difficult to derive the solution to the above equation because of the expression being written in the reverse. However, by rearranging the various factors, the expression can be simplified to permit easy visualization; thus:

$$P = .006 \times \text{antilog } \frac{N_{db}}{10} \quad (6)$$

where P is the desired power level; .006, the reference level in milliwatts; N_{db}, the decibels to be converted, and 10, the divisor.

To determine the power level, P, from a decibel equivalent, simply divide the decibel value by 10, then take the number comprising the antilog and multiply it by .006; the product gives the power level of the decibel value.

NOTE: In all problems dealing with the conversion of *minus* decibels to power, it often happens that the decibel value $—N_{db}$, is not always equally divisible by 10. When this is the case, the numerator in the factor $—N_{db}/10$ must be made evenly divisible by the denominator in order to derive the proper power ratio. Note that the value $—N_{db}$ is negative; hence, when dividing by 10, the negative signs must be observed and the quotient labeled accordingly.

To make the numerator in the value $—N_{db}$ equally divisible by 10, proceed as follows: Assume $—N_{db}$ to be the value —38; hence, to make this figure equally divisible by 10, we must add a —2 to it, and, since we have added a negative 2 to it, we must also add a positive 2 to make the net result the same.

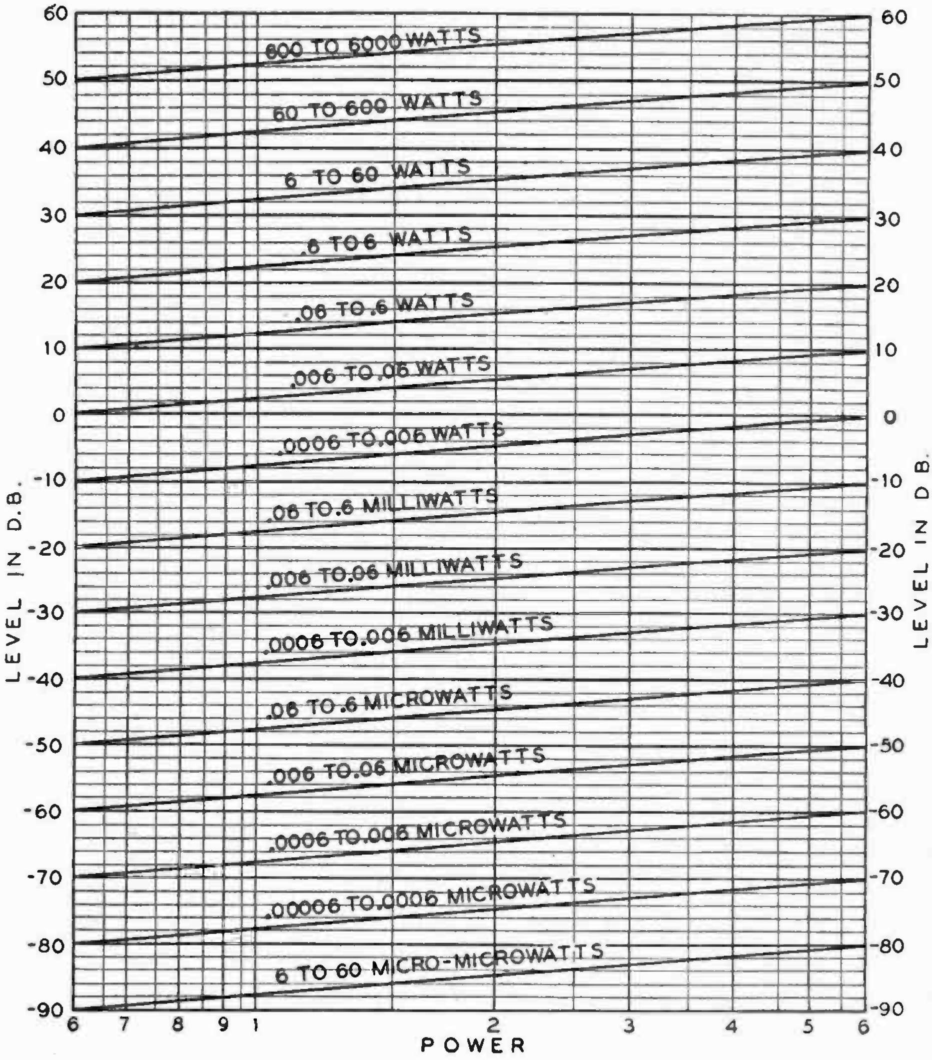
Our decibel value now stands, —40 +2. Dividing both of these figures by 10 (as in equation 6), we have —4 and a plus 0.2. Putting the two of them together, we have —4.2 as our resulting logarithm, with the negative characteristic and positive mantissa required to indicate a number smaller than one.

While the above discussion applies strictly to negative values, the following examples will clearly show the technique to be followed for almost all practical problems.

(a) The output level of a popular velocity ribbon microphone is rated at

KEN-O-GRAF

WATTS · VS · DECIBELS



Based on .006 watts at zero level.

Chart Courtesy Kenyon Transformer Co.

Power levels between 6 micromicrowatts and 6000 watts may be referred to corresponding decibel levels between —90 and 60 db, and vice versa, by means of the above chart. Fifteen ranges are provided. Each curve begins at the same point where the preceding one ends, enabling uninterrupted coverage of the wide db and power ranges with condensed chart. For example: the lowermost curve ends at —80 db or 60 micromicrowatts and the next range starts at the same level. Zero db is taken as 6 milliwatts (.006 watt).

—74 db. What is the equivalent in milliwatts?

Solution by equation (6)

$$\frac{-N_{db}}{10} = \frac{-74}{10} \text{ (not equally divisible by 10)}$$

Routine:

$$\begin{array}{rr} -74 & \\ -\ 6 & +6 \\ \hline -80 & +6 \end{array}$$

$$\frac{-N_{db}}{10} = \frac{-80 \ +6}{10} = -8.6$$

Antilog —8.6 = .00000004
.006 x .00000004 = .00000000024 watt or 240 micro-microwatts.

(b) This example differs somewhat from that of the foregoing one in that the mantissas are added differently. A low-powered amplifier has an input signal level of —17.3 db. How many milliwatts does this value represent?

Solution by equation (6)

Routine:

$$\begin{array}{rr} -17.3 & \\ -\ 2.7 & +2.7 \\ \hline -20.0 & +2.7 \end{array}$$

$$\frac{-N_{db}}{10} = \frac{-20 \ +2.7}{10} = -2.27$$

Antilog —2.27 = .0186
.006 × .0186 = .0001116 watt or .1116 milliwatts.

Voltage Amplifiers

When plans are being drafted contemplating the design of power amplifiers, it is essential that the following data be determined: first, the input and output signal levels to be used; second, the size of the power tubes that will adequately deliver sufficient undistorted output; third, the input signal voltage that must be applied to the amplifier to deliver the desired output. This last requirement is the most important in the design of voltage amplifiers.

The voltage step-up in a transformer-coupled amplifier depends chiefly upon the μ of the tubes and the turns ratio of the interstage coupling transformers. The step-up value in any amplifier is calculated by multiplying the step-up factor of each voltage amplifying or step-up device. Thus, for example, if an amplifier were designed having an output transformer with a ratio of 3:1 coupled to a tube having a μ of 7, the voltage step-up would be approximately 3 times 7 or 21. It is seldom that the total product will be exactly the figure derived because it is not quite possible to realize amplification equal to the full μ of the tube.

Decibel-Voltage Ratios

From the voltage gain in an amplifier, it is possible to calculate the input and output signal levels and at the same time be able to determine at what level the input signal must be in order to obtain the desired output. By converting voltage ratios into decibels, power levels can be determined. Hence, to find the gain in db when the input and output voltages are known, the following expression is used:

$$\text{(gain) } N_{db} = 20 \text{ Log } \frac{E_1}{E_2} \qquad (7)$$

where E_1, is the output voltage, and E_2, the input voltage.

Employing the above equation in a practical problem, note the logarithm is multiplied by 20 instead of by 10 as in previous examples. For instance:

A certain one-stage amplifier consists of the following parts: 1 input transformer, ratio 2:1, and 1 output tube having a μ of 95. Determine the gain in decibels with an input voltage of 1 volt.

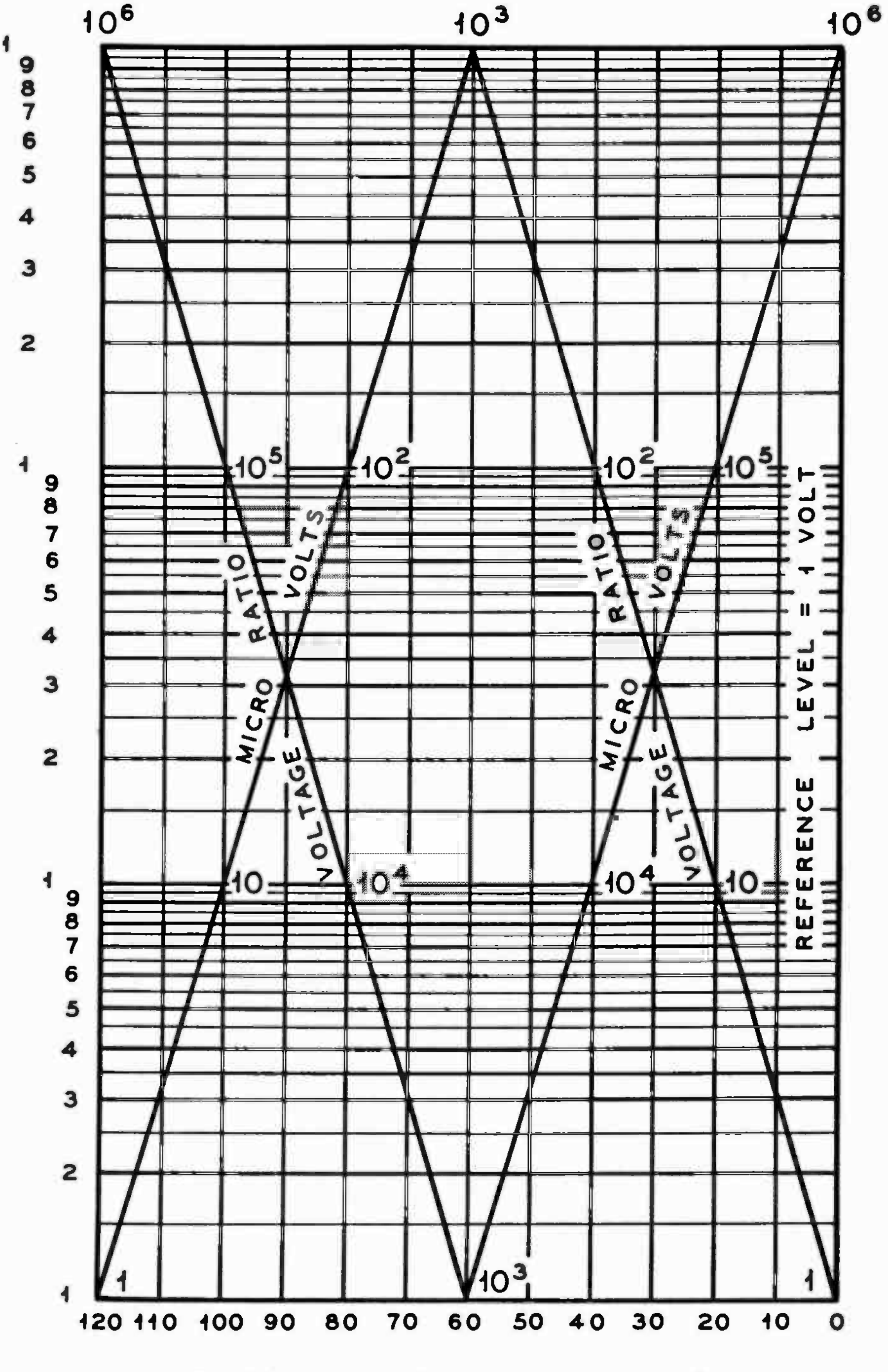
Solution by equation (7)

$$2 \times 95 = 190 \text{ voltage gain}$$

$$\text{therefore, } \frac{E_1}{E_2} = \frac{190}{1} = 190$$

$$\text{Log } 190 = 2.278$$

$$20 \times 2.278 = 45.56 \text{ decibels gain.}$$



DECIBELS (VOLTAGE RATIO)

To reverse the above and convert decibels to voltage ratios, use the following expression:

$$E\ (\text{gain}) = \text{antilog}\ \frac{N_{db}}{20} \qquad (8)$$

where E is the voltage gain (power ratio); N_{db}, the decibels, and 20, the divisor.

To find the gain, simply divide the decibels by 20, then extract the antilog from the quotient; the result gives the voltage ratio.

Input Voltages

In designing power amplifiers, it is paramount to have *exact* knowledge of the magnitude of the input signal voltage necessary to drive the output power tubes to maximum undistorted output.

To determine the input voltage, take the *peak voltage* necessary to drive the grid of the last class-A amplifier tube to maximum output and divide this figure by the total overall gain *preceding this stage.*

Computing Specifications

From the preceding explanations the following data can be computed with a very high degree of accuracy:

(1) Voltage amplification
(2) Overall gain in db
(3) Output signal level in db
(4) Input signal level in db
(5) Input signal level in watts
(6) Input signal voltage.

Microphone Levels

Practically all acoustic-electric apparatus used to energize amplifiers have output levels rated in decibels. The output signal levels of these devices vary considerably, as may be noted from the table below:

	Decibels	Average
Phonographic pickup	0 to — 30	—15
Carbon microphones	—30 to — 60	—45
Piezo-electric microphones	—55 to — 80	—60
Dynamic microphones	—75 to — 95	—85
Condenser microphones	—80 to —100	—90
Velocity microphones	—70 to —110	—85

In general, the lower the output signal level, the higher will be the acoustic fidelity over the entire audio spectrum.

The output levels of microphones and phonograph pickups have the same power values ascribed to them as those derived from calculating power output levels of amplifiers. Therefore, the same equations employed in connection with power ratios are similarly applied when converting output signal levels to power levels.

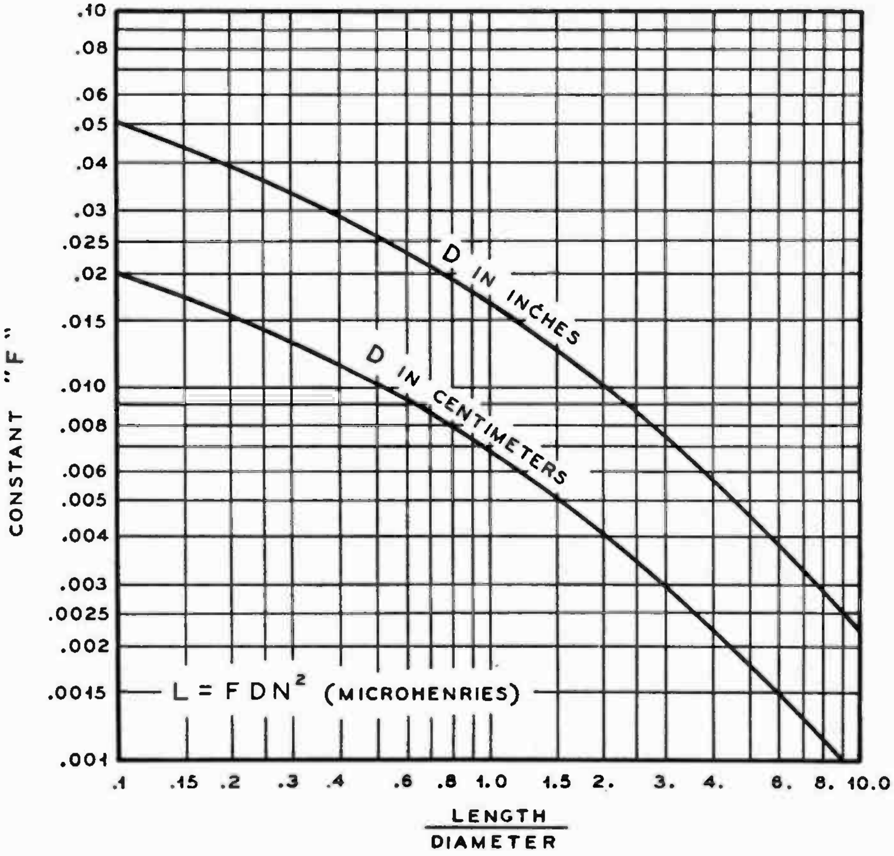
Push-Pull Amplifiers

To double the output of any cascade amplifier, it is only necessary to connect in push-pull the last amplifying stage and replace the interstage and output transformers with push-pull types.

To determine the voltage gain (voltage ratio) of a push-pull amplifier, take the ratio of one *half* of the secondary winding of the push-pull transformer and multiply it by the μ of one of the output tubes in the push-pull stage; the product, *when doubled,* will be the voltage amplification or step-up.

Acoustically, that is from the loudspeaker standpoint, it takes approximately three db before any change in the volume of sound is noted. This is because the intensity of sound as heard by the ear varies logarithmically with the acoustic power. For practical purposes it is only necessary to remember that if two sounds differ in physical intensity by less than three db, they sound practically alike.

Preamplifiers are employed to raise low input signal levels up to some required input level of another intermediate or succeeding amplifier. For example: if an amplifier was designed to operate at an input level of —30 db and instead a considerably lower input level were used, a preamplifier would then have to be designed to bring the low input signal up to the rated input-signal level of —30



COIL INDUCTANCE CALCULATION CHART.

db to obtain the full undistorted output from the power tubes in the main amplifier. The amount of gain necessary to raise a low input-signal level up to another level may be determined by the following equation:

$$E \text{ (gain)} = \text{antilog} \frac{N_{db1} - N_{db2}}{20} \qquad (9)$$

where E is the voltage step-up or gain; N_{db1}, the input signal level of the preamplifier or the new input signal level; N_{db2}, the input signal level to the intermediate amplifier, and 20, the divisor.

CALCULATION OF INDUCTANCE

The calculation of inductance values for coils in radio transmitter and receiver circuits is not difficult when certain basic considerations are taken into account. There are a number of formulas for such inductance calculations, some laying claim to greater accuracy than others. It must be remembered that most of such formulas give only approximate solutions to practical problems; few claim absolute accuracy. There is lacking an absolutely accurate means of inductance calculations at the frequency at which the inductance is to be used. The following discussion is confined to calculations for single-layer solenoids.

Frequency of Resonance

If it is desired to find the value of inductance to tune a receiver circuit to

3500 kc. with a 50-$\mu\mu$fd. maximum capacity variable condenser the formula is:

$$L = \frac{25{,}330}{f^2 \times C}$$

For ease of calculation assume that C was to be approximately 41 $\mu\mu$fds., and f was 3.5 megacycles; these values would then give a value of L equal to 50 microhenrys.

From the formula:

$$N = \sqrt{\frac{L}{df}}$$

where

N = number of turns,
L = inductance in microhenrys,
d = diameter of coil measured to center of wire,
f = a factor dependent upon the ratio of length of winding to coil diameter.

The value of L is known; the diameter d will be dependent upon the coil form which has been selected. Once the ratio of length to diameter is known, the value of f (constant) can readily be found from the accompanying graph. If the coil diameter is one inch, and if it is assumed that the winding will be one inch long, the ratio of the two will be unity. From the graph, a ratio of 1 corresponds to factor f of .0175. This graph is published by courtesy of Professor F. E. Terman of Stanford University, in whose textbook, *Radio Engineering*, the original presentation was made.

Continuing with the coil calculations, the values are now substituted in an equation, as follows:

$$N = \sqrt{\frac{50}{1 \times .0175}} = 53.5 \text{ turns.}$$

Referring to the *copper wire table* in the chapter, *Power Supplies*, it is found that a wire size which will wind approximately 53 turns per inch will be size no. 28 double cotton covered (dcc). This wire size will actually wind 54.6 turns per inch, yet it comes closest to what is here desired, and consequently must be used. The actual difference between 53 turns per inch and 54.6 turns is negligible.

The chart will require a bit of practice when used with the foregoing formula; it is suggested that several ratios of length to diameter be experimented with, insofar as the calculations are concerned, before a coil is actually wound. If the wire size is very small as compared with the diameter of the coil, the stipulation that the diameter be regarded as that measured from the center of the wire can be neglected. If greater accuracy is required, the formula should be converted into centimeters insofar as units of length and diameter are concerned.

Accurate results may be obtained with either inches or centimeters as the units of measurement, but *it is important that the same unit* must be used in every case for *both* the coil length and the coil diameter.

TWENTY TWO

Amateur Radio Laws and Regulations

DEFINITIONS

150.01. Amateur service.—The term "amateur service", means a radio service carried on by amateur stations.

150.02. Amateur station.—The term "amateur station" means a station used by an "amateur," that is, a duly authorized person interested in radio technique solely with a personal aim and without pecuniary interest. It embraces all radio transmitting apparatus at a particular location used for amateur service and operated under a single instrument of authorization.

150.03. Amateur portable station.—The term "amateur portable station" means an amateur station that is portable in fact, that is so constructed that it may conveniently be moved about from place to place for communication, and that is in fact so moved from time to time, but which is not operated while in motion.

150.04. Amateur portable-mobile station.—The term "amateur portable-mobile station" means an amateur station that is portable in fact, that is so constructed that it may conveniently be transferred to or from a mobile unit or from one such unit to another. and that is in fact so transferred from time to time and is ordinarily used while such mobile unit is in motion.

150.05. Amateur radio communication.—The term "amateur radio communication" means radio communication between amateur stations solely with a personal aim and without pecuniary interest.

150.06. Amateur operator.—The term "amateur operator" means a person holding a valid license issued by the Federal Communications Commission authorizing him to operate licensed amateur stations.

AMATEUR OPERATORS

License—Privileges

151.01. Eligibility for license.—The following are eligible to apply for amateur operator license and privileges:

Class A—A United States citizen who has within 5 years of receipt of application held license as an amateur operator for a year or who in lieu thereof qualified under section 151.20.

Class B—Any United States citizen.

Class C—A United States citizen whose actual residence, address, and station are more than 125 miles airline from the nearest point where examination is given at least quarterly for class B; or is shown by physician's certificate to be unable to appear for examination due to protracted disability; or is shown by certificate of the commanding officer to be in a camp of the Civilian Conservation Corps or in the regular military or naval service of the United States at a military post or naval station and unable to appear for class B examination.

151.02. Classification of operating privileges.—Amateur operating privileges are as follows:

Class A—All amateur privileges.

Class B—Same as class A except specially limited as in section 152.28.

Class C—Same as class B.

151.03. Scope of operator authority.—Amateur operators' licenses are valid only for the operation of licensed amateur stations; Provided, however, Any person holding a valid radio operator's license of any class may operate stations in the experimental service licensed for, and operating on, frequencies above 300,000 kilocycles.

151.04. Posting of license.—The original operator's license shall be posted in a conspicuous place in the room occupied by such operator while on duty or kept in his personal possession and available for inspection at all times while the operator is on duty, except when such license has been filed with application for modification or renewal, or has been mutilated, lost, or destroyed, and application has been made for a duplicate.

151.05. Duplicate license.—Any licensee applying for a duplicate license to replace an original which has been lost, mutilated, or destroyed, shall submit to the Commission such mutilated license or affidavit attesting to the facts regarding the manner in which the original was lost or destroyed. If the original is later found, it or the duplicate shall be returned to the Commission.

151.06. Renewal of amateur operator license.—An amateur operator license may be renewed upon proper application and a showing that within 3 months of receipt of the application by the Commission the licensee has lawfully operated an amateur station licensed by the Commission, and that he has communicated by radio with at least three other such amateur stations. Failure to meet the requirements of this secion will make it necessary for the applicant to again qualify by examination.

151.07. Who may operate an amateur station.—An amateur station may be operated only by a person holding a valid amateur operator's license, and then only to the extent provided for by the class of privileges for which the operator's license is endorsed. When an amateur station uses radiotelephony (type A-3 emission) the licensee may permit any person to transmit by voice, provided a duly licensed amateur operator maintains control over the emissions by turning the carrier on and off when required and signs the station off after the transmission has been completed.

Examinations

151.15. When required.—Examination is required for a new license as an amateur operator or for change of class of privileges.

151.16. Elements of examination. — The examination for amateur operator privileges will comprise the following elements:

1. Code test—ability to send and receive, in plain language, messages in the International Morse Code at a speed of not less than 13 words per minute, counting 5 characters to the word, each numeral or punctuation mark counting as 2 characters.
2. Amateur radio operation and apparatus, both telephone and telegraph.
3. Provisions of treaty, statute, and regulations affecting amateurs.
4. Advanced amateur radiotelephony.

151.17. Elements required for various privileges.—Examinations for class A privileges will include all four examination elements as specified in section 151.16.

Examinations for classes B and C privileges will include elements, 1, 2, and 3 as set forth in section 151.16.

151.18. Manner of conducting examination.—Examinations for class A and class B privileges will be conducted by an authorized Commission employee or representative at points specified by the Commission.

Examinations for class C privileges will be given by volunteer examiner(s), whom the Commission may designate or permit the applicant to select; in the latter event the examiner giving the code test shall be a holder of an amateur license with class A or B privileges, or have held within 5 years a license as a professional radiotelegraph operator or have within that time been employed as a radiotelegraph operator in the service of the United States; and the examiner for the written test, if not the same individual, shall be a person of legal age.

151.19. Additional examination for holders of class C privileges.—The Commission may require a licensee holding class C privileges to appear at an examining point for a class B examination. If such licensee fails to appear for examination when directed to do so, or fails to pass the supervisory examination, the license held will be canceled and the holder thereof will not be issued another license for the class C privileges.

Whenever the holder of class C amateur operator privileges changes his actual residence or station location to a point where he would not be eligible to apply for class C privileges in the first instance, or whenever a new examining point is established in a region from which applicants were previously eligible for class C privileges, such holders of class C privileges shall within 4 months thereafter appear at an examining point and be examined for class B privileges. The license will be canceled if such licensee fails to appear, or fails to pass the examination.

151.20. Examination abridgment. — An applicant for class A privileges, who holds a license with class B privileges, will be required to pass only the added examination element No. 4. (See Sec. 151.16.)

A holder of class C privileges will not be accorded an abridged examination for either class B or class A privileges.

An applicant who has held a license for the class of privileges specified below, within 5 years prior to receipt of application, will be credited with examination elements as follows:

Class of license or privileges:	Credits
Commercial extra first	Elements 1, 2, and 4.
Radiotelegraph first, second or third	Elements 1 and 2.
Radiotelephone first or second	Elements 2 and 4.
Class A	Elements 2 and 4.

No examination credit is given on account of license of radiotelephone third class, nor for other class of license or privileges not above listed.

151.21. Examination procedure. — Applicants shall write examinations in longhand—code tests and diagrams in ink or pencil, written tests in ink—except that applicants unable to do so because of physical disability may typewrite or dictate their examinations and, if unable to draw required diagrams, may make instead a detailed description essentially equivalent. The examiner shall certify the nature of the applicant's disability and, if the examination is dictated, the name and address of the person(s) taking and transcribing the applicant's dictation.

151.22. Grading.—Code tests are graded as passed or failed, separately for sending and receiving tests. A code test is failed unless free of omission or other error for a continuous period of at least 1 minute at required speed. Failure to pass the required code test will terminate the examination. (See sec. 151.23.)

A passing grade of 75 per cent is required separately for class B and class A written examinations.

151.23. Eligibility for reexamination.—An applicant who fails examination for amateur privileges may not take another examination for such privileges within 2 months, except that this rule shall not apply to an examination for class B following one for class C.

AMATEUR RADIO STATIONS

Licenses

152.01. Eligibility for amateur station license.—License for an amateur station will be issued only to a licensed amateur operator who has made a satisfactory showing of control of proper transmitting apparatus and control of the premises upon which such apparatus is to be located: Provided, however, That in the case of an amateur station of the military or Naval Reserve of the United States located in approved public quarters and established for training purposes, but not operated by the United States Government, a station license may be issued to a person in charge of such a station although not a licensed amateur operator.

152.02. Eligibility of corporations or organizations to hold license.—An amateur station license will not be issued to a school, company, corporation, association, or other organization; nor for their use: Provided, however, That in the case of a bona-fide amateur radio society a station license may be issued in accordance with section 152.01 to a licensed amateur operator as trustee for such society.

152.03. Location of station.—An amateur radio station, and the control point thereof when remote control is authorized, shall not be located on premises controlled by an alien.

152.04. License period.—License for an amateur station will normally be for a period of 3 years from the date of issuance of a new, renewed, or modified license.

152.05. Authorized operation.—An amateur station license authorizes the operation of all transmitting apparatus used by the licensee at the location specified in the station license and in addition the operation of portable and portable-mobile stations at other locations under the same instrument of authorization.

152.06. Renewal of amateur station license.—An amateur station license may be renewed upon proper application and a showing that, within 3 months of receipt of the application by the Commission, the licensee thereof has lawfully operated such station in communication by radio with at least three other amateur stations licensed by the Commission, except that in the case of an application for renewal of station license issued for an amateur society or reserve group, the required operation may be by any licensed amateur operator. Upon failure to comply with the above requirements, a successor license will not be granted until 2 months after expiration of the old license.

152.07. Posting of station license.—The original of each station license or a facsimile thereof shall be posted by the licensee in a conspicuous place in the room in which the transmitter is located or kept in the personal possession of the operator on duty, except when such license has been filed with application for modification or renewal, or has been mutilated, lost, or destroyed, and application has been made for a duplicate.

Call Signals

152.08. Assignment of call letters.—Amateur station calls will be assigned in regular order and special requests will not be considered except that a call may be reassigned to the latest holder, or if not under license during the past 5 years to any previous holder, or to an amateur organization in memoriam to a deceased member and former holder, and particular calls may be temporarily assigned to stations connected with events of general public interest

152.09. **Call signals for member of U. S. N. R.**—In the case of an amateur licensee whose station is licensed to a regularly commissioned or enlisted member of the United States Naval Reserve, the Commandant of the naval district in which such station is located may authorize, in his discretion, the use of the call-letter prefix N in lieu of the prefix W or K, assigned in the license issued by the Commission, provided that such N prefix shall be used only when operating in the frequency bands 1715-2000[1] kilocycles, 3500-4000 kilocycles, 56000-60000 kilocycles, and 400000-401000 kilocycles in accordance with instructions to be issued by the Navy Department.

152.10. **Transmission of call signals.**—An operator of an amateur station shall transmit its assigned call at the end of each transmission and at least once every 10 minutes during transmission of more than 10 minutes' duration. Provided, however, That transmission of less than 1 minute duration from stations employing break-in operation need be identified only once every 10 minutes of operation and at the termination of the correspondence. In addition, an operator of an amateur portable or portable-mobile radiotelegraph station shall transmit immediately after the call of the station the fraction-bar character $\overline{\text{(DN)}}$ followed by the number of the amateur call area in which the portable or portable-mobile amateur station is then operating, as for example:

Example 1.—Portable or portable-mobile amateur station operating in the third amateur call area calls a fixed amateur station: W1ABC W1ABC W1ABC DE W2DEF $\overline{\text{DN}}$ 3 W2DEF $\overline{\text{DN}}$ 3 W2DEF $\overline{\text{DN}}$ 3 AR.

Example 2.—Fixed amateur station answers the portable or portable-mobile amateur station: W2DEF W2DEF W2DEF DE W1ABC W1ABC W1ABC $\overline{\text{K}}$.

Example 3.—Portable or portable-mobile amateur station calls a portable or portable-mobile amateur station: W3GHI W3GHI W3GHI DE W4JKL $\overline{\text{DN}}$ 4 W4JKL $\overline{\text{DN}}$ 4 W4JKL $\overline{\text{DN}}$ 4 AR.

If telephony is used, the called sign of the station shall be followed by an announcement of the amateur call area in which the porable or portable-mobile station is operating.

152.11. **Requirements for portable and portable-mobile operation.**—A licensee of an amateur station may operate portable amateur stations (sec. 150.03) in accordance with the provisions of sections 152.09, 152.10, 152.12, and 152.45. Such licensee may operate portable and portable-mobile amateur stations without regard to section 152.12, but in compliance with sections 152.09, 152.10, and 152.45, when such operation takes place on authorized amateur frequencies above 28000 kilocycles.

152.12. **Special provisions for portable stations.**—Advance notice in writing shall be given by the licensee to the inspector in charge of the district in which such portable station is to be operated. Such notices shall be given prior to any operation contemplated, and shall state the station call, name of licensee, the date of proposed operation, and the locations as specifically as possible. An amateur station operating under this section shall not be operated during any period exceeding 1 month without giving further notice to the inspector in charge of the radio-inspection district in which the station will be operated, nor more than four consecutive periods of 1 month at the same location. This section does not apply to the operation of portable or portable-mobile amateur stations on frequencies above 2800 kilocycles. (See sec. 152.11.)

152.13. **Special provisions for nonportable stations.**—The provisions for portable stations shall not be applied to any nonportable station except that—

(a) An amateur station that has been moved from one permanent location to another permanent location may be operated at the latter location in accordance with the provisions governing portable stations for a period not exceeding 60 days, but in no event beyond the expiration date of the license, provided an application for modification of license to change the permanent location has been made to the Commission.

(b) The licensee of an amateur station who is temporarily residing at a location other than the licensed location for a period not exceeding 4 months may for such period operate his amateur station at his temporary address in accordance with the provision governing portable stations.

Use of Amateur Stations

152.14. **Points of communication.**—An amateur station shall communicate only with other amateur stations, except that in emergencies or for testing purposes it may be used also for communication with commercial or Government radio stations. In addition, amateur stations may communicate with any mobile radio station which is licensed by the Commission to communicate with amateur stations, and with stations of expeditions which may also be authorized to communicate with amateur stations. They may also make transmissions to points equipped only with receiving apparatus for the measurement of emissions, observation of transmission phenomena, radio control of remote objects, and similar purely experimental purposes.

152.15. **No remuneration for use of station.**—An amateur station shall not be used to transmit or receive messages for hire, nor for communication for material compensation, direct or indirect, paid or promised.

152.16. **Broadcasting prohibited.**—An amateur station shall not be used for broadcasting any form of entertainment, nor for the simultaneous re-transmission by automatic means of programs or signals emanating from any class of station other than amateur.

152.17. **Radiotelephone tests.**—The transmission of music by an amateur station is forbidden. However, single audio-frequency tones may be transmitted by radiotelephony for test purposes of short duration in connection with the development of experimental radio-telephone equipment.

Allocation of Frequencies

152.25 **Frequencies for exclusive use of amateur stations.**—The following bands of frequencies are allocated exclusively for use by amateur stations:

1715 to 2000 kilocycles.[2]
3500 to 4000 kilocycles.
7000 to 7300 kilocycles.
14000 to 14400 kilocycles.
28000 to 30000 kilocycles.
56000 to 60000 kilocycles.
112000 to 116000 kilocycles.[3]
224000 to 230000 kilocycles.[3]
400000 to 401000 kilocycles.

152.26. **Use of frequencies above 300000 kilocycles.**—The licensee of an amateur station may, subject to change upon further order, operate amateur stations, with any type of emission authorized for amateur stations, on any frequency above 300000 kilocycles without separate licenses therefor.

152.27. **Frequency bands for telephony.**—The following bands of frequencies are allocated for use by amateur stations using radiotelephony, type A-3 emission:

1800 to 2000 kilocycles.
28500 to 30000 kilocycles.
56000 to 60000 kilocycles.
112000 to 116000 kilocycles.[3]
224000 to 230000 kilocycles.[3]
400000 to 401000 kilocycles.

152.28. **Additional hands for telephony.**—An amateur station may use radiotelephony, type A-3 emission. in the following additional bands of frequencies; Provided The station is licensed to a person who holds an amateur operator's license endorsed for class A privileges, and actually is operated by an amateur operator holding class A privileges:

3900 to 4000 kilocycles.
14150 to 14250 kilocycles.

152.29. **Television and frequency-modulation transmission.**—The following bands of frequencies are allocated for use by amateur stations for television and radiotelephone frequency-modulation transmission:

112000 to 116000 kilocycles.[3]
224000 to 230000 kilocycles.[3]
400000 to 401000 kilocycles.

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[1] Subject to change to "1750 to 2050" kilocycles in accordance with the "Inter-American Arrangement Covering Radiocommunication," Havana, 1937.

[2] Subject to change to "1750 to 2050" kilocycles in accordance with the "Inter-American Arrangement Covering Radiocommunication," Havana, 1937.

[3] The Commission reserves the right to change or cancel these frequencies without advance notice or hearing.

152.30. Facsimile transmission. — The following bands of frequencies are allocated for use by amateur stations for facsimile transmission:

1715 to 2000 kilocycles.[2] 224000 to 230000 kilocycles.[3]
56000 to 60000 kilocycles. 400000 to 401000 kilocycles.
112000 to 116000 kilocycles.[3]

152.31. Individual frequency not specified.—Transmissions by an amateur station may be on any frequency within the bands above assigned. Sideband frequencies resulting from keying or modulating a transmitter shall be confined within the frequency band used.

152.32. Types of emission.—All bands of frequencies allocated to the amateur service may be used for radiotelegraphy, type A-1 emission. Type A-2 emission may be used in the following bands of frequencies only:

56000 to 60000 kilocycles.
112000 to 116000 kilocycles.[3]
224000 to 230000 kilocycles.[3]
400000 to 401000 kilocycles.

Equipment and Operation

152.40. Maximum power input.—The licensee of an amateur station is authorized to use a maximum power input of 1 kilowatt to the plate circuit of the final amplifier stage of an oscillator-amplifier transmitter or to the plate circuit of an oscillator transmitter. An amateur transmitter operating with a power input exceeding 900 watts to the plate circuit shall provide means for accurately measuring the plate power input to the vacuum tube, or tubes, supplying power to the antenna.

152.41. Power supply to transmitter.—The licensee of an amateur station using frequencies below 60000 kilocycles shall use adequately filtered direct-current plate power supply for the transmitting equipment to minimize frequency modulation and to prevent the emission of broad signals.

152.42. Requirements for prevention of interference. —Spurious radiations from an amateur transmitter operating on a frequency below 60000 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 be 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 in any radiation from a transmitter which is outside the frequency band of emission normal for the type of transmission employed, including any component whose frequency is an integral multiple or submultiple of the carrier frequency (harmonics and subharmonics), spurious modulation products, key clicks, and other transient effects, and parasitic oscillations. The frequency of emission shall be as constant as the state of the art permits.

152.43. Modulation of carrier wave.—Except for brief tests or adjustments, an amateur radiotelephone station shall not emit a carrier wave unless modulated for the purpose of communication.

152.44. Frequency measurement and regular check. —The licensee of an amateur station shall provide for measurement of the transmitter frequency and establish procedure for checking it regularly. The measurement of the transmitter frequency shall be made by means independent of the frequency control of the transmitter and shall be of sufficient accuracy to assure operation within the frequency band used.

152.45. Logs.—Each licensee of an amateur station shall keep an accurate log of station operation, including the following data:

(a) The date and time of each transmission. (The date need only be entered once for each day's operation. The expression "time of each transmission" means the time of making a call and need not be repeated during the sequence of communication which immediately follows; however, an entry shall be made in the log when "signing off" so as to show the period during which communication was carried on.)

(b) The signature of the person manipulating the transmitting key of the radiotelegraph transmitter or the signature of the person operating a transmitter of any other type (type A-3 or A-4 emission) with statement as to type of emission, and the signature of any other person who transmits by voice over a radiotelephone transmitter (type A-3 emission). (The signature need only be entered once in the log, provided the log contains a statement to the effect that all transmissions were made by the person named except where otherwise stated. The signature of any other person who operates the station shall be entered in the proper space for his transmissions.)

(c) Call letter 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 1 year.)

The log shall be preserved for a period of at least 1 year following the last date of entry. The copies of record communications and station log, as required under this section, shall be available for inspection upon request by an authorized Government representative.

Special Conditions

152.50. Additional conditions to be observed by licensee.—An amateur station license is granted subject to the conditions imposed in sections 152.51 to 152.54 inclusive, in addition to any others that may be imposed during the term of the license. Any licensee receiving due notice requiring the station licensee to observe such conditions shall immediately act in conformity therewith.

152.51. Quiet hours.—In the event that the operation of an amateur station causes general interference to the reception of broadcast programs with receivers of modern design, such amateur stations shall not operate during the hours from 8 o'clock p.m. to 10:30 p.m., local time, and on Sunday for the additional period from 10:30 a.m. until 1 p.m., local time, upon such frequency or frequencies as cause such interference.

152.52. Second notice of same violation.—In every case where an amateur station licensee is cited a second time within a year for the same violation under section 152.25, 152.27, 152.28, 152.30, 152.31, 152.41, or 152.42, the Commission will direct that the station remain silent from 6 p.m. to 10:30 p.m., local time, until written notice has been received authorizing full-time operation. The licensee shall arrange for tests at other hours with at least two amateur stations within 15 days of the date of notice, such tests to be made for the specific purpose of aiding the licensee in determining whether the emissions of his station are in accordance with the Commission's regulations. The licensee shall report under oath to the Commission at the conclusion of the tests as to the observations reported by amateur licensees in relation to the reported violation. Such reports shall include a statement as to the corrective measures taken to insure compliance with the regulations.

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[2] Subject to change to "1750 to 2050" kilocycles in accordance with the "Inter-American Arrangement Covering Radiocommunication," Havana, 1937.

[3] The Commission reserves the right to change or cancel these frequencies without advance notice or hearing.

152.53. Third notice of same violation.—In every case where an amateur station licensee is cited the third time within a year for the same violation as indicated in section 152.52, the Commission will direct that the station remain silent from 8 a.m. to 12 midnight, local time, except for the purpose of transmitting a prearranged test to be observed by a monitoring station of the Commission to be designated in each particular case. Upon completion of the test the station shall again remain silent during these hours until authorized by the Commission to resume full-time operation. The Commission will consider the results of the tests and the licensee's past record in determining the advisability of suspending the operator license and/or revoking the station license.

152.54. Operation in emergencies.—In the event of widespread emergency conditions affecting domestic communication facilities, the Commission may confer with representatives of the amateur service and others and, if deemed advisable, will declare that a state of general communications emergency exists, designating the licensing area or areas concerned (in general not exceeding 1,000 miles from center of the affected area), whereupon it shall be incumbent upon each amateur station in such area or areas to observe the following restrictions for the duration of such emergency:

(a) No transmissions except those relating to relief work or other emergency service such as amateur nets can afford, shall be made within the 1715-2000[2] kilocycle or 3500-4000 kilocycle amateur bands. Incidental calling, testing, or working, including casual conversation or remarks not pertinent or necessary to constructive handling of the general situation shall be prohibited.

(b) The frequencies 1975-2000, 3500-3525, and 3975-4000 kilocycles shall be reserved for emergency calling channels, for initial calls from isolated stations or first calls concerning very important emergency relief matters or arrangements. All stations having occasion to use such channels shall, as quickly as possible, shift to other frequencies for carrying on their communications.

(c) A 5-minute listening period for the first 5 minutes of each hour shall be observed for initial calls of major importance, both in the designated emergency calling channels and throughout the 1715-2000[2] and 3500-4000 kilocycle bands. Only stations isolated or engaged in handling official traffic of the highest priority may continue with transmissions in these listening periods, which must be accurately observed. No replies to calls or resumption of routine traffic shall be made in the 5 minute listening period.

(d) The Commission may designate certain amateur stations to assist in promulgation of its emergency announcement, and for policing the 1715-2000[2] and 3500-4000 kilocycle bands and warning non-complying stations noted operating therein. The operators of these observing stations shall report fully the identity of any stations failing, after due notice, to comply with any section of this regulation. Such designated stations will act in an advisory capacity when able to provide information on emergency circuits. Their policing authority is limited to the transmission of information from responsible official sources, and full reports of noncompliance which may serve as a basis for investigation and action under section 502 of the Communications Act. Policing authority extends only to 1715-2000[2] and 3500-4000 kilocycle bands. Individual policing transmissions shall refer to this section by number, shall specify the date of the Commissions declaration, the area and nature of the emergency, all briefly and concisely. Policing-observer stations shall not enter into discussions beyond essentials with the stations notified, or other stations.

(e) These special conditions imposed under this section will cease to apply only after the Commission shall have declared such emergency to be terminated.

GENERAL RULES APPLICABLE TO AMATEUR SERVICE

103.6. Applications.—Each application . . . shall be made in writing, under oath of the applicant, on a form prescribed and furnished by the Commission . . . The required forms may be obtained from the Commission or from any of its field offices.

103.7. Place of filing; number of copies.—Each application . . . shall be submitted as follows:

Class of station	Number of application forms required and method of filing
* * * * *	* * * * * * * * *
g Amateur	1 copy to be sent as follows: (a) To proper district office if it requires personal appearance for operator examination under direct supervision from that office. (b) Direct to Washington, D. C., in all other cases, including examinations for class C privileges.

103.15. Renewal of license.—Unless otherwise directed by the Commission, each application for renewal of license shall be filed at least 60 days prior to the expiration date of the license sought to be renewed.

105.23. Answers to notice of violations.—Any licensee receiving official notice of a violation of the terms of the Communications Act of 1934, any legislative act, Executive order, treaty to which the United States is a party, or the rules and regulations of the Federal Communications Commission, which are binding upon licensee or the terms and conditions of a license, shall, within 3 days from such receipt, send a written reply direct to the Federal Communications Commission at Washington, D. C., and a copy thereof to the office of the Commission originating the official notice, when the originating office is other than the office of the Commission in Washington, D. C. The answer to each notice shall be complete in itself and shall not be abbreviated by reference to other communications or 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.

If the notice of violation relates to some lack of attention or improper operation of the transmitter, the name and license number or the operator in charge shall be given.

105.29. Revocation proceedings under section 312 (a) of the act.—Whenever the Commission shall institute a revocation proceeding against the holder of any radio station construction permit or license under section 312 (a), it shall initiate said proceeding by serving upon said licensee an order of revocation effective not less than 15 days after written notice thereof is given the licensee. The order of revocation shall contain a statement of the grounds and reasons for such proposed revocation and a notice of the licensee's right to be heard by filing with the Commission a written request for hearing within 15 days after receipt of said order. Upon the filing of such written request for hearing by said licensee the order of revocation shall stand suspended and the Commission will set a time and place for hearing and shall give the licensee and other interested parties notice thereof. If no request for hearing on any order of revocation is made by the licensee against whom such an order is directed within the time hereinabove set forth, the order of revocation shall become final and effective, without further action of the Commission.

105.31. Suspension of operator license.[4]—Proceedings for the suspension of an operator license shall in all cases be initiated by the entry of an order of suspension, a copy of which shall be served upon or mailed to the holder of the license involved, (to become effective on a day certain, in no event less than 40 days after date of serving or mailing such order.) The order shall set forth the name of the operator, class and grade of license, (the effective date of the order,) the period of suspension, and a statement of the reasons for suspension, and shall contain a notice to the holder of such license of his right to be heard and contest the order, by filing with the Commission (within 35 days from the receipt of said

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[2] Subject to change to "1750 to 2050" kilocycles in accordance with the "Inter-American Arrangement Covering Radiocommunication," Havana, 1937.

order) a written request for hearing (with a statement executed by him under oath, denying or explaining specifically and in detail the charges set forth in the order of suspension.) Upon receipt of such request (and statement) the effective date of the suspension of such license will be extended; and the Commission (upon consideration of the licensee's statement, as herein provided) will (either revoke its order of suspension, or) fix a time and place for hearing, and notify the licensee thereof.

If no request for hearing on any order or suspension is made by the licensee against whom such order is directed within (35) days of receipt of such order of suspension, the same shall become final and effective.

Where any order of suspension has become final, the person whose license has been suspended shall forthwith send the operator's license in question to the office of the Commission in Washington, D. C.

204. Allocation of bands of frequencies to services. —Allocations of bands of frequencies to services such as mobile, fixed, broadcast, amateur, etc., are set forth in article 7 of the General Radio Regulations annexed to the International Telecommunication Convention[5] and in the North American Radio Agreement.[6] These allocations will be adhered to in all assignments to stations capable of causing international interference.[7]

205. Frequency standard.—The national standard of radio frequency maintained by the Bureau of Standards, Department of Commerce, shall be the basis for all frequency measurements, and assignments will be made on the basis of this standard.

210. Distress messages.—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.

211. No station shall resume operation until the need for distress traffic no longer exists, or it is determined that said station will not interfere with distress traffic as it is then being routed and said station shall again discontinue if the routing of distress traffic is so changed that said station will interfere. The status of distress traffic may be ascertained by communication with Government and commercial stations.

212. The Commission may require at certain stations an effective, continuous watch on the distress frequency, 500 kilocycles (410 kilocycles in the Great Lakes area) . . .

213. Operators.—One or more licensed operators of the 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 broadcasting, 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.

EXAMINING POINTS

Amateur operator examinations are given frequently, under announced schedules, at the Commission's office in Washington, D. C., and at each of its district offices. For a list of such offices see the following pages.

Examinations are also given frequently, by appointment, at the Commission's offices at the following points:

Savannah, Ga.
San Diego, Calif.
Tampa, Fla.
Juneau, Alaska

Examinations are also given at greater intervals at the places named below, which are visited for that purpose by Commission examiners from the district offices for such locations. For current schedules, exact time, place and other details, inquiry should be addressed to the office conducting examinations at the chosen point.

Quarterly Examinations

Cincinnati, Ohio
Cleveland, Ohio
Columbus, Ohio
Des Moines, Iowa
Nashville, Tenn.
Oklahoma City, Okla.
Pittsburgh, Pa.
St. Louis, Mo.
San Antonio, Tex.
Schenectady, N. Y.
Winston-Salem, N. C.

Semi-Annual Examinations

Albuquerque, N. Mex.
Billings, Mont.
Bismarck, N. Dak.
Boise, Idaho
Butte, Mont.
Jacksonville, Fla.
Little Rock, Ark.
Phoenix, Ariz.
Salt Lake City, Utah
Spokane, Wash.

Arrangements have also been made, including cooperation of other Federal agencies, for classes A and B examinations in outlying areas as follows:

Alaska: United States Signal Corps stations; at other points by coast guard officers.

Guam: District communications officer, United States naval station.

Hawaii: At not exceeding one point on any island, by the inspector in charge (Honolulu).

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[4] The provisions of Rule 105.31 are in process of revision by reason of the amendment to the Communications Act of 1934 which was approved on May 20, 1937. The matter in parentheses is no longer applicable. The provisions of law which are applicable in this connection are contained in section 303(m) of such Act, reading as follows: "No order of suspension of any operator's license shall take effect until 15 days' notice in writing thereof, stating the cause for the proposed suspension, has been given to the operator licensee who may make written application to the Commission at any time within said 15 days for a hearing upon such order. The notice to the operator licensee shall not be effective until actually received by him, and from that time he shall have 15 days in which to mail the said application. In the event that physical conditions prevent mailing of the application at the expiration of the 15-day period, the application shall then be mailed as soon as possible thereafter, accompanied by a satisfactory explanation of the delay. Upon receipt by the Commission of such application for hearing said order of suspension shall be held in abeyance until the conclusion of the hearing which shall be conducted under such rules as the Commission may prescribe. Upon the conclusion of said hearing the Commission may affirm, modify, or revoke said order of suspension."

[5] Treaty Series 867. See also Revision of Cairo, 1938.

[6] Treaty Series 777-A. See also North and Central American Regional Conference, Mexico City, July-August, 1933.

[7] See also Inter-American Radiocommunications Convention and Annexes, Havana, 1937.

RADIO DISTRICTS

Radio district	Address of the inspector in charge	Territory within district	
		States, etc.	Counties
1	Customhouse, Boston, Mass.	Connecticut	All counties.
		Maine	Do.
		Massachusetts	Do.
		New Hampshire	Do.
		Rhode Island	Do.
		Vermont	Do.
2	Federal Building, New York, N. Y.	New Jersey	Bergen, Essex, Hudson, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Passaic, Somerset, Sussex, Union, and Warren.
		New York	Albany, Bronx, Columbia, Delaware, Dutchess, Greene, Kings, Nassau, New York, Orange, Putnam, Queens, Rensselaer, Richmond, Rockland, Schenectady, Suffolk, Sullivan, Ulster, and Westchester.
3	New United States Customhouse, Philadelphia, Pa.	Delaware	Newcastle.
		New Jersey	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Ocean, and Salem.
		Pennsylvania	Adams, Berks, Bucks, Carbon, Chester, Cumberland, Dauphin, Delaware, Lancaster, Lebanon, Lehigh, Monroe, Montgomery, Northampton, Perry, Philadelphia, Schuylkill, and York.
4	Fort McHenry, Baltimore, Md.	Delaware	Kent and Sussex.
		District of Columbia	All counties.
		Maryland	Do.
		Virginia	Arlington, Clark, Fairfax, Fauquier, Frederick, Loudoun, Page, Prince William, Rappahannock, Shenandoah, and Warren.
5	New Post Office Building, Norfolk, Va.	North Carolina	All except district 6.
		Virginia	All except district 4.
6	New Post Office Building, Atlanta, Ga.	Alabama	All except district 8.
		Georgia	All counties.
		North Carolina	Ashe, Avery, Buncombe, Burke, Caldwell, Cherokee, Clay, Cleveland, Graham, Haywood, Henderson, Jackson, McDowell, Macon, Madison, Mitchell, Polk, Rutherford, Swain, Transylvania, Watauga, and Yancey.
		South Carolina	All counties.
		Tennessee	Do.
7	Post Office Box 150, Miami, Fla.	Florida	All except district 8.
8	Customhouse, New Orleans, La.	Alabama	Mobile, Baldwin.
		Arkansas	All counties.
		Florida	Escambia.
		Louisiana	All counties.
		Mississippi	Do.
		Texas	City of Texarkana only.
9	Federal Building, Galveston, Tex.	Texas	Aransas, Brazoria, Brooks, Calhoun, Cameron, Chambers, Fort Bend, Galveston, Goliad, Harris, Hidalgo, Jackson, Jefferson, Jim Wells, Kenedy, Kleberg, Matagorda, Nueces, Refugio, San Patricio, Victoria, Wharton, and Willacy.
10	U. S. Terminal Annex Building, Dallas, Tex.	New Mexico	All counties.
		Oklahoma	Do.
		Texas	All except district 9 and the city of Texarkana.
11	Rives-Strong Building, Los Angeles, Calif.	Arizona	All counties.
		California	Imperial, Inyo, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, and Ventura.
		Nevada	Clarke.
12	Customhouse, San Francisco, Calif.	California	All except district 11.
		Nevada	All except Clarke.
		Guam	
		Midway	
		Wake	
		American Samoa	
13	New United States Courthouse, Portland, Oreg.	Idaho	All except district 14.
		Oregon	All counties.
14	Federal Office Building, Seattle, Wash.	Alaska	
		Idaho	Benewah, Bonner, Boundary, Clearwater, Idaho, Kootenai, Latah, Lewis, Nez Perce, and Shoshone.

Radio district	Address of the inspector in charge	Territory within district	
		States, etc.	Counties
		Montana	Beaverhead, Broadwater, Cascade, Deerlodge, Flathead, Gallatin, Glacier, Granite, Jefferson, Lake, Lewis and Clark, Lincoln, Madison, Meagher, Mineral, Missoula, Pondera, Powell, Ravalli, Sanders, Silver Bow, Teton, and Toole.
		Washington	All counties.
15	Customhouse, Denver, Colo.	Colorado	Do.
		Montana	Except district 14.
		Utah	All counties.
		Wyoming	Do.
16	New Main Post Office Building, St. Paul, Minn.	Minnesota	Do.
		Michigan	Alger, Baraga, Chippewa, Delta, Dickinson, Gogebic, Houghton, Iron, Keweenaw, Luce, Mackinac, Marquette, Menominee, Ontonagon, and Schoolcraft.
		North Dakota	All counties.
		South Dakota	Do.
		Wisconsin	All except district 18.
17	Pickwick Building, Kansas City, Mo.	Iowa	Do.
		Kansas	All counties.
		Missouri	Do.
		Nebraska	Do.
18	U. S. Court House, Chicago, Ill.	Illinois	Do.
		Indiana	Do.
		Iowa	Allamakee, Buchanan, Cedar, Clayton, Clinton, Delaware, Des Moines, Dubuque, Fayette, Henry, Jackson, Johnson, Jones, Lee, Linn, Louisa, Muscatine, Scott, Washington, and Winneshiek.
		Wisconsin	Columbia, Crawford, Dane, Dodge, Grant, Green, Iowa, Jefferson, Kenosha, Lafayette, Milwaukee, Ozaukee, Racine, Richland, Rock, Sauk, Walworth, Washington, and Waukesha.
19	New Federal Building, Detroit, Mich.	Kentucky	All counties.
		Michigan	All except district 16.
		Ohio	All counties.
		West Virginia	Do.
20	Federal Building, Buffalo, N. Y.	New York	All except district 2.
		Pennsylvania	All except district 3.
21	Aloha Tower, Honolulu. Territory of Hawaii.	Territory of Hawaii	
22	Ochoa Building, San Juan, Puerto Rico.	Puerto Rico	
		Virgin Islands	

AMATEUR CALL AREAS

Call area	States, etc.	Counties
1	Connecticut	All counties.
	Maine	Do.
	Massachusetts	Do.
	New Hampshire	Do.
	Rhode Island	Do.
	Vermont	Do.
2	New Jersey	Bergen, Essex, Hudson, Middlesex, Monmouth, Ocean, Passaic, and Union.
	New York	Albany, Bronx, Columbia, Dutchess, Greene, Kings, Nassau, New York, Orange, Putnam, Queens, Rensselaer, Richmond, Rockland, Schenectady, Suffolk, Ulster, and Westchester.
3	Delaware	All counties.
	District of Columbia	Do.
	Maryland	Do.
	New Jersey	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Hunterdon, Mercer, Morris, Salem, Somerset, Sussex, and Warren.
	Pennsylvania	Adams, Berks, Bucks, Chester, Cumberland, Dauphin, Delaware, Franklin, Lancaster, Lebanon, Lehigh, Montgomery, Northampton, Philadelphia, and York.
	Virginia	All counties.
4	Alabama	Do.
	Florida	Do.
	Georgia	Do.

Amateur Call Areas
(Continued)

Call area	States, etc.	Counties
	North Carolina	Do.
	Puerto Rico	
	South Carolina	Do.
	Tennessee	Do.
	Virgin Islands	
5	Arkansas	All.
	Louisiana	Do.
	Mississippi	Do.
	New Mexico	Do.
	Oklahoma	Do.
	Texas	Do.
6	Arizona	Do.
	California	Do.
	Guam	Do.
	Hawaii	Do.
	Midway	Do.
	Nevada	Do.
	Utah	Do.
	Wake	Do.
7	Alaska	Do.
	Idaho	Do.
	Montana	Do.
	Oregon	Do.
	Washington	Do.
	Wyoming	Do.
8	Michigan	Alcona, Allegan, Alpena, Antrim, Arenac, Barry, Bay, Benzie, Berrien, Branch, Calhoun, Cass, Charlevoix. Cheboygan, Clare, Clinton, Crawford, Eaton, Emmet, Genesee, Gladwin, Grand Traverse, Gratiot, Hillsdale, Huron, Ingham, Ionia, Iosoca, Isabella, Jackson, Kalamazoo. Kalkaska. Kent. Lake, Lapeer, Leelanau, Lenawee, Livingston, Macomb, Manistee, Mason, Mecosta, Midland, Missaukee. Monroe, Montcalm. Montmorency, Muskegon, Newaygo, Oakland, Oceana, Oglemaw, Osceola, Oscoda. Otsego, Ottawa, Presque Isle, Roscommon. St. Clair. St. Joseph, Saginaw, Sanilac, Shiawassee, Tuscola, Van Buren, Wachtenaw, Wayne, and Wexford.
	New York	Allegany, Broome. Cattaragus, Cayuga, Chautauqua. Chemung, Chenango, Clinton, Cortland. Delaware, Erie. Essex, Franklin, Fulton, Genessee, Hamilton, Herkimer. Jefferson, Lewis, Livingston, Madison, Monroe, Montgomery, Niagara, Oneida, Onondaga, Ontario, Orleans, Oswego, Otsego, St. Lawrence, Saratoga. Schoharie, Schuyler. Seneca, Steuben, Sullivan, Tioga, Tompkins, Warren, Washington, Wayne, Wyoming, and Yates.
	Ohio	All counties.
	Pennsylvania	Allegheny, Armstrong, Beaver, Bedford, Blair, Bradford, Butler, Cambria, Cameron, Carbon, Center, Clarion, Clearfield. Clinton, Columbia, Crawford, Elk, Erie, Fayette, Forest, Fulton, Greene, Huntingdon, Indiana, Jefferson, Juniata, Lackawanna. Lawrence. Luzerne, Lycoming. McKean, Mercer, Miflin, Monroe, Montour, Northumberland, Perry, Pike, Potter, Schuylkill, Snyder, Somerset, Sullivan, Susquehanna, Tioga, Union, Venango, Warren, Washington, Wayne, Westmoreland, and Wyoming.
	West Virginia	All counties.
9	Colorado	Do.
	Illinois	Do.
	Indiana	Do.
	Iowa	Do.
	Kansas	Do.
	Kentucky	Do.
	Michigan	Alger, Baraga. Chippewa, Delta, Dickinson, Gogebic, Houghton, Iron. Keweenaw, Luce, Mackinac, Marquette, Menominee, Ontonagon, and Schoolcraft.
	Minnesota	All counties.
	Missouri	Do.
	Nebraska	Do.
	North Dakota	Do.
	South Dakota	Do.
	Wisconsin	Do.

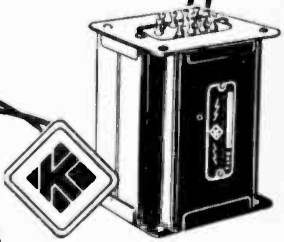
Appendix

Quick Reference Index

THE "Q" SIGNALS

Abbreviation	Question	Answer
QRA	What is the name of your station?	The name of my station is ....
QRB	How far approximately are you from my station?	The approximate distance between our stations is .... nautical miles (or .... kilometers).
QRC	What company (or Government Administration) settles the accounts for your station?	The accounts for my station are settled by the .... company (or by the Government Administration of ....).
QRD	Where are you bound and where are you from?	I am bound for .... from ....
QRG	Will you tell me my exact frequency (wavelength) in kc/s (or m)?	Your exact frequency (wavelength) is .... kc/s (or .... m).
QRH	Does my frequency (wavelength) vary?	Your frequency (wavelength) 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).
QRR	———————————————	*Amateur "SOS" or distress call (U.S.A.). Use only in serious emergency.*
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).

Everything in TRANSFORMERS



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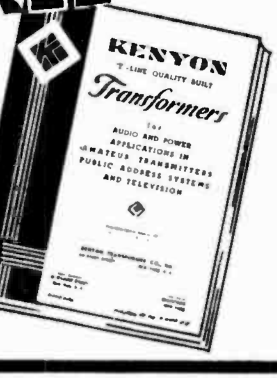

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- ★ FOR INDUSTRIAL USES
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Plate Transformers for Standard Amateur Duty

Type	D. C. Volts	MA DC	Net
T-668*	500-750	300	$ 5.85
T-669*	1000-1250	300	9.60
T-670*	1500-1750-2000	300	12.90
T-671*	1000-1250	500	12.90

* Tapped secondaries

Ken-O-Tap Universal Modulation Transformers

Type	Watts	Class C-Load Watts	Net
T-489	15	30	$2.40
T-493	40	80	3.60
T-494	75	150	5.40
T-495	125	250	12.00
T-496	300	600	18.00

Filter Chokes

Type	Henries	MA	Res	Ins	Net
T-153	30	90	350	1000	$1.80
T-152	10	200	100	1000	2.10
T-166	11	300	125	1500	4.20
T-167	11	400	80	3000	5.70
T-177	12	500	95	5000	9.00

Swinging Chokes

Type	Henries	MA	Res	Ins	Net
T-517	15-45	90-20	350	1000	$1.80
T-506	5-20	200-30	100	1000	2.10
T-510	6-19	300-30	125	1500	4.20
T-516	5-20	400-50	80	3000	5.70
T-521	6-21	500-60	95	5000	9.00

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840 BARRY ST., NEW YORK, N. Y.
Export Department: 25 Warren St., New York, N. Y.

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☐ Please send me your Hammanual. I enclose 10c to cover cost of mailing and handling.

☐ Please send me your New FREE Catalog.

NAME ....
ADDRESS ....
CITY .... STATE ....

Abbreviation	Question	Answer
QSB	Does the strength of my signals vary?	The strength of your signals varies.
QSD	Is my keying correct; are my signals distinct?	Your keying is incorrect; your signals are bad.
QSG	Shall I send .... telegrams (or one telegram) at a time?	Send .... telegrams (or one telegram) at a time.
QSJ	What is the charge per word .... including your internal telegraph charge?	The charge per word for .... is .... francs, including my internal telegraph charge.
QSK	Shall I continue with the transmission of all my traffic, I can hear you through my signals?	Continue with the transmission of all your traffic, I will interrupt you if necessary.
QSL	Can you give me acknowledgment of receipt?	I give you acknowledgment of receipt.
QSM	Shall I repeat the last telegram I sent you?	Repeat the last telegram you have sent me.
QSO	Can you communicate with .... direct (or through the medium of ....)?	I can communicate with .... direct (or through the medium of ....).
QSP	Will you retransmit to .... free of charge?	I will retransmit to .... free of charge.
QSR	Has the distress call received from .... been cleared?	The distress call received from .... has been cleared by ....
QSU	Shall I send (or reply) on .... kc/s) (or m) and/or on waves of Type A1, A2, A3, or B?	Send (or reply) on .... kc/s (or ...... m) and/or on waves of Type A1, A2, A3, or B.
QSV	Shall I send a series of VVV ....?	Send a series of VVV ....
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	Change to transmission on .... kc/s (or .... m) without changing the type of wave.
	Shall I change to transmission on another wave?	Change to transmission on another wave.
QSZ	Shall I send each word or group twice?	Send each word or group twice.
QTA	Shall I cancel telegram No. ...... as if it had not been sent?	Cancel telegram No. .... as if it had not been sent.
QTB	Do you agree with my number of words?	I do not agree with your number of words; I will repeat the first letter of each word and the first figure of each number.
QTC	How many telegrams have you to send?	I have .... telegrams for you (or for ....).

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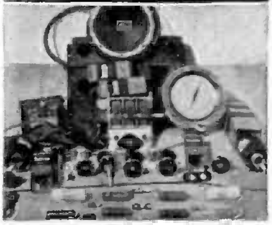
146 RADIO PARTS



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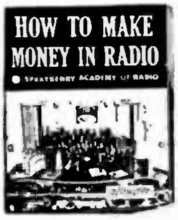

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Abbreviation	Question	Answer
QTE	What is my true bearing in relation to you? or What is my true bearing in relation to .... (call sign)? or What is the true bearing of ...... (call sign) in relation to ...... (call sign)?	Your true bearing in relation to me is .... degrees or Your true bearing in relation to .... (call sign) is .... degrees at .... (time) or The true bearing of .... (call sign) in relation to .... (call sign) is .... degrees at ...... (time).
QTF	Will you give me the position of my station according to the bearings taken by the direction-finding stations which you control?	The position of your station according to the bearings taken by the direction-finding stations which I control is ...... latitude .... longitude.
QTG	Will you send your call sign for fifty seconds followed by a dash of ten seconds on .... kc/s (or .... m) in order that I may take your bearing?	I will send my call sign for fifty seconds followed by a dash of ten seconds on .... kc/s (or .... m) in order that you may take my bearing.
QTH	What is your position in latitude and longitude (or by any other way of showing it)?	My position is .... latitude .... longitude (or by any other way of showing it).
QTI	What is your true course?	My true course is .... degrees.
QTJ	What is your speed?	My speed is .... knots (or .... kilometers) per hour.
QTM	Send radioelectric signals and submarine sound signals to enable me to fix my bearing and my distance.	I will send radioelectric signals and submarine sound signals to enable you to fix your bearing and your distance.
QTO	Have you left dock (or port)?	I have just left dock (or port).
QTP	Are you going to enter dock (or port)?	I am going to enter dock (or port).
QTQ	Can you communicate with my station by means of the International Code of Signals?	I am going to communicate with your station by means of the International Code of Signals.
QTR	What is the exact time?	The exact time is ....
QTU	What are the hours during which your station is open?	My station is open from .... to ....
QUA	Have you news of .... (call sign of the mobile station)?	Here is news of .... (call sign of the mobile station).
QUB	Can you give me in this order, information concerning: visibility, height of clouds, ground wind for .... (place of observation)?	Here is the information requested ....
QUC	What is the last message received by you from .... (call sign of the mobile station)?	The last message received by me from .... (call sign of the mobile station) is ....
QUD	Have you received the urgency signal sent by .... (call sign of the mobile station)?	I have received the urgency signal sent by .... (call sign of the mobile station) at .... (time).

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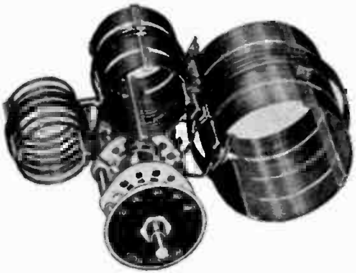
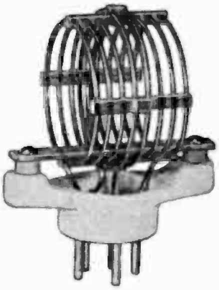
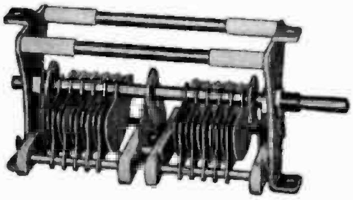


A complete line of TRANSMITTING COILS, designed to a high standard of quality for better efficiency and built for mechanical ruggedness. This complete series of coils and coil assemblies includes band switching and plug-in types for either push-pull or single ended circuits in OSCILLATOR, BUFFER and AMPLIFIER stages. Sizes for each amateur band from 5 to 160 meters and for any power from 5 to 1,000 watts.



CONDENSERS



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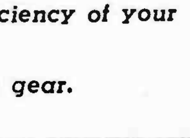

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Write for Catalog J140 containing 40 pages of ham gear.

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BUD RADIO, INC. BUD

CLEVELAND, OHIO

Abbreviation	Question	Answer
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).

ABBREVIATIONS USED BY AMATEURS

Short	**Full**	**Short**	**Full**
ABT	About	FR	For
AGN	Again	FRQ	Frequency
AHD	Ahead	GA	Go Ahead
AHR	Another	GB	Good-Bye
ANI	Any	GM	Good Morning
APRX	Approximate-Approximately	GN	Good Night
BC	Broadcast	GG	Going
BD	Bad	GT	Got—Get
B4	Before	GND	Ground
BI	By	HA(HI)	Laughter
BK	Break	HM	Him
BN	Been	HR	Here—Hear
BT	But	HV	Have
BCUZ	Because	HW	How
BTWN	Between	IC	I See
BIZ	Business	ICW	Interrupted Continuous Wave
C	See, Yes	K	Go Ahead
CLR	Clear	LID	Poor Operator
CN	Can	LIL	Little
CNT	Can't	LFT	Left
CK	Check	LST	Last—Listen
CKT	Circuit	LTR	Letter
CMG	Coming	MA	Milliampere
CUD	Could	MC	Megacycle
CW	Continuous Wave	MG	Motor Generator
CUL	See You Later	MI	My
CUAGN	See You Again	MK	Make
DE	From	MO	More
DA	Day	MSG	Message
DNT	Don't	MT	Empty
DINT	Did Not	N	No
DH	Deadhead	ND	Nothing Doing
DC	Direct Current	NG	No Good
DX	Long Distance	NIL	Nothing
ES	And	NM	No More
EZ	Easy	NR	Number
FB	Fine Business	NW	Now
FM	From	OB	Old Boy

GAMMATRON

offers a Beam Pentode

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Easy to Drive
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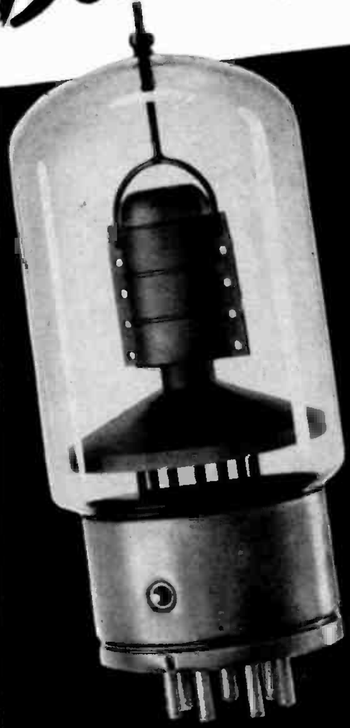

Power Output, watts	225
Plate Dissipation, watts	75
Maximum Plate volts	2000
Maximum Plate M. A.	150
Screen, volts	300
Filament, volts	5.0
Filament, Amps.	7.5

TYPE **257**
PRICE $22.00

Gammatron offers the 257 Beam Pentode, a tube of advanced design using Tantalum elements, eliminating insulators and "getter." It offers high voltage and power capabilities, suppressor grid modulation and requires very low driving power, no neutralization and low screen current.

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HEINTZ AND HK KAUFMAN
SOUTH SAN FRANCISCO LTD. CALIFORNIA U·S·A·

ABBREVIATIONS USED BY AMATEURS

(Continued from Page 564)

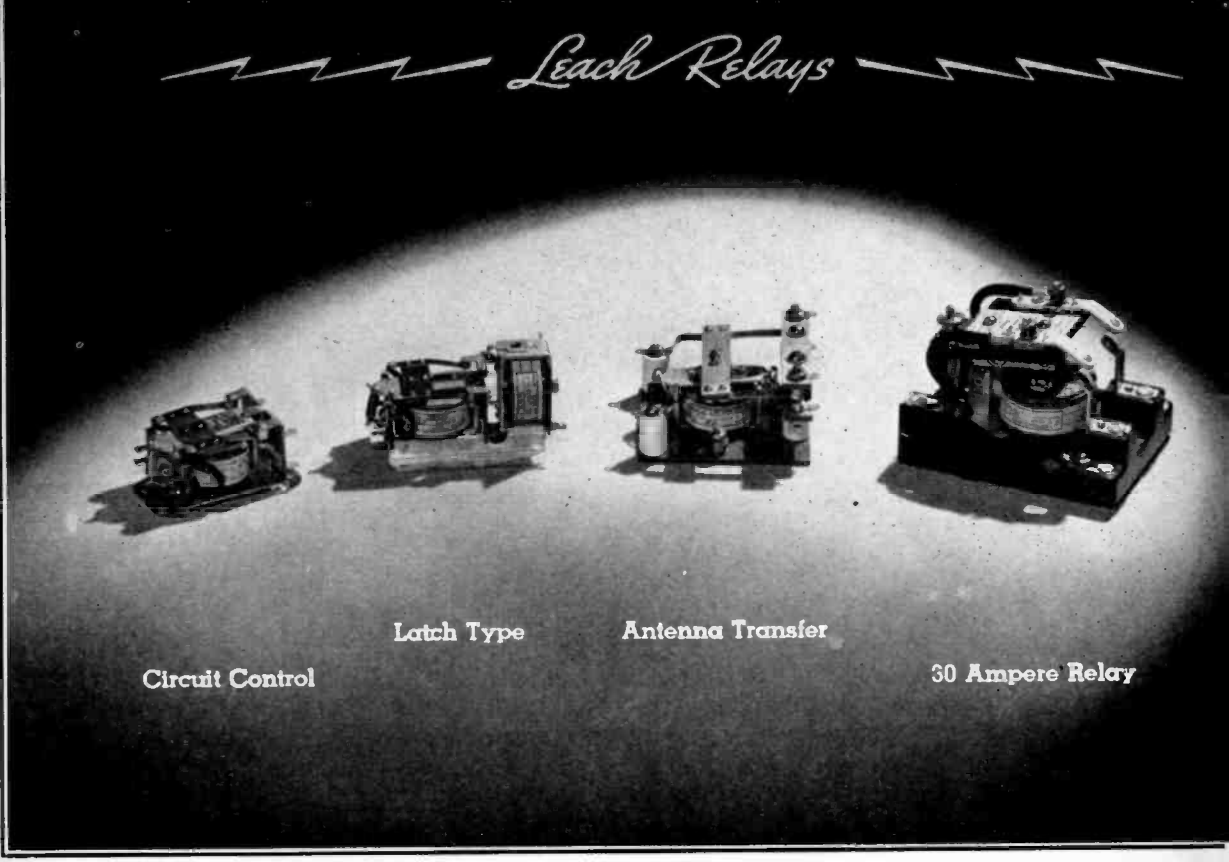
Short	**Full**	**Short**	**Full**
OL	Old Lady	TNX	Thanks
OM	Old Man	U	You
OP	Operator	UD	You Would
OT	Old Top—Timer	UL	You Will
OW	Old Woman	UR	Your
PLS	Please	VB	Very bad
PSE	Please	VT	Vacuum Tube
PX	Press	VY	Very
R	OK	WA	Word After
RCD	Received	WB	Word Before
RCVR	Receiver	WD	Would
RI	Radio Inspector	WF	Word Following
SA	Say	WK	Work
SEZ	Says	WL	Will—Would
SM	Some	WN	When
SW	Short-wave	WT	What
SIG	Signal	WX	Weather
SKED	Schedule	X	Interference
TFC	Traffic	XMTR	Transmitter
TMW	Tomorrow	YF	Wife
TR	There	YL	Young Lady
TT	That	YR	Your
TK	Take	30	Finish—End
TKS	Thanks	73	Best Regards
TNK	Think	88	Love and Kisses

PANEL LAMP CHARACTERISTICS

Type No.	Circuit Volts	Design		Bead Color	Bulb Style	Miniature Base	Usual Service
		Volts	Ampere				
S40	6–8	6.3	0.15	Brown	T-3¼	Screw	Radio dials
S41	2.5	2.5	0.50	White	T-3¼	Screw	Radio dials
S42	3.2	3.2	0.35	Green	T-3¼	Screw	Radio dials
S43	2.5	2.5	0.50	White	T-3¼	Bayonet	Radio dials and tuning meters
S44	6–8	6.3	0.25	Blue	T-3¼	Bayonet	Radio dials and tuning meters
S45	3.2	3.2	0.35	White	T-3¼	Bayonet	Radio dials
S46	6–8	6.3	0.25	Blue	T-3¼	Screw	Radio dials and tuning meters
S47-40A	6–8	6.3	0.15	Brown	T-3¼	Bayonet	Radio dials
S48	2.0	2.0	0.06	Pink	T-3¼	Screw	Battery set dials
S49-49A	2.0	2.0	0.06	Pink	T-3¼	Bayonet	Battery set dials
S50	6–8	7.5	0.20	White	G-3½	Screw	Auto sets, flash lights
S51	6–8	7.5	0.20	White	G-3½	Bayonet	Auto sets, auto panels
S55	6–8	6.5	0.40	White	G-4½	Bayonet	Auto sets, parking lights
S292	2.9	2.9	0.17	White	T-3¼	Screw	Radio dials

Panel lamps are useful not only for illumination but also as resonance indicators, "rough reading" milliammeters, fuses, etc.

Chart Courtesy Highgrade Sylvania Corp.


Leach Relays
Circuit Control
Latch Type
Antenna Transfer
30 Ampere Relay

R. M. A. COLOR CODE

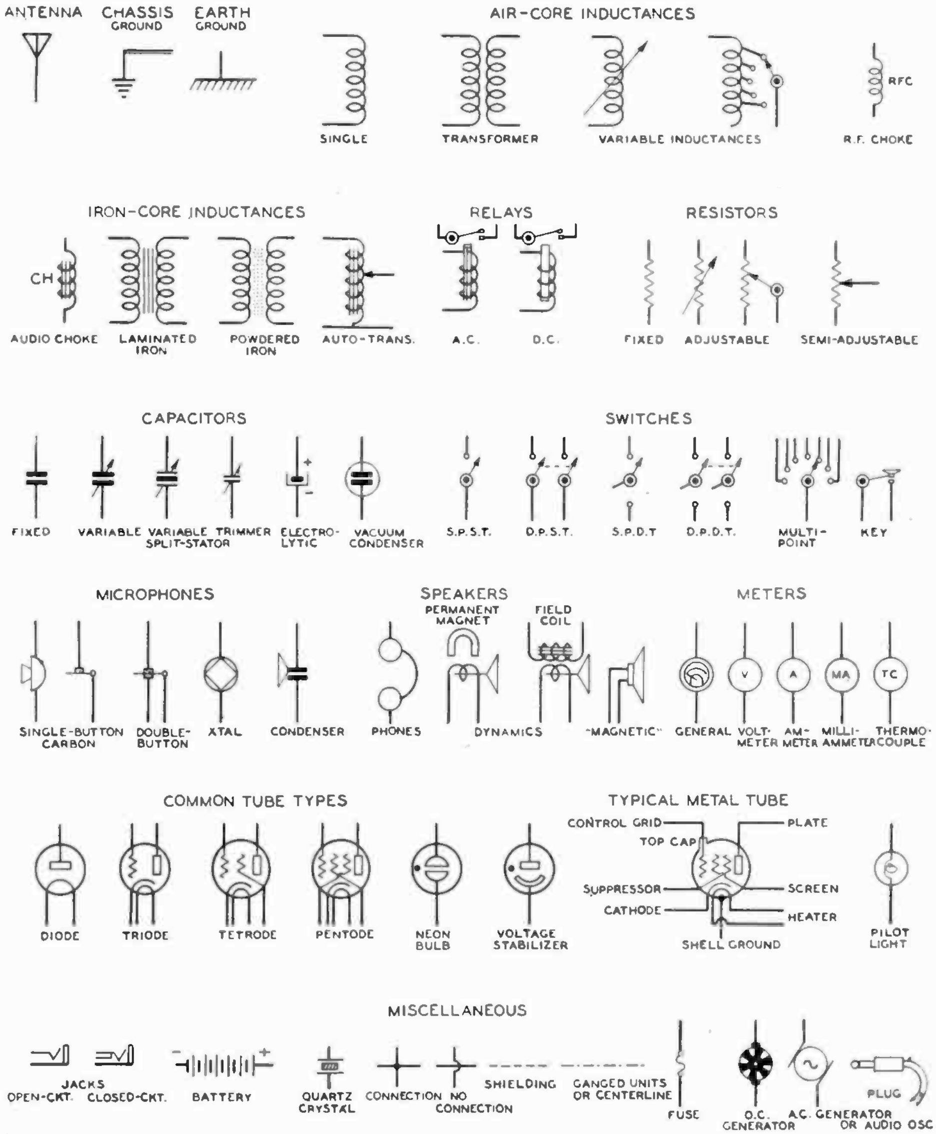
For Fixed Condensers, Unit: Micro-Microfarads

FIRST DOT		SECOND DOT		THIRD DOT	
Black	0	Black	0		
Brown	1	Brown	1	Brown	0
Red	2	Red	2	Red	00
Orange	3	Orange	3	Orange	000
Yellow	4	Yellow	4	Yellow	0000
Green	5	Green	5	Green	00000
Blue	6	Blue	6	Blue	000000
Purple	7	Purple	7	Purple	0000000
Gray	8	Gray	8	Gray	00000000
White	9	White	9	White	000000000

For Resistors, Unit: Ohms

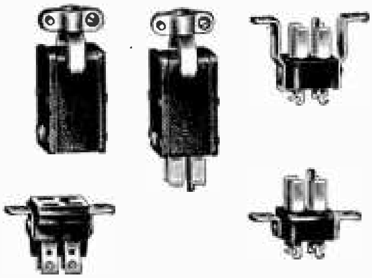
BODY COLOR		END COLOR		DOT COLOR	
Black	0	Black	0		
Brown	1	Brown	1	Brown	0
Red	2	Red	2	Red	00
Orange	3	Orange	3	Orange	000
Yellow	4	Yellow	4	Yellow	0000
Green	5	Green	5	Green	00000
Blue	6	Blue	6	Blue	000000
Purple	7	Purple	7	Purple	0000000
Gray	8	Gray	8	Gray	00000000
White	9	White	9	White	000000000

RADIO SYMBOLS USED IN CIRCUIT DIAGRAMS



JONES

PLUGS—SOCKETS AND TERMINAL PANELS



Heavy Duty Series

Five numbers of over 200 in the Heavy Duty series fulfilling practically every plug and socket requirement in the Public Address, Radio and kindred fields. Rugged construction will withstand hardest usage. Socket contacts are of the knife switch type, of phosphor bronze and tin plated. Plug contacts are of hard brass, tin plated, with 1/4" x 1/16" cross section. Moulded Bakelite insulation. Caps are of steel with baked black crackle enamel. Made in 2, 4, 6, 8, 10 and 12 contacts.

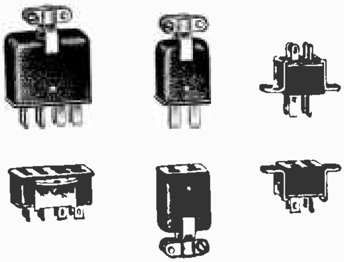
The best all around plug and socket at popular prices

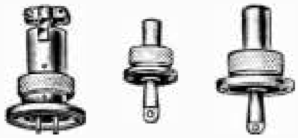
"300" Series

Six numbers of over 100 in the "300" series. A popular line of high grade small plugs and sockets adaptable to thousands of uses.

All plugs and sockets are polarized. Phosphor bronze knife switch type female contacts. Tin plated brass male contacts, bar type with 5/32" x 3/64" cross section. Moulded Bakelite insulation. Drawn metal caps. Formed fibre linings. Made in 2 to 33 contacts. Simple assembly. Inexpensive.

Priced low, but should not be confused with plugs and sockets manufactured with the express purpose of selling below competition.





202-CCT 101 101-D

Shielded Type

A new line of completely shielded plugs and sockets. Plugs are securely held to sockets by a threaded bushing. Housing of brass screw machine parts, with burnished tin plate finish. XX Bakelite insulation. No. 202-CCT has two contacts, Nos. 101 and 101-D have a single contact.

Ideal for microphone connections, photo cell work, etc.

Terminal Panels

To Manufacturers—For years we have been serving manufacturers on requirements for special terminal panels to blue print. Our line of terminals has been developed by customer needs and range from small sizes (2-56 screws), to large sizes (10-32 screws). *Prompt quotations will be supplied upon receipt of blue print or sketch.*

Request our Catalog

Jobbers . . No. J-40 Manufacturers . . No. M-40 Radio Amateurs . . No. A-40

HOWARD B. JONES

2300 WABANSIA AVE. CHICAGO, ILLINOIS

RADIO SYMBOLS

The following symbols are commonly used in radio work and many of these symbols are used in the pages of this book:

E_F ....Filament (or heater) terminal voltage.
E_B ....Average plate voltage (d.c.).
I_B ....Average plate current (d.c.).
E_P ..........A.C. component of plate voltage (effective value).
I_P ....A. C. component of plate current (effective value).
E_C ....Average grid voltage (d.c.).
I_C ....Average grid current (d.c.).
E_G ..........A.C. component of grid voltage (effective value).
I_G ..........A.C. component of grid current (effective value).
E_{FF} ....Filament (or heater) supply voltage.
E_{BB} ....Plate supply voltage (d.c.).
E_{CC} ....Grid supply voltage (d.c.).
M_U or μ .....Amplification factor.
r_P ....Plate resistance.
S_M ....Grid-plate transconductance (also mutual conductance, gm).
R_P ....Plate load resistance.
Z_P ....Plate load impedance.
D.C. ....Direct Current.
A.C. ....Alternating Current.
RMS ....Root Mean Square.
U.P.O. ....Undistorted power output.
C_{GK} ....Grid-cathode (or filament) capacitance.
C_{PK} ....Plate-cathode (or filament) capacitance.
C_{G1P} ....Effective grid-plate capacitance in a tetrode (cathode [or filament] and screen grounded).
$C_{G1}(k+g_2)$ ...Direct interelectrode capacitance of grid to cathode (or filament) and screen.
$C_P(k+g)$ ....Direct interelectrode capacitance of plate to cathode (or filament) and screen.
α, alpha—Coefficients.
β, beta—Coefficients.
γ, gamma—Coefficients.
Δ, delta (capital)—Decrements, increments, variations.
δ, delta (lower case)—Same as capital delta.
Θ, theta—Angles, phase displacement.
λ, lambda—Wavelength.
μ, mu—Amplification factor, prefix micro-.
π, pi—3.1416, circumference divided by diameter.
ϕ, phi—Angles.
τ, tau—Time constant, coefficients.
ω, omega—Resistance in ohms, 2π times frequency.

CONVERSION TABLE

Factors for conversion, alphabetically arranged

MULTIPLY	BY	TO GET
Amperes	×1,000,000	microamperes
Amperes	×1,000	milliamperes
Cycles	×.000,001	megacycles
Cycles	×.001	kilocycles
Farads	×1,000,000,000,000	micromicrofarads
Farads	×1,000,000	microfarads
Henrys	×1,000,000	microhenrys
Henrys	×1,000	millihenrys
Kilocycles	×1,000	cycles
Kilovolts	×1,000	volts
Kilowatts	×1,000	watts
Megacycles	×1,000,000	cycles
Mhos	×1,000,000	micromhos
Microamperes	×.000,001	amperes
Microfarads	×.000,001	farads
Microhenrys	×.000,001	henrys
Micromhos	×.000,001	mhos
Micro-ohms	×.000,001	ohms
Microvolts	×.000,001	volts
Microwatts	×.000,001	watts
Micromicrofarads	×.000,000,000,001	farads
Milliamperes	×.001	amperes
Millihenrys	×.001	henrys
Millimhos	×.001	mhos
Milliohms	×.001	ohms
Millivolts	×.001	volts
Milliwatts	×.001	watts
Ohms	×1,000,000	micro-ohms
Volts	×1,000,000	microvolts
Volts	×1,000	millivolts
Watts	×1,000,000	microwatts
Watts	×1,000	milliwatts
Watts	×.001	kilowatts

Fractional-Decimal Equivalents

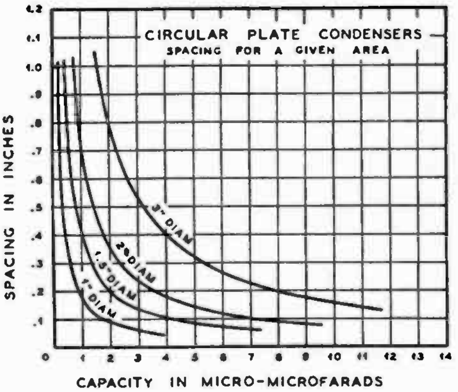
A time-saving table is given for fractional-decimal conversion. Many of the commonly used fractions and their decimal equivalents are shown. Others can be calculated by dividing the numerator by the denominator.

1/64 = .0165
1/32 = .0312
3/64 = .0468
1/16 = .0625
3/32 = .0936
1/8 = .125
3/16 = .1875
1/4 = .250
5/16 = .3125
3/8 = .3750

7/16 = .4375
1/2 = .500
9/16 = .5625
5/8 = .625
11/16 = .6825
3/4 = .750
13/16 = .8125
7/8 = .875
15/16 = .9375

BREAKDOWN RATINGS OF COMMON PLATE SPACINGS

AIR-GAP IN INCHES	PEAK VOLTAGE BREAKDOWN
.030	750
.050	1500
.070	3000
.078	3500
.084	3800
.100	4150
.144	5000
.175	5700
.200	6200
.250	7200
.300	8200
.350	9250
.375	10,000
.500	12,000

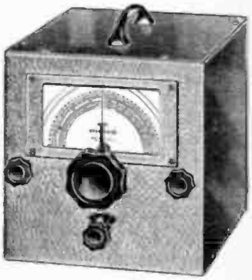


Design Charts for Home Made Neutralizing Condensers

RME COMMUNICATION EQUIPMENT

. . . of universal adaptability

What are your requirements?



A PORTABLE-MOBILE-EMERGENCY UNIT OF SMALL SIZE TO COVER THE INTERMEDIATE FREQUENCIES?

Try the ME-14, a 6 tube self-contained battery operated portable, especially designed for many important services including aircraft. Frequency range 180 to 4100 KC.

RECEPTION OF LOW FREQUENCIES?

Use the LF-90, a low frequency INVERTER designed to be used in conjunction with a receiver capable of tuning to 1550 KC. Frequency range covered: 90-608 KC.

A COMPLETE 5 AND 10 METER RECEIVER?

The HF-10 is a complete 5 and 10 meter receiver consisting of 11 tubes, speaker, R-meter, automatic noise suppressor, and may be had for use with AC or 6 volt DC current.

PRESELECTION FOR THE IMPROVEMENT OF ANY RECEIVER?

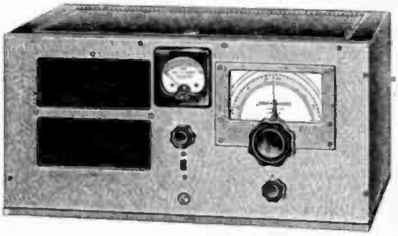
The well-known DB-20 fits the need perfectly. This unit has three stages with power supply. Standard frequency coverage of 550 to 32,000 KC.

BAND EXPANDER FOR CONVERTING A STANDARD COMMUNICATION RECEIVER FOR RECEPTION OF 5 AND 10 METER SIGNALS?

The DM-36 provides unusually high-gain reception in these two bands.

BAND EXPANDER FOR THE CONVERSION OF AN AUTOMOBILE BROADCAST RECEIVER FOR 5 AND 10 METER OPERATION?

The DM-36A does the job, operated from the 6 volt storage battery.



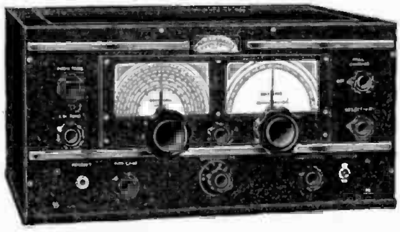
FOR GENERAL HIGH FREQUENCY RECEPTION?

Use the 510X FREQUENCY EXPANDER for coverage from 27.8 to 70 MC.

A STANDARD COMMUNICATION RECEIVER?

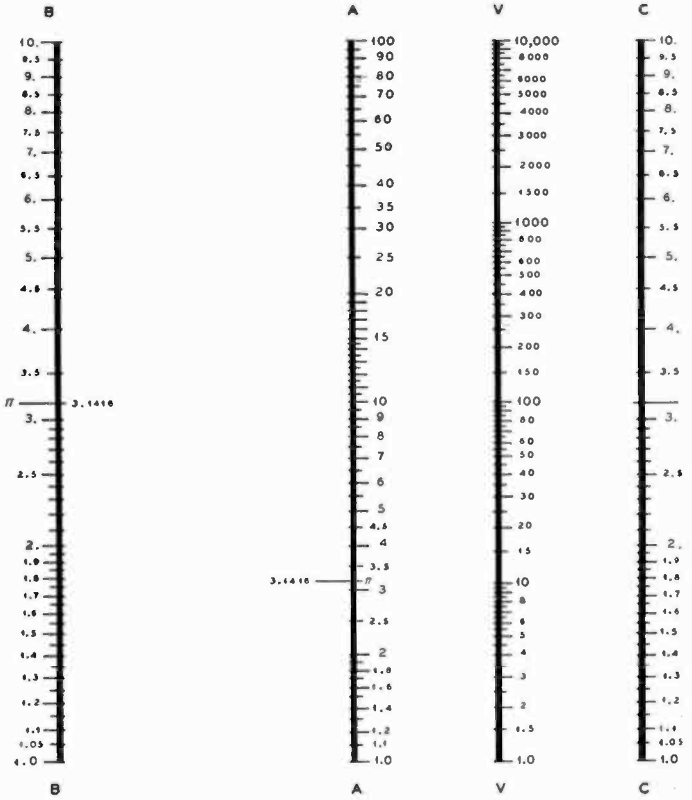
We have two. The RME-69, the old standby of the communication world; and the RME-70, the latest of the ultra-modern models.

A new 12 page catalog with complete descriptions of these and other units is now available.



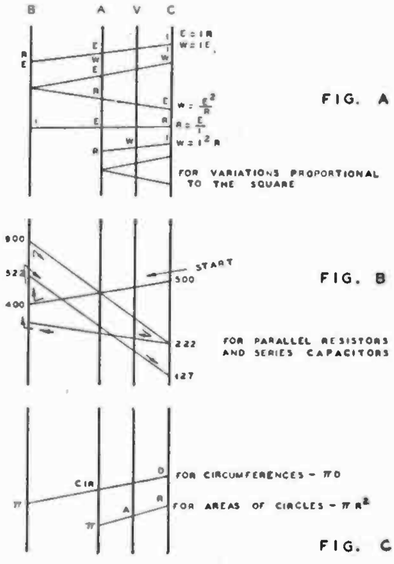
RADIO MFG. ENGINEERS
INCORPORATED
ONE-ELEVEN HARRISON ST.
PEORIA ILLINOIS

RADIO HANDBOOK LOGARITHMIC ALIGNMENT NOMOGRAM



To use the chart properly and to prevent disfiguring the page, simply place a piece of tracing paper, celluloid or waxed paper over the scales; then the index line which intersects the scales may be drawn with a hard pencil and a straight edge.

To find the voltage drop for a certain bias for a self-biased tube, add three ciphers to the value desired, seek this value on scale A; next, search on the B scale for the value which corresponds to the cathode current (this will be the same as the plate current in the case of a triode; the sum of the plate and screen currents in the case of a tetrode). Now, drawing a line between these two points will intersect a point on C; this corresponds to the ohmage. Hence, a resistance required to produce 9-volts bias for a triode which operates at 3-ma. plate current is: on the A scale, 9 plus three ciphers equals 9000; on the B scale 3 ma. The ohmage 3000, is found on C.



AUXILIARY CHART

Wattage or Heat Capacity of Resistors

To find the power in watts dissipated by a certain resistor when ohmage and voltage are known, proceed as follows: On C find the voltage, on A, the resistance; draw a line connecting these two points over to the B scale. Next, find the voltage (for the second time) on the A scale and draw a line from point B through A. The wattage will be given on C. See the auxiliary figure for an example.

If the current instead of the voltage is known in the above procedure, the technique is as follows: On C find the value of current; on A, the resistance. A line drawn connecting these points will intercept the wattage rating on V.

Greek Alphabet

GREEK LETTER	GREEK NAME
Α α	Alpha
Β β	Beta
Γ γ	Gamma
Δ δ	Delta
Ε ε	Epsilon
Ζ ζ	Zeta
Η η	Eta
Θ θ	Theta
Ι ι	Iota
Κ κ	Kappa
Λ λ	Lambda
Μ μ	Mu
Ν ν	Nu
Ξ ξ	Xi
Ο ο	Omicron
Π π	Pi
Ρ ρ	Rho
Σ σ	Sigma
Τ τ	Tau
Υ υ	Upsilon
Φ φ	Phi
Χ χ	Chi
Ψ ψ	Psi
Ω ω	Omega

R-S-T REPORTING SYSTEM

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 Trace of Ripple.
9. Purest D.C. Note.

If the Note Appears to Be Crystal Controlled, Simply Add an X After the Appropriate Number.

LIGHT BULB RESISTORS

Ordinary tungsten filament light bulbs make excellent load resistors for radio-frequency and audio tests, since they are noninductive. However, their resistance increases with an increase in power that is applied to them. The table gives the resistance of standard 115-volt bulbs at various wattages. At approximately one-third rated wattage, the filament will show dull red. At two-thirds rated wattage, the filament is bright yellow.

If it is desired to test a 30-watt audio amplifier having a 500-ohm output, two 40-watt bulbs could be used in series. At 30 watts output from the amplifier, the two bulbs will light to a dull red since each one will be dissipating 15 watts, and the load on the amplifier will be 510 ohms.

Light bulb resistors are very useful for terminating untuned feed lines while adjusting coupling to the final amplifier. The bulb will serve as an indicator of maximum r.f. at the same time coupling adjustments are being made.

Various series or parallel arrangements of bulbs will enable the user to secure an infinite number of resistance values. One of the most valuable uses of the light bulb resistor is as a dummy antenna for adjustment of the transmitter.

The resistor may either be clipped across a few turns of the tank coil in the same manner that an untuned transmission line is coupled, or it may be connected across a tuned circuit which is then coupled to the tank. The transmitter can then be completely checked for frequency, percentage of modulation, quality and power output without causing QRM or undergoing the risk of receiving a "pink slip" from the F.C.C.

If the resistance of the dummy antenna is reasonably close to that of the radiation resistance of the antenna, a double-pole, double-throw switch can easily be arranged to shift the output of the transmitter from one to the other. The readings on the r.f. ammeters, with the dummy antenna connected, will give a quick check on the performance of the transmitter.

LIGHT BULB RESISTANCE CHART

Resistance of 115-Volt Tungsten Bulbs

	WATTAGE RATING					
Watts	25	40	50	60	75	100
5	349	195	148	119	90	65
10	412	228	175	139	106	74
15	470	255	194	153	116	81
20	497	273	207	163	124	87
25	529	291	220	172	132	92
30		306	231	181	137	96
35		319	241	189	143	100
40		331	249	197	148	103
45			257	204	153	106
50			265	211	158	110
55				215	162	112
60				220	166	115
65					169	117
70					173	120
75					176	122
80						124
85						126
90						128
95						130
100						132

(Table courtesy "Thordarson Transformer Guide")

STANCOR'S
New 1940 Kits

Stancor presents two of the many new 1940 Kits incorporated in the Fourth Edition Stancor Hamanual (out Oct. 1st). The rigs are versatile in design and application and represent excellent values. Additional information may be obtained from the Hamanual.

STANCOR "10-P" TRANSMITTER

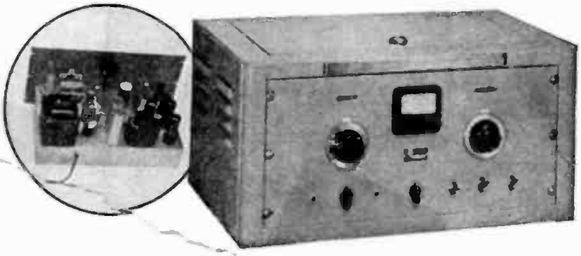
A compact, multi-band, phone-CW rig allowing operation on all bands from 10-160 meters with three crystals. Uses an oscillator-amplifier circuit involving but one tuned circuit. Power amplifier input—12 watts phone—20 watts CW.

Approximate net price, including cabinet escutcheon, etc. .... Less tubes, crystal, meter and coil. **$19.95**

STANCOR "60-P" TRANSMITTER

An entirely self-contained 60 watt phone-CW rig employing the new HK24 in the R.F. amplifier. Its design makes for simplicity of operation and allows either standard rack or table cabinet mounting. Such features as oscillator keying, high fidelity audio channel, well-regulated power supplies and low impedance output termination are all incorporated in this kit.

Approximate net price Less tubes, crystal, meter, coils and cabinet. **$44.80**



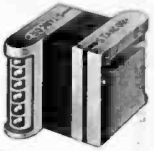
The Fourth Edition Hamanual fully describes these and many other values in transmitter and amplifier kits.

AVAILABLE FROM YOUR STANCOR JOBBER ABOUT OCT. 1st.

Catalog FREE

Stancor's Catalog No. 140A lists transformers for all types of application. The complete listing is enhanced by valuable charts that assure the correct unit being used at all times. Contains valuable information for the amateur. Get it from your Stancor Jobber.

STANCOR



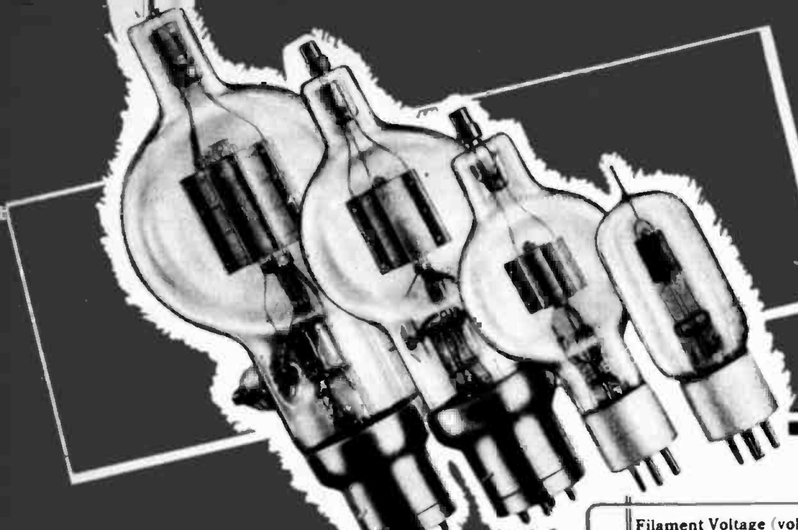
STANCOR THOROBRED

America's first safety plate transformer. The only transformer of its kind—anywhere. Your Stancor Jobber has it—be sure to see it.

STANDARD TRANSFORMER CORPORATION
1500 NORTH HALSTED STREET, CHICAGO

INTERNATIONAL PREFIXES

AC4	Tibet
AR	Syria
CE	Chile
CM, CO	Cuba
CN8	Morocco (French)
CO	Cuba (Phones)
CP	Bolivia
CR4	Cape Verde Is.
CR5	Portuguese Guinea
CR6	Angola
CR7	Mozambique
CR8	Portuguese India
CR9	Macao
CR10	Timor
CT1	Portugal
CT2	Azores
CT3	Madeira
CX	Uruguay
D	Germany
EA1-5, 7	Spain
EA6	Balearic Island
EA8	Canary Islands
EA9	Spanish Morocco (No. Africa)
EI	Eire (formerly Irish Free State)
EK1	Tangier Zone
EL	Liberia
EP	Iran (ex-Persia)
ES	Estonia
F	France
FA	Algeria
FB8	Madagascar
FD8	Togoland (French)
FE8	Cameroons (French)
FF8	French West Africa
FG8	Guadeloupe
FI8	French Indo-China
FK8	New Caledonia
FL8	French Somaliland
FM8	Martinique
FN	French India
FO8	Tahiti
FP8	St. Pierre & Miquelon Is.
FQ8	French Equatorial Africa
FR8	Reunion Is.
FT4	Tunis
FU8, YJ	New Hebrides
FY8	French Guiana
G	England, the Channel Islands and the Isle of Man
GI	Northern Ireland
GM	Scotland
GW	Wales
HA	Hungary
HB	Switzerland
HC	Ecuador
HH	Haiti
HI	Dominican Republic
HK	Colombian Republic
HP	Panama
HR	Honduras
HS	Siam
HZ	Hedjaz
I	Italy
I7	Italian East Africa (Ethiopa)
J	Japan
J8	Chosen (Korea)
J9	Marshall Islands & Formosa (Taiwan)
KA	Philippine Is.
K4	Puerto Rico, Virgin Islands
KB4	Virgin Islands
K5, NY	Canal Zone
K6	Hawaiian Islands (U. S.)
K7	Alaska
KB6	Guam
KC6	Wake I.
KD6	Midway I.
KE6	Johnston I.
KF6	Baker, Howland, Enderbury, Canton, & Am. Phoenix Is.
KG6	Jarvis I.
KH6	Samoa (U. S.)
LA	Norway
LU	Argentina
LX	Luxembourg
LY	Lithuania
LZ	Bulgaria
MX	Manchukuo
N	U. S. Naval Communication Reserve Stations
OA	Peru
OH	Finland
ON	Belgium
OQ5	Belgian Congo
OX	Greenland
OY	Faeroes Islands
OY	Jan Mayen Island
OZ	Denmark
PA	Netherlands
PI	Netherlands (Schools)
PJ	Curacao
PK 1, 2, 3	Java
PK4	Sumatra
PK5	Borneo (Neth. Indies)
PK6	Celebes and Molucca Is., and New Guinea (Neth. Indies)
PX	Andorra
PY	Brazil



Eimac TUBES

UNCONDITIONALLY GUARANTEED AGAINST TUBE FAILURES WHICH RESULT FROM GAS RELEASED INTERNALLY

		35T 35TG*	75T	100 TL	100 TH	250 TL	250 TH	450 TL	450 TH	750 TL	1500 T	2000 T	UH 35	UH 50	UH 51	Twin 30	1000 UHF
CHARACTERISTICS	Filament Voltage (volts)	-5	5	5	5	5	5	7.5	7.5	7.5	7.5	10	5	7.5	5	6	7.5
	Filament Current (amperes)	4	6.5	6.5	6.5	10.5	10.5	12	12	21	26	26	4	3.25	6.5	4	16
	Amplification Factor	30	10.6	12	30	13	32	16	30	13.5	18.5	18.5	30	10.6	10.6	32	30
	Grid-Plate Capacity (mmfds)	1.9	2.3	2.3	2	3.5	3.3	4	4	4.5	7	9	1.6	2.6	2.3	2*	4
	Grid-Filament Cap. (mmfds)	4.0	2.2	2	2.2	3	3.5	4	4	6.0	10	13	1.4	2.2	2.2	1.9*	6
	Plate-Filament Cap. (mmfds)	.2	.3	.4	.3	.5	.3	.6	.6	.8	.9	1	1.9	.3	.3	.2	.6
	Bulb	T14 Nonex	G22 Nonex	GT25 Nonex	GT25 Nonex	GT30 Nonex	GT30 Nonex	GT40 Nonex	GT40 Nonex	GT56 Nonex	GT56 Nonex	GT64 Pyrex	T14 Nonex	S21 Nonex	S21 Nonex	T14 Nonex	GT40 Nonex
	Base	Isolantite UX4 Prong	Isolantite UX4 Prong	Isolantite UX4 Prong	Isolantite UX4 Prong	Standard 50 Watts	Standard 50 Watts	Standard 50 Watts	Standard 50 Watts	Special	Special	Special	Isolantite UX4 Prong	Isolantite UX4 Prong	Isolantite UX4 Prong	Isolantite UX4 Prong	Standard 50 Watts
	Overall Height (inches)	5½	7	7½	7½	9¾	9¾	12½	12½	16½	16½	17½	5½	6¾	6¾	4¾	12½
	Maximum Diameter (inches)	1¾	2¾	3⅛	3⅛	3¾	3¾	5	5	7	7	8	1¾	2⅝	2⅝	3	5
Maximum Ratings	Max. Plate Voltage (volts)	2000	3000	3000	3000	3000	3000	6000	6000	6000	6000	6000	2000	1250	2000	1500	6000
	Max. Plate Current (millamps)	150	175	225	225	350	350	500	500	1000	1250	1750	150	125	175	85*	750
	Max. Grid Current (millamps)	35	30	35	50	50	100	75	125	125	175	225	35	25	25	30*	125
	Plate Dissipation (watts)	70	75	100	100	250	250	450	450	750	1500	2000	70	50	50	30*	1000
	Power Output (watts)	240	300	400	400	800	800	1800	1800	3000	5000	7500	240	125	300	175	3500
FCC	Power Output (watts) High Level Modulated	50	100	100	100	350	350	500	500	1000 2500‡	2500	2500 7500‡	....	....	....	....	1000 2500‡
	Power Output (watts) Linear Amplifier	....	25	50	50	125	125	125	125	350	500	1000	....	....	....	....	350
	LIST PRICE	$6.00	$9.00	$13.50	$13.50	$24.50	$24.50	$75.00	$75.00	$175	$225	$300	$10.00	$12.50	$12.50	$13.50	$175

*Same as 35T except: Grid to filament capacity 1.9 Grid to plate capacity 1.7

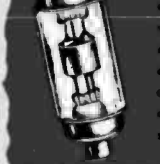
‡Two tubes

*Characteristics per section

MERCURY VAPOR RECTIFIERS

	RX21	GRID CONTROL KY21
Filament Voltage	2.5 volts	2.5 volts
Filament Current	10 amperes	10 amperes
Peak Inverse Voltage	11,000 volts	11,000 volts
Peak Plate Current	3 amperes	3 amperes
Average Plate Current	.75 amps.	.75 amps.

VACUUM TANK CONDENSER



This new condenser eliminates the use of the old fashioned open plate type, provides a positive, accurate means to determine the optimum "Q" of your tank circuit, assures proper load balance on each of the tubes and minimizes "splatter" on phone signals. No loss of power on a stray harmonic, no loss of efficiency.

The single units are available in 6, 12, 25, and 50 mmfd capacities . . . priced net at $7.50, $8.50, $10.50 and $12.50 respectively.

EITEL-McCULLOUGH, INC., SAN BRUNO, CALIFORNIA

INTERNATIONAL PREFIXES

(Continued)

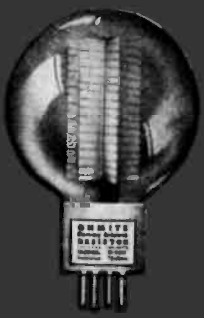
PZ	Surinam
SM	Sweden
SP	Poland
ST	Sudan
SU	Egypt
SV	Greece, Crete (Is.)
TA	Turkey
TF	Iceland
TG	Guatemala
TI	Costa Rica
U1, 3, 4, 7	European R. S. F. S. R.
U2	White R. S. S. R.
U5	Ukrainian S. S. R.
U6	Transcauscasian S. F. S. R.
U8	Turkoman S. S. R., Uzbeck S. S. R.
U9, 0	Asiatic S. F. S. R.
VE	Canada
VK	Australia
VK4	Papua Territory
VK7	Tasmania
VK9	New Guinea (Terr. of)
VO	Newfoundland (Labrador)
VP1	British Honduras and Zanzibar
VP2	Leeward and Windward Islands
VP3	British Guiana
VP4	Trinidad & Tobago Is.
VP5	Cayman Islands, Jamaica, Turks & Caicos Islands
VP6	Barbados
VP7	Bahamas
VP8	Falkland Islands South Georgia South Orkney Islands & South Shetland Islands
VP9	Bermuda Islands
VQ2	Northern Rhodesia
VQ3	Tanganyika
VQ4	Kenya
VQ5	Uganda
VQ6	British Somaliland
VQ8	Chagos Islands, Mauritius
VQ9	Seychelles
VR1	Gilbert & Ellice Islands & Ocean Islands
VR2	Fiji Islands
VR3	Fanning Island
VR4	Br. Solomon Islands
VR5	Tonga (Friendly) Islands
VR6	Pitcairn Island
VS1	Straits Settlements
VS2	Federated Malay States
VS3	Non-Federated Malay States
VS4	British N. Borneo
VS5	Sarawak
VS6	Hong Kong
VS7	Ceylon
VS9	Maldive Islands
VU	India
VU7	Bahrein Island
W	United States
XE	Mexico
XU	China
XZ	Burma
YA	Afghanistan
YI	Iraq
YJ	(See FU8; not a separate country.)
YL	Latvia
YM	Danzig
YN	Nicaragua
YR	Roumania
YS	Salvador
YT, YU	Jugoslavia
YV	Venezuela
ZA	Albania
ZB1	Malta
ZB2	Gibraltar
ZC1	Transjordania
ZC2	Cocos Islands
ZC3	Christmas Islands
ZC4	Cyprus
ZC6	Palestine
ZD1	Sierra Leone
ZD2	Nigeria, Cameroons (British)
ZD3	Gambia
ZD4	Gold Coast, Togoland (British)
ZD6	Nyasaland
ZD7	Saint Helena
ZD8	Ascension I.
ZD9	Tristan da Cunha
ZE	Southern Rhodesia
ZK1	Cook Islands
ZK2	Niue
ZL	New Zealand
ZM	Samoa (Western)
ZP	Paraguay
ZS	Union of So. Africa, South Africa
ZS3	South-West Africa

(See pages 586 and 587 for WAZ Map of the World)

Be Right with OHMITE

DUMMY ANTENNA RESISTOR

To Check R.F. Power and Tune Up



Check your R.F. Power and tune up to peak efficiency — determine transmission line losses—check line to antenna impedance match — all through the use of this new Ohmite Dummy Antenna. Non-inductive, non-capacitive, constant in resistance. Mounts in standard tube socket.

Model D-100, 100 watts, in popular 73 ohm and 600 ohm resistance values. Also in 13, 18, 34, 64, 100, 146, 219, 300, 400, 500 ohm values.

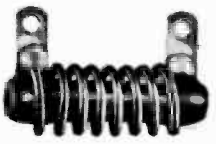
List Price $5.50

Model D-250, 250 watts, in 73 ohm and 600 ohm values. **List Price** $11

Send for Free Dummy Antenna Bulletin 111A

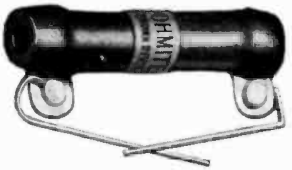
Patents Pending

PARASITIC SUPPRESSOR



Ohmite P-300 Parasitic Suppressor—convenient, compact, efficient . . . designed to prevent ultra-high-frequency parasitic oscillations which occur in the plate and grid leads of push-pull and parallel tube circuits. Non-inductive, vitreous-enameled resistor combined with a choke into one small integral unit. Only 1¼" long overall and ⅝" diameter.

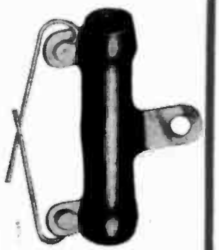
List Price $1.50



POPULAR BROWN DEVILS

There's good reason for the world-wide popularity of Ohmite "Brown Devil" Resistors. They're tough, extra-sturdy units — built right, sealed tight and permanently protected by Ohmite Vitreous Enamel. 10 and 20 watt sizes, in resistances from 1 to 100,000 ohms.

CENTER-TAPPED RESISTORS



Especially designed for use across tube filaments to provide an electrical center for the grid and plate returns. Center tap accurate to plus or minus 1%. Available in Wirewatt (1 watt) and Brown Devil (10 watt) units, in resistances from 10 to 200 ohms.

R. F. PLATE CHOKES

High frequency solenoid chokes designed to avoid either fundamental or harmonic resonance in the amateur bands. Single-layer wound on low power factor steatite cores with non-magnetic mounting brackets. Moisture-proof. Built to carry A THOUSAND MA. 4 stock sizes for 5 to 160 meter bands. Details in Bulletin 106.

R. F. POWER LINE CHOKES

Just the thing to keep R. F. currents from going out over the power line, lessen interference with BCL receivers. Also to prevent high frequency and R. F. interference from coming in to the receiver. 3 stock sizes, rated at 5, 10, and 20 amperes. Consists of two chokes wound on a single core. Details in Bulletin 105.

SEND FOR YOUR FREE COPY OF NEW CATALOG 17

RHEOSTATS ★ RESISTORS ★ SWITCHES ★ CHOKES

★ Ohmite Vitreous Enamel is unexcelled as a protective and bonding covering for power rheostats and resistors.

Vitreous-Enameled RHEOSTATS

These are the rheostats used by amateurs and broadcast stations alike to keep power tube filaments at rated value all the time—increase tube life—get peak efficiency. Time-proved Ohmite all-porcelain vitreous-enameled construction and metal-graphite contact assure permanently smooth, safe, exact control. Available in 25, 50, 75, 100, 150, 225, 300, 500, and 1,000 watt sizes, for all tubes and transmitters. (Underwriters' Laboratories Listed).

OHMITE BAND-SWITCH

A flick-of-the-wrist on the knob of this popular Ohmite Band-Change-Switch gives you instant, easy change from one frequency to another, with really low-loss efficiency. Band changing may be provided in all stages of the transmitter, and "ganged" for complete front-of-panel control. Can be used in rigs up to 1 K.W. rating.

Ask Your Jobber for the Ohmite parts you need, or Write today for Catalog 17.

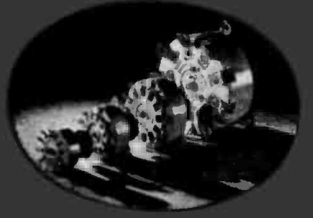
FIXED RESISTORS

These are the same dependable Ohmite vitreous-enameled resistors that are almost universally used by eminent designers and manufacturers of amateur and commercial transmitters and receivers. Available in 25, 50, 100, 160, and 200 watt stock sizes, in resistances from 5 to 250,000 ohms.

ADJUSTABLE DIVIDOHMS

Mighty handy resistors to have around when you need a change of resistor value or a replacement in a hurry. You can quickly adjust the Dividohms to the exact resistance you want and put on one or more taps wherever needed. Patented percentage of resistance scale. 7 ratings from 10 to 200 watts. Resistances up to 100,000 ohms.

New, All-Enclosed High-Current OHMITE TAP SWITCHES



Multi-point, load-break, non-shorting, single-pole, rotary selector switches particularly designed for alternating current use. Ideal for high current circuit switching in transmitter power supply and many heavy duty industrial applications. All-enclosed, ceramic construction. Extremely compact yet perfectly insulated. Self-cleaning, silver-to-silver contacts. "Slow-break", quick-make action. Shafts electrically "dead"—insulated with steatite. Available in single or tandem units; in 10, 20, 40, 75 ampere models, 2¼" diam. to 6" diam.

Send for Tap Switch Bulletin 114

Patents Pending

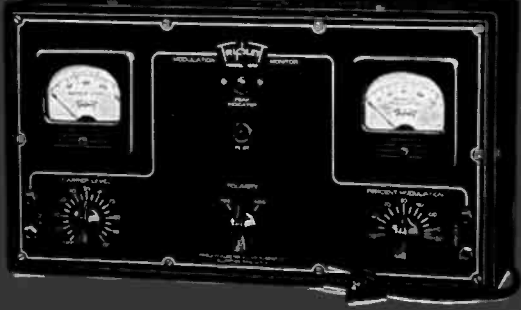
OHMITE

OHMITE MANUFACTURING CO.
4848 FLOURNOY STREET
CHICAGO, U.S.A. • *Cable "Ohmiteco"*

PREFIXES BY COUNTRIES

Afghanistan (A)	YA
Alaska (NA)	K7
Albania (E)	ZA
Algeria (AF)	FA
Andorra (E)	PX
Angola (AF)	CR6
Antigua (NA)	VP2
Argentina (SA)	LU
Ascension (AF)	ZD8
Australia (O)	VK
Azores (AF)	CT2
Bahamas (NA)	VP7
Bahrein Island (A)	VU7
Baker Island (O)	KF6
Balearic Islands (E)	EA6
Barbados (NA)	VP6
Belgian Congo (AF)	OQ5
Belgium (E)	ON
Bermuda Islands (NA)	VP9
Bolivia (SA)	CP
Borneo (Br. North) (O)	VS4
Borneo (Neth. Indies) (O)	PK5
Brazil (SA)	PY
British Guiana (SA)	VP3
British Honduras (NA)	VP1
Br. Solomon Islands (O)	VR4
British Somaliland (AF)	VQ6
Bulgaria (E)	LZ
Burma (A)	XZ
Cameroons (British) (AF)	ZD2
Cameroons (French) (AF)	FE8
Canada (NA)	VE
Canal Zone (NA)	K5, NY
Canary Islands (AF)	EA8
Canton Island (O)	KF6
Cape Verde (AF)	CR4
Cayman Islands (N)	VP5
Ceylon (A)	VS7
Chagos Islands (AF)	VQ8
Channel Islands (E)	G
Chile (SA)	CE
China (A)	XU
Chosen (Korea) (A)	J8
Christmas Island (O)	ZC3
Cocos Islands (O)	ZC2
Colombian Republic (SA)	HK
Cook Islands (O)	ZK1
Costa Rica (NA)	TI
Crete (E)	SV
Cuba (NA)	CM, CO
Curacao (SA)	PJ
Cyprus (E)	ZC4
Danzig (E)	YM
Denmark (E)	OZ
Dominica (NA)	VP2
Dominican Republic (NA)	HI
Dutch East Indies (see Neth. Indies)	
Ecuador (SA)	HC
Egypt (AF)	SU
Eire (E)	EI
Ellice Islands (See Gilbert) (O)	VR1
Enderbury Island (O)	KF6
England (E)	G
Estonia (E)	ES
Ethiopia (AF)	I7
Faeroes Islands (E)	OY
Falkland Islands (SA)	VP8
Fanning Island (O)	VR3
Fed. Malay States (A)	VS2
Fiji Islands (O)	VR2
Finland (E)	OH
France (E)	F
French Equatorial Africa (AF)	FQ8
French Guiana (SA)	FY8
French India (A)	FN
French Indo-China (A)	FI8
French Somaliland (AF)	FL8
French West Africa (AF)	FF8
Gambia (AF)	ZD3
Germany (E)	D
Gibraltar (E)	ZB2
Gilbert & Ellice Islands (O)	VR1
Goa (A)	CR8
Gold Coast (AF)	ZD4
Great Britain (E)	G, GI, GM, GW
Greece (E)	SV
Greenland (NA)	OX
Grenada (NA)	VP2
Guadeloupe (NA)	FG8
Guam (O)	KB6
Guatemala (NA)	TG
Haiti (NA)	HH
Hawaiian Islands (O)	K6
Hedjaz (A)	HZ
Honduras (NA)	HR
Hong Kong (A)	VS6
Howland Island (O)	KF6
Hungary (E)	HA
Iceland (E)	TF
India, British (A)	VU
Iran (ex-Persia) (A)	EP
Iraq (A)	YI
Ireland (see Eire)	
Isle of Man (E)	G
Italy (E)	I
Jamaica (NA)	VP5
Jan Mayen Island (E)	OY
Japan (A)	J
Jarvis Island (O)	KG6
Java (O)	PK1, 2, 3
Johnston Island, (O)	KE6
Jugoslavia (E)	YT, YU

Peak Efficiency with Triplett

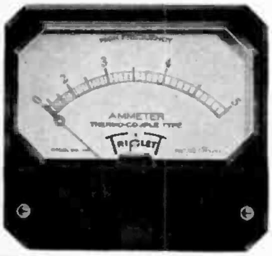


MODEL 1696

MODULATION MONITOR

Usable on all broadcasting bands . . .Has two Triplett RED ● DOT lifetime guaranteed indicating instruments —one serves as a carrier level meter and the other as a percent modulation meter . . . High speed meter reaches full scale deflection in less then 300 milliseconds. Has delay circuit on downstroke (requires 700 Milliseconds for return to zero) . . . Neon flasher indicates overmodulation for peaks of extremely short duration . . . Calibrated modulation control for neon flasher from 50% to 120% . . . Self-contained adjustment for carrier level . . . Polarity switch permits checking positive and negative peaks . . . Tip jacks for phone connection . . . Vacuum tube rectification throughout. 110 Volt A. C. 60 cycle operation . . . Modernistic metal case with black suede finish, 14½" x 7⅝" x 4½". Etched panel. . . . .$33.00 Net.

Also available as a rack panel mounting unit. Monitor is mounted in a heavy steel panel, 19" x 10½" $33.67 Net.



Model 426

Today's Most Modern Instruments

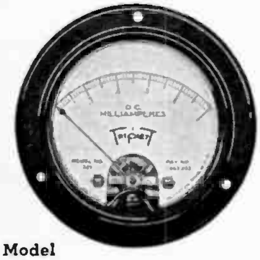
Triplett's advanced line of modern electrical measuring instruments includes 21 styles, round, square and fan cases, 2", 3", 4", 5", 7",10" and twin models. Front and rear instrument illumination is available. Voltmeters, Ammeters, Milliameters, Millivoltmeters, Microammeters, R Meters, Thermo Ammeters, approved Decibel Meters, Dynamometer type instruments and Instrument Relays.

A FEW TYPICAL BARGAINS

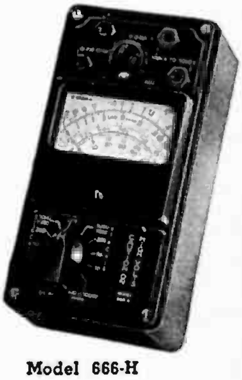
Models 341 (3" round) and 347-A (3" square) Thermo Ammeters, 0-.5, 0-1, 0-1.5, 0-2.5 and 0-5 Amp. ranges, with internal couples. . . . . .$4.50 Net Each. Models 321 (3" round) Decibel Meter. Standard range, up 6, down 10 $7.84 Net Each.

Models 321 (3" round), 327-A (3" square) D. C. Voltmeters, 1000 ohms per volt. Provided with special external metallized multipliers on bakelite strip. 0-1000, 0-1500, 0-2000, 0-2500, 0-3000, 0-4000 ranges . . . $8.67 Net Each

New methods and extremely accurate processes representing years of instrument building experience are embodied in every Triplett design. Today's most modern instruments, the Triplett line will give you a new conception of quality.



Model 321



Model 666-H

POCKET VOLT-OHM-MILLIAMMETER

A pocket Volt-Ohm-Milliammeter that is a "must" for every ham shack. A.C.-D.C. Voltage 0-10-50-250-1000-5000 at 1000 ohms per volt D.C. Milliamperes 0-10-100-500; Resistance 0-300 ohms (shunt type circuit); 0-250,000 ohms (series type circuit). Higher resistance readings with external batteries. Molded case and panel, completely insulated. $14.50 net.

Vacuum tube voltmeters and a complete line of radio test equipment also is available. Write for free catalogs.

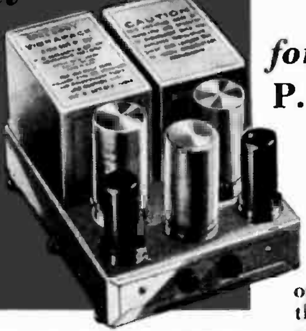
THE TRIPLETT ELECTRICAL INSTRUMENT COMPANY
999 HARMON DRIVE
BLUFFTON, OHIO, U.S.A.

PREFIXES BY COUNTRIES

(Continued)

Kenya (AF)	VQ4
Korea (Chosen) (A)	J8
Labrador (NA)	VO
Latvia (E)	YL
Liberia (AF	EL
Lithuania (E)	LY
Luxembourg (E)	LX
Macao (A)	CR9
Madagascar (AF)	FB8
Madeira (AF)	CT3
Malaya (A) ....Federated States,	VS2
Non-Federated States,	VS3
Maldive Islands (A)	VS9
Malta (E)	ZB1
Manchukuo (A)	MX
Marshall Is. (O)	J9
Martinique (NA)	FM8
Mauritius (AF)	VQ8
Mexico (NA)	XE
Midway Island (O)	KD6
Miquelon & St. Pierre Is. (NA)	FP8
Molucca Islands (O)	PK6
Morocco, French (AF)	CN8
Morocco, Spanish (AF)	EA9
Mozambique (AF)	CR7
Netherlands (E)	PA, PI
Netherland Indies (O)	PK
Neth. West Indies (SA)	PJ
New Caledonia (O)	FK8
Newfoundland (NA)	VO
New Hebrides (O)	FU8, YJ
New Zealand (O)	ZL
Nicaragua (NA)	YN
Nigeria (AF)	ZD2
Niue (O)	ZK2
Non-Fed. Malay States (A)	VS3
Northern Ireland (E)	GI
Northern Rhodesia (AF)	VQ2
Norway (E)	LA
Nyasaland (AF)	ZD6
Ocean Island (see Gilbert) (O)	VR1
Palestine (A)	ZC6
Panama (NA)	HP
Paraguay (SA)	ZP
Persia (see Iran) (A)	EP
Peru (SA)	OA
Philippines (O)	KA
Phoenix Is. (U.S.) (O)	KF6
Pitcairn Island (O)	VR6
Poland (E)	SP
Portugal (E)	CT1
Puerto Rico (NA)	K4
Portuguese Guinea (AF)	CR5
Portuguese India (A)	CR8
Reunion Islands (AF)	FR8
Roumania (E)	YR
Saint Helena (A)	ZD7
St. Kitts-Nevis (NA)	VP2
St. Lucia (NA)	VP2
St. Pierre & Miquelon (NA)	FP8
St. Vincent (NA)	VP2
Salvador (NA)	YS
Samoa (U.S.) (O)	KH6
Samoa (Western) (O)	ZM6
Sarawak (O)	VS5
Saudi Arabia (see Hedjaz) (A)	HZ
Scotland (E)	GM
Seychelles (AF)	VQ9
Siam (A)	HS
Siberia (see U.S.S.R.)	
Sierra Leone (AF)	ZD1
Somaliland (British) (AF)	VQ6
Somaliland (French) (AF)	FL8
South Africa (AF)	ZS
South Georgia (SA)	VP8
South Orkney Is. (SA)	VP8
South Shetland Is. (SA)	VP8
Southern Rhodesia (AF)	ZE
Spain (E)	EA1-5, 7
Straits Settlements (A)	VS1
Sudan (AF)	ST
Sumatra (O)	PK4
Surinam (Dutch Guiana) (SA)	PZ
Sweden (E)	SM
Switzerland (E)	HB
Syria (A)	AR
Tahiti (O)	FO8
Tanganyika (AF)	VQ3
Tangier Zone (AF)	EK1
Tibet (A)	AC4
Timor (O)	CR10
Tobago (SA)	VP4
Togoland (British) (AF)	ZD4
Togoland (French) (AF)	FD8
Tonga Islands (O)	VR5
Transjordania (A)	ZC1
Trinidad (SA)	VP4
Tristan da Cunha (AF)	ZD9
Tunis (AF)	FT4
Turkey (E & A)	TA
Uganda (AF)	VQ5
Union of South Africa (AF)	ZS
United States (NA)	W
U. A. Naval Communication Reserve Stations (NA)	N
Uruguay (SA)	CX
U.S.S.R. (E & A)	U
Venezuela (SA)	YV
Virgin Islands (NA)	K4, KB4
Wake Island (O)	KC6
Wales (E)	GW
Zanzibar (AF)	VP1

Perfect Portable Power



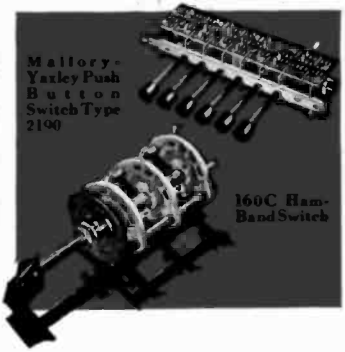
for Transmitters, Receivers, P. A. Systems *with* Vibrapack

Mallory Vibrapacks have won top honors with radio operators, engineers and public address men everywhere as the most economical source of plate voltage for battery operated equipment. The Vibrapack line includes types for 6, 12 and 32 volt operation, with outputs up to 60 watts in the new dual units. Send for free booklet giving complete technical data.

MALLORY *Transmitting Capacitors*

Mallory Transmitting Capacitors are a real safeguard for expensive rigs. Constructed with an exclusive impregnating compound that gives longer life and greater dependability . . . Not a wax . . . not an oil. Its high dielectric constant and unusual heat resistance assures good power factor with extremely stable DC resistance. See your distributor for TX, TR and TZ types.

. . *for* Band Switching . . *for* Meter Switching



Mallory-Yaxley Push Button Switch Type 2190

160C Ham-Band Switch

Here are two Mallory-Yaxley switches that open new operating vistas for amateurs. The push button switch makes it possible to measure a number of circuits with a single meter while other circuits connected remain closed. The HamBand Switch brings new convenience to band switching . . . makes it as easy as receiver band switching. Unique design offers wide range of applications. Write for details.

Other MALLORY-YAXLEY *Products for Amateurs*

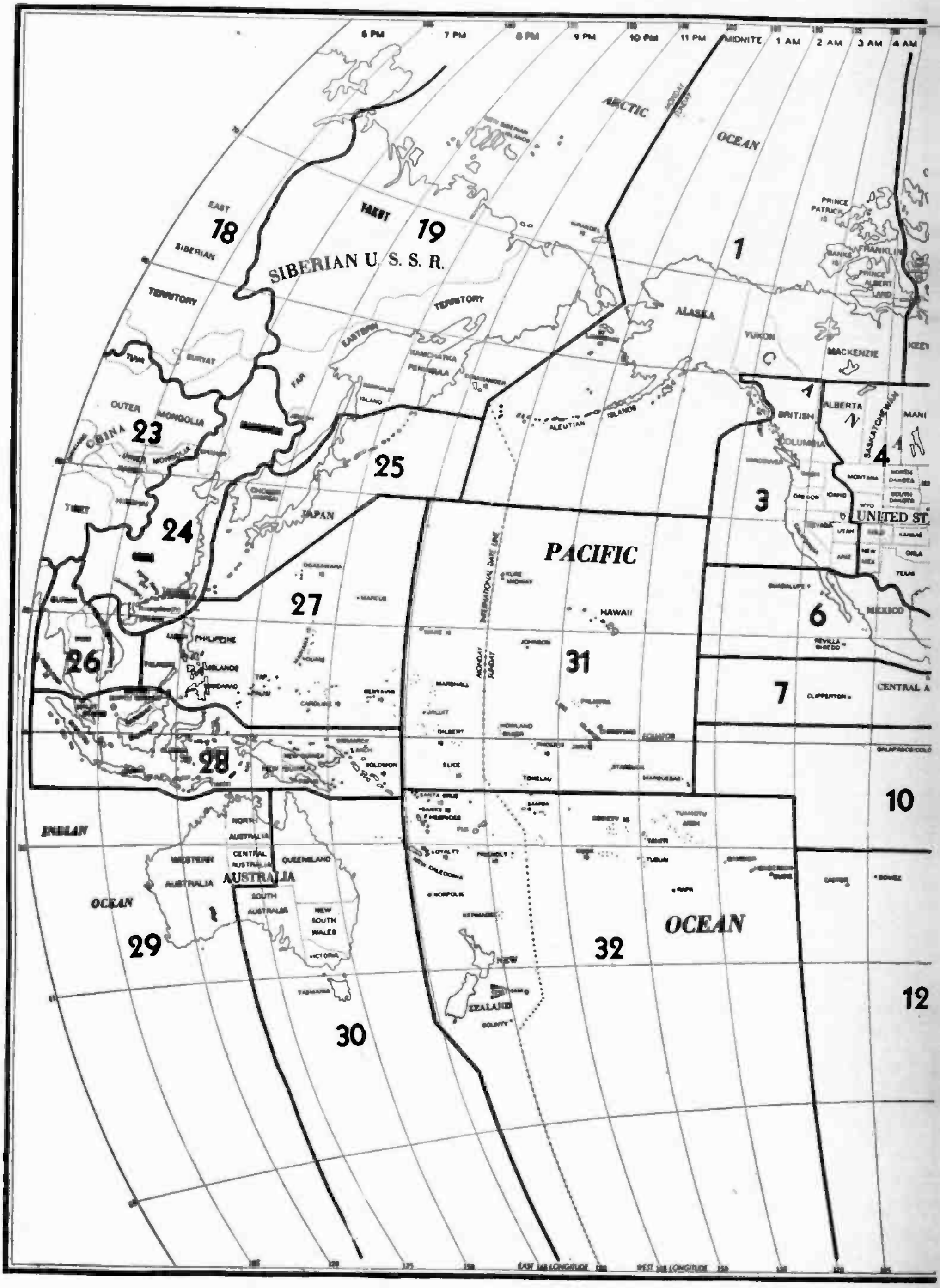
Dry Electrolytic Condensers
Wet Electrolytic Condensers
Tip Jacks and Plugs
Phone Plugs
Jacks and Jack Switches
Grid Bias Cells
Vitreous Resistors
Truvolt Resistors
Variohm Resistors
Rheostats
Potentiometers
Volume Controls
T & L Pads
Rotary Switches
Cable Connectors
Dial and Panel Lights
Radio Convenience Outlets
Knobs—Nuts—Washers
Dry Disc Rectifiers
Auto Radio Vibrators

P. R. MALLORY & CO. INC.
MALLORY

YAXLEY

P. R. MALLORY & CO., Inc.
INDIANAPOLIS INDIANA
Cable Address—PELMALLO

W. A. Z. MAP


6 PM
7 PM
8 PM
9 PM
10 PM
11 PM
MIDNITE
1 AM
2 AM
3 AM
4 AM
ARCTIC
OCEAN
18
19
1
EAST
SIBERIAN
TERRITORY
YAKUT
SIBERIAN U. S. S. R.
TERRITORY
EASTERN
FAR
KAMCHATKA PENINSULA
ALASKA
YUKON
MACKENZIE
PRINCE PATRICK IS
BANKS IS
FRANKLIN
PRINCE ALBERT LAND
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JAPAN
ALEUTIAN ISLANDS
BRITISH COLUMBIA
ALBERTA
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MONTANA
NORTH DAKOTA
SOUTH DAKOTA
OREGON
IDAHO
WYO
NEVADA
UTAH
UNITED ST
TEXAS
PACIFIC
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HAWAII
INTERNATIONAL DATE LINE
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MEXICO
PHILIPPINE ISLANDS
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CENTRAL A
MARSHALL
GILBERT
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PHOENIX
SOLOMON
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INDIAN
NORTH AUSTRALIA
CENTRAL AUSTRALIA
WESTERN AUSTRALIA
QUEENSLAND
AUSTRALIA
SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
TASMANIA
OCEAN
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NEW CALEDONIA
NORFOLK
NEW ZEALAND
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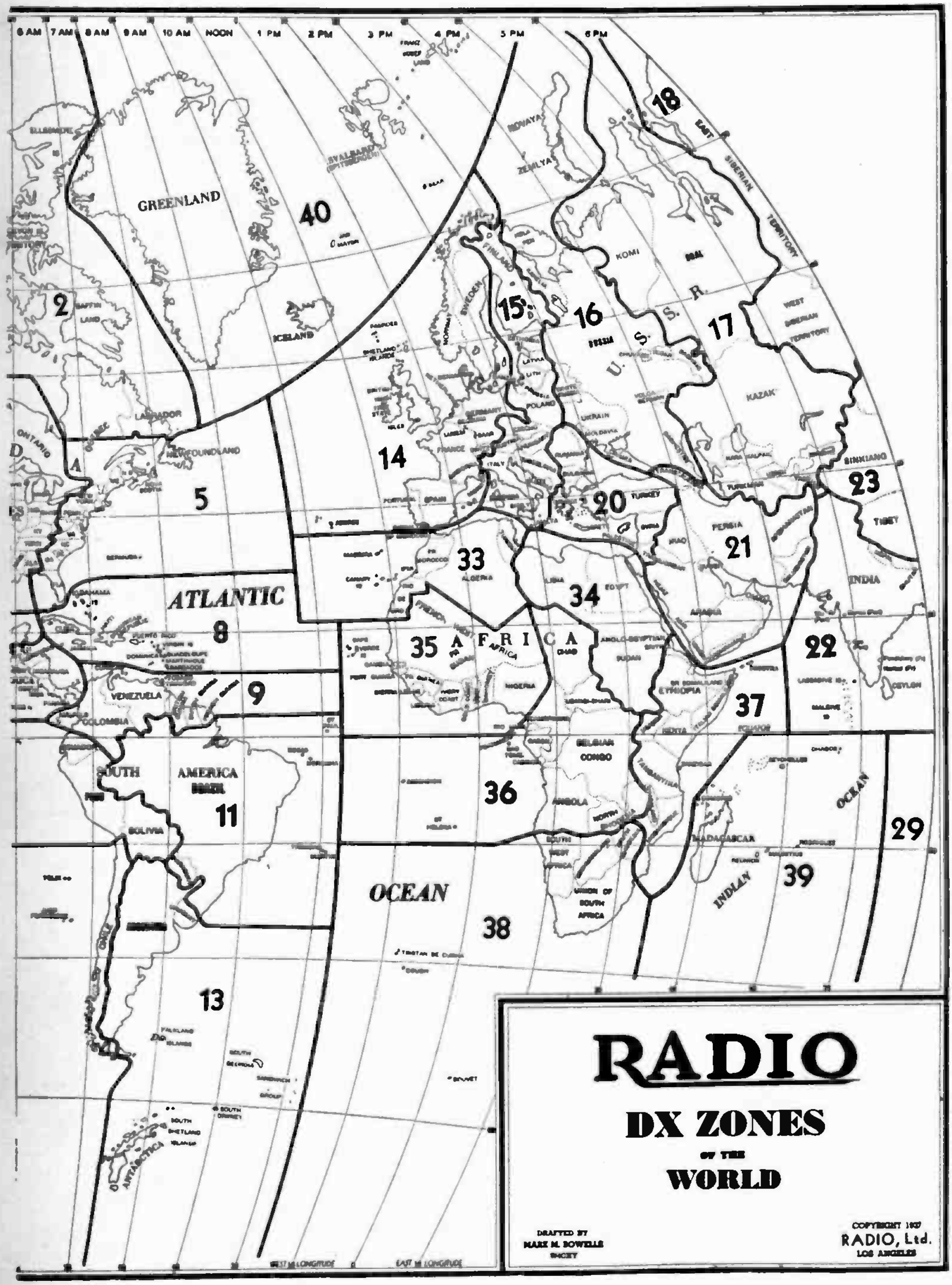
OCEAN
12
EAST 180 LONGITUDE
WEST 180 LONGITUDE

OF THE WORLD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7 AM
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ICELAND
NOVAYA ZEMLYA
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18
EAST SIBERIAN TERRITORY
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U. S. S. R.
KOMI
RUSSIA
WEST SIBERIAN TERRITORY
KAZAK
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NEWFOUNDLAND
LABRADOR
ONTARIO
SINKIANG
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TIBET
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TURKEY
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INDIA
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ALGERIA
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EGYPT
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AFRICA
ARABIA
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CEYLON
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VENEZUELA
COLOMBIA
ETHIOPIA
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SOUTH AMERICA
BRAZIL
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BOLIVIA
BELGIAN CONGO
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ANGOLA
OCEAN
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MADAGASCAR
INDIAN
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OCEAN
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UNION OF SOUTH AFRICA
13
FALKLAND ISLANDS
SOUTH GEORGIA
SOUTH SANDWICH GROUP
SOUTH ORKNEY
SOUTH SHETLAND ISLANDS
ANTARCTICA
BOUVET
TRISTAN DE CUNHA
GOUGH
WEST LONGITUDE
EAST LONGITUDE
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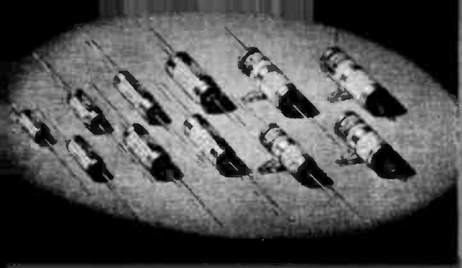
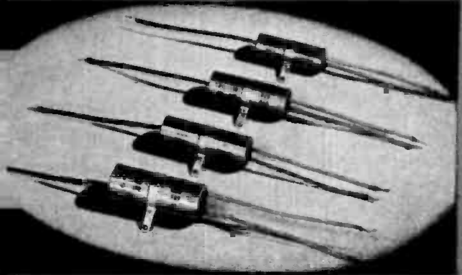
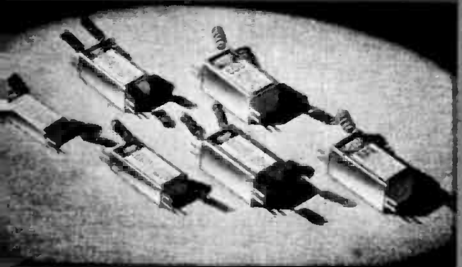
LOS ANGELES



Type BR — "Blue Beavers"



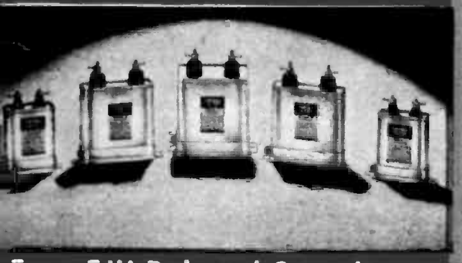
Type BRL — dual "Beavers"



Type JR, JRC and JRX

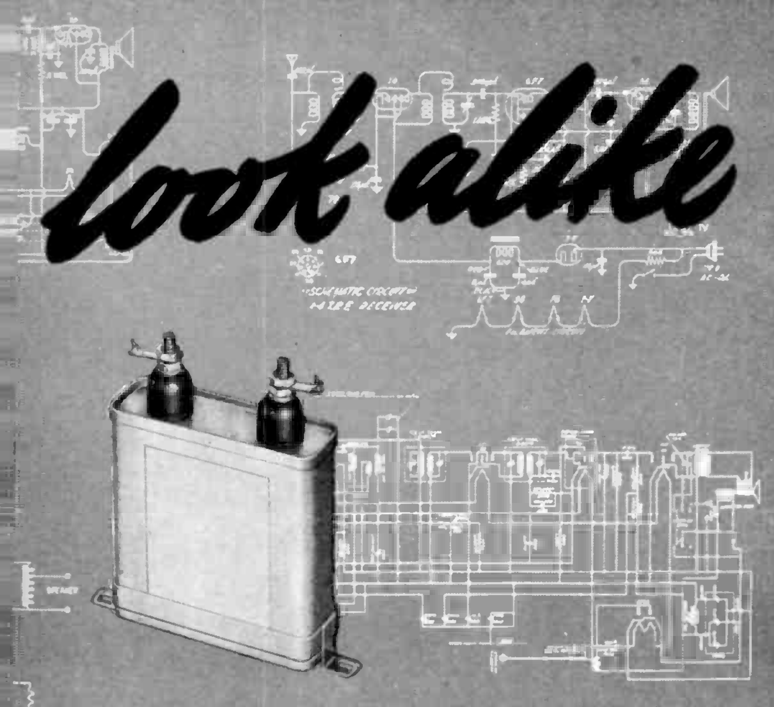
Type UP — Electrolytics

Type EX and EY



Type TJU Dykanol Capacitors

look alike

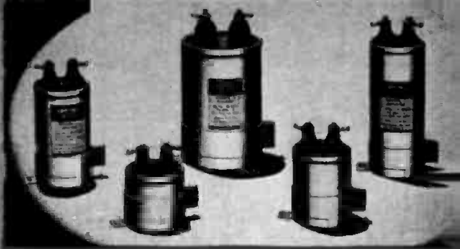


the all-around tops in capacitor value. Look for the name CORNELL-DUBILIER on the label. Only capacitors bearing this name are backed by laboratory *life tests* for performance, and the specialized experience of 29 manufacturing years—your guarantee of outstanding performance on the job.

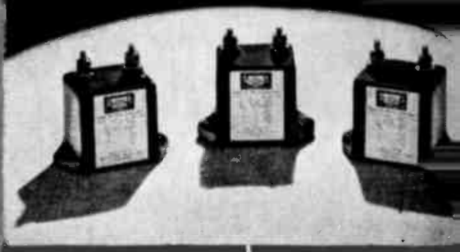
CORNELL-DUBILIER

the top name in capacitors

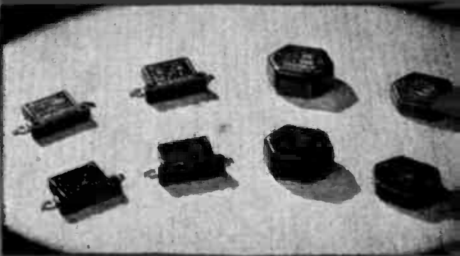
For the complete listing of all C-D Capacitors, Capacitor Test Instruments and Quietone Interference Filters, ask your local C-D distributor for Cat. 175A. Or write to Cornell-Dubilier Electric Corp., So. Plainfield, N. J.



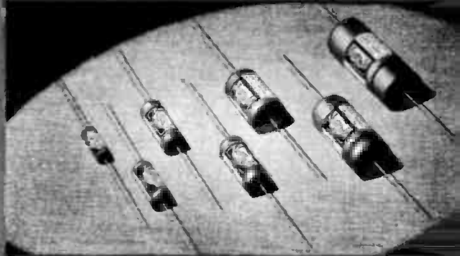
Type TQ Dykanol Capacitors



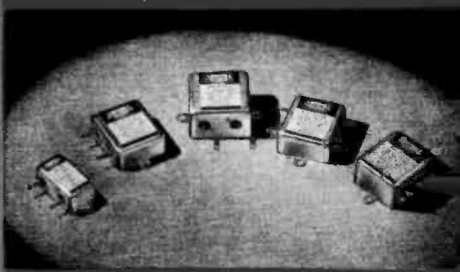
Type 86 Mica Capacitors



Types 4 and 9 Mica Capacitors



Type DT—"Dwarf Tigers"



Type DA, DB, DC and DD Bypass

BF-50 Capacitor Analyzer

ARTIFICIAL RESPIRATION

By the Prone Pressure Method

(ILLUSTRATIONS COURTESY OF NATIONAL SAFETY COUNCIL, CHICAGO)

The following is the accepted, standardized technique of "How To Give Artificial Respiration by the Prone Pressure Method," agreed upon by a special committee of national organizations and persons appointed by the United States Public Health Service of the Treasury Department.

The Prone Pressure Method of artificial respiration described in these rules should be used in cases of suspended respiration from all causes—drowning, *electric shock*, carbon monoxide poisoning, injuries, etc. Delay of even one minute in the application of the method may lose a life. Follow the instructions even if the patient appears dead. Continue artificial respiration until natural breathing is restored or until a physician declares rigor mortis (stiffening of the body) has set in. Success *has come* after three and one half hours of effort.

Learn this method now. Don't wait for an accident. Practice on a friend. Let him practice on you.

1. Lay the patient on his belly, one arm extended directly overhead, the other arm bent at elbow and with the face turned outward and resting on hand or forearm so that the nose and mouth are free for breathing. (See figure 1.)

2. Kneel straddling the patient's thighs with your knees placed at such a distance from the hip bones as will allow you to assume the position shown in figure 1.

Place the palms of the hands on the small of the back with fingers resting on the ribs, the little finger just touching the lowest rib, with the thumb and fingers in a natural position, and the tips of the fingers just out of sight. (See figure 1.)

3. With arms held straight, swing forward slowly so that the weight of your body is gradually brought to bear upon the patient. The shoulder should be directly over the heel of the hand at the end of the forward swing. (See figure 2.) Do not bend your elbows. This operation should take about two seconds.

4. Now immediately swing backward so as to completely remove the pressure, thus returning to the position in figure 3.

5. After two seconds, swing forward again. Thus repeat deliberately twelve to fifteen times a minute the double movement of compression and release, a complete respiration in four or five seconds.

6. Continue artificial respiration without interruption until natural breathing is restored if necessary, four hours or longer, or until a physician declares the patient is dead.

7. As soon as this artificial respiration has been started and while it is being continued, an assistant should loosen any tight clothing about the patient's neck, chest, or waist. Keep the patient warm. Do not give any liquids whatever by mouth until the patient is fully conscious.

8. To avoid strain on the heart when the patient revives, he should be kept lying down and not allowed to stand or sit up. If the doctor has not arrived by the time the patient has revived, he should be given some stimulant, such as one teaspoonful of aromatic spirits of ammonia in a small glass of water or a hot drink of coffee or tea, etc. The patient should be kept warm.

9. Resuscitation should be carried on at the nearest possible point to where the patient received his injuries. He should not be moved from this point until he is breathing normally of his own volition and then moved only in a lying position. Should it be necessary, due to extreme weather conditions, etc., to move the patient before he is breathing normally, resuscitation should be carried on during the time he is being moved, if practicable.

10. A brief return of natural respiration is not a certain indication for stopping the resuscitation. Not infrequently the patient, after a temporary recovery of respiration, stops breathing again. The patient must be watched and if natural breathing stops, artificial respiration should be resumed at once.

11. In carrying out resuscitation it may be necessary to change the operator. This change must be made without losing the rhythm of respiration. By this procedure no confusion results at the time of change of operator and a regular rhythm is kept up.

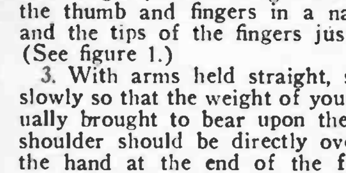


FIGURE 1

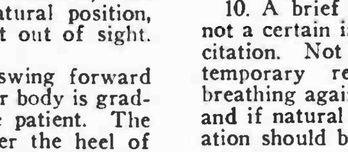


FIGURE 2

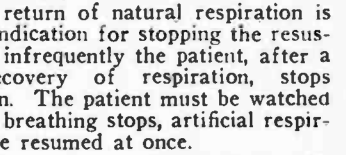


FIGURE 3

A Complete Line of Condensers

Backed by 28 Years Experience

EVERY HAMMARLUND product embodies over a quarter of a century of experience in precision manufacturing. Whether you are building a simple one-tube receiver or a multi-stage 1 KW. transmitter you will be safe in using Hammarlund components.

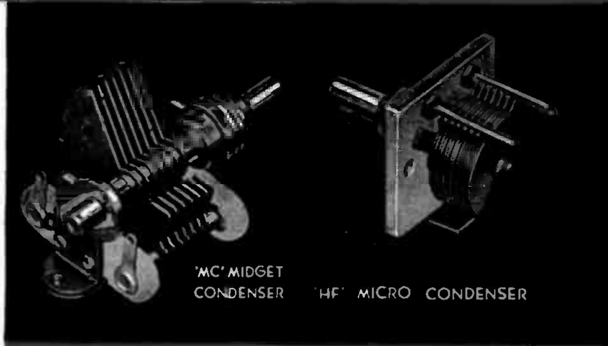
"MC" and "HF" midget condensers are used extensively by amateurs and experimenters in receivers both for high and ultra-high frequencies and also in low power transmitters and exciter units. Many laboratories specify these precision condensers in the design of commercial equipment. Outstanding features are: Isolantite insulation, cadmium plated soldered brass plates, silver plated Beryllium contacts and universal mounting.

"MTC" and "N-10" are companion units designed for low and medium power transmitters. "MTC" is available in a wide range of capacities and in peak voltages from 1000 to 5000 with either single or dual stator. Type "N" neutralizing condensers are made in three ranges. "N-10," the smallest, is for use with medium-power high efficiency tubes. "N-15" is for high-power tubes, and "N-20" is for high-power tubes with rather large inter-electrode capacities.

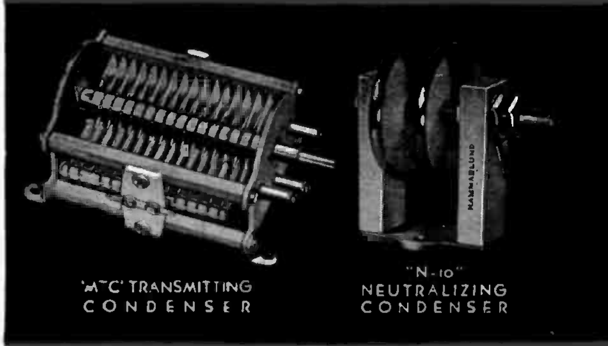
"TC" is a new series of moderately priced transmitting condensers for transmitters up to 1 KW. input. These, like the "MTC", feature silver plated Beryllium contacts, Isolantite insulation, non-magnetic rotor assembly, special cushioned bearing which eliminates shaft binding and twisting resulting in smooth electrical and mechanical operation. There are 29 different types in the "TC" line with voltage ratings from 2000 to 7500 and in capacities suitable for every conceivable amateur and laboratory application.

WRITE FOR GENERAL CATALOG

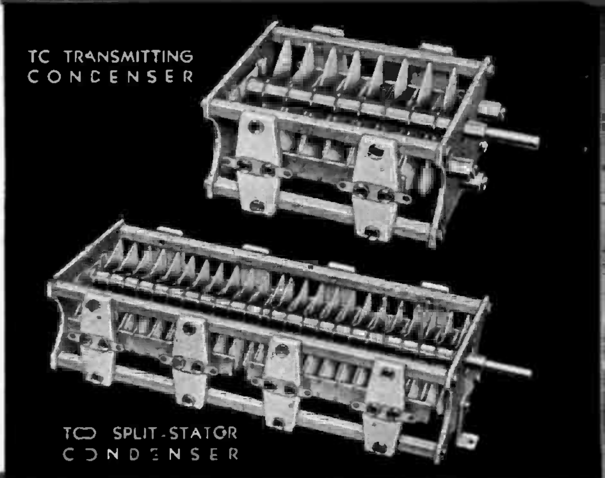
Our general catalog contains technical data on these and many other items of interest to the ham and experimenter. Write Dept. RH-4 for your copy.



"MC" and "HF" condensers are ideal for receivers, low power transmitters and exciters.



"MTC" and "N-10" for medium power.
"TC" and "TCD" for rigs up to 1 KW.



HAMMARLUND MFG. CO., INC.

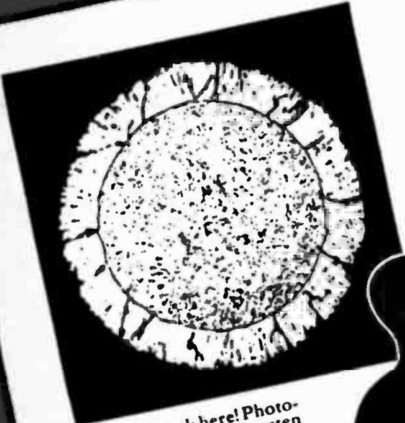
424 W. 33rd St., New York City

CANADIAN OFFICE: 41 West Av. No., Hamilton, Ont.

PROVED DEPENDABILITY

● 250-DIAMETER ENLARGEMENTS

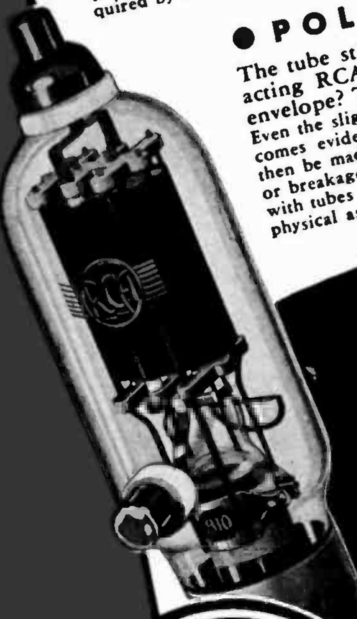
By means of the microscope, RCA engineers check cross-sections of thoriated-tungsten filaments which are tremendously enlarged to eliminate all chance for inaccuracies in application of the carbide filament layer so essential in maintaining a uniform layer of thorium on the surface. It is because of this sort of engineering care that RCA filaments are noted for longer life, greater dependability.



No guesswork here! Photomicrographs of tungsten filament cross-sections *prove* the uniformity of the outer carbide layer required by RCA standards.

● POLARISCOPE...

The tube structure has passed all the exacting RCA tests, but what of its glass envelope? This polariscope tells the story. Even the slightest stress or strain in the glass becomes evident and engineering corrections can then be made to eliminate any danger of leakage or breakage. As always, the aim is to supply you with tubes of unquestioned dependability in *every* physical as well as every electrical characteristic.



● HOT STUFF..

Here, an RCA engineer is using a portable pyrometer to determine the exact degree of heat applied to the anode of a Transmitting Tube during the exhaust process. The elimination of guesswork in this im portant operation means tha every tube receives the sam thorough exhaust.

Depicted here are but a few of the many unusual RCA processes painstaking engineering tests that make RCA Transmitting T unexcelled for long, trouble-free performance plus real tube econ

RCA Radio Tubes

FIRST IN METAL FOREMOST IN GLASS FINEST IN PERFORMANCE

. Less Cost Per Hour of Service

3 RCA LEADERS THAT TELL THEIR OWN STORY OF QUALITY

RCA 866

LESS COST PER HOUR OF SERVICE

When you install RCA-866 Mercury-Vapor Rectifier Tubes, you can forget rectification problems for a long, long time. That's why they're the best known, most widely used tubes of this type on the market. Peak plate current 1 amp. max.; peak inverse voltage 7,500 max. .... **$1.50 Net**

For higher voltages use RCA-866-A. Peak plate current, 1 amp. max.; peak inverse voltage, 10,000 max. **$2.50 Net**

RCA 807

LITTLE MAGICIAN OF TRANSMITTING TUBES

This little Beam Power Amplifier is really half a dozen tubes in one. Crystal oscillator, doubler, quadrupler, buffer, Class C r-f amplifier, grid-modulated r-f amplifier, modulator—almost like magic, the RCA-807 fits them all. Class C ratings for amateur service: D.C. Plate voltage, 750; D.C. plate current, 100 ma.; D.C. plate input, 75 watts; plate dissipation, 30 watts...... **$3.50**

RCA 809

BIG RESULTS AT LOW COST...

The RCA-809 costs less, your driver stage costs less, and your power supply and amplifier equipment cost less. Two RCA-809's have a power output for amateur service of more than 150 watts with only 7.6 watts driving power. A precision-manufactured Transmitting Tube that gives you outstanding performance at a Receiving Tube price............ **$2.50**

TRANSMITTING TUBES

TRIODES

203A	$10.00
211	10.00
800	10.00
801	3.45
805	13.50
806	22.00
808	7.75
809	2.50
810	13.50
811	3.50
812	3.50
833	85.00
834	12.50
838	11.00
845	10.00
1623	2.50

BEAM POWER

807	$ 3.50
813	28.50
814	17.50
828	17.50
832	28.75

PENTODES

802	$ 3.50
803	28.50
804	15.00
837	7.50

RECTIFIERS

866	$ 1.50
866A	2.50
872	9.00
872A	11.00

TELEVISION TUBES

KINESCOPES

3AP4/906P4	$18.25
5AP4/1805P4	27.50
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12AP4/1803P4	75.00

AMPLIFIERS

6AC7/1852	$ 2.50
6AB7/1853	2.50
6AG7	2.75

RECTIFIERS

2V3-G	$ 3.00
2X2/879	2.00

SPECIAL PURPOSE TUBES

CATHODE-RAY

902	$ 7.50
906P1	13.50
913	4.00
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ACORN

954	$ 5.00
955	3.00
956	5.00
957	3.00
958	3.00
959	5.00

PHOTOTUBES

868	$ 3.70
917	4.75
918	4.50
919	4.75
920	5.25
921	2.00
922	2.00
923	2.60
924	2.00
925	2.00
926	3.00

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YOUR GUIDE TO BETTER TUBES

Use the famous RCA Technical Manual TT-3 (192 pages) as your guide to dependable Transmitting Tubes for every amateur or commercial need. Contains full details on RCA air-cooled transmitting types plus a wealth of handy information. 25c net at RCA jobbers. RCA Transmitting Tube Folder TT-100 (16 pages) free upon request.

HAM TIPS—FREE!

A helpful publication of worthwhile information, technical data, diagrams, etc. for amateurs—free at all RCA Power Tube Distributors.

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FOR EVERY AMATEUR APPLICATION

RCA MANUFACTURING CO., INC., CAMDEN, N. J.

A Service of The Radio Corporation of America

DANGER–HIGH VOLTAGE

The high voltage power supplies even in a low-power transmitter are potentially lethal. They are also potential fire hazards. Pages could be written on "don'ts" and precautionary measures, but the important thing is to *use your head;* don't fool with any part of your transmitter or power supply unless you know exactly what you are doing and have your mind on what you are doing.

Not only should your transmitter installation be so arranged to minimize the danger of accidental shock for your own safety, but also because "haywire" installations that do not pass the underwriters' rules will invalidate your fire insurance. You have no claim against the insurance company if they can prove that the installation did not meet underwriters' specifications.

Some of the most important things to remember in regard to the high voltage danger are the following:

Do not rely upon bleeders to discharge your filter condensers; short the condenser with an insulated-handle screwdriver before handling any of the associated circuits. Bleeders occasionally blow out, and good filter condensers hold a charge a long time.

Beware of "zero adjuster" devices on meters placed in positive high-voltage leads. Also be careful of dial set screws if the rotor shaft of the condenser is "hot." Both of these situations represent poor practice to begin with.

Don't touch any transmitter components without first turning off all switches. If you do insist on making coupling adjustments, etc., with the transmitter on (very bad practice), keep ONE HAND BEHIND YOU.

Do not work on the high-voltage circuits or make adjustments where it is necessary to reach inside the transmitter UNLESS SOMEONE ELSE IS PRESENT. Ninety per cent of the deaths of amateurs due to electrocution could have been prevented if someone had been present to kill the high voltage or remove the victim and to call the doctor and administer first aid before he arrived.

High-voltage gear should be so fixed that small children cannot manipulate the switches or come in contact with any of the wires or components. Either keep the radio room or gear under lock and key or else provide an "interlock" system whereby all primary circuits are broken when the transmitter cabinet is opened.

Familiarize yourself with the latest approved methods of first aid treatment for electrical shock. It may enable you to save a life some time.

Don't attempt to hurry too much if a companion comes in contact with high voltage and cannot extricate himself. Act quickly but do not act without deliberation or you may be in as bad a fix as the person you are trying to help. Do not touch the victim with your bare hands if things are wet. Otherwise, it is safe to grab him by a loose fold of clothing to pull him free, first making sure that you are well-insulated from anything grounded. Turning off the voltage is simpler, when possible. However, do not waste precious moments dashing around trying to discover how to open the circuit. If you do not already know, try to remove the victim if it can be done safely.

A main primary switch at the entrance to the radio room, killing all primary circuits, will reduce the fire hazard and help your peace of mind, provided you make it an iron-clad rule always to throw the switch when leaving the room.

Beware of strange equipment. It may contain unconventional wiring or circuits. Do not take for granted that it is wired the way you would do it.

Bliley Crystals

40-80 METERS

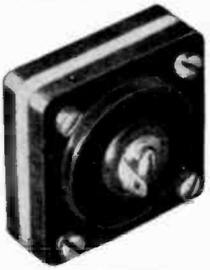
Variable Frequency

Type VF1

Dodging QRM is easy with this low-drift crystal unit. Its frequency is continuously variable up to 6kc. at 80 meters, or 12kc. at 40 meters. No special circuits are required.

Price, 40-meter band, ±15kc.	$6.60
Price, 80-meter band, ± 5kc.	$6.60

CALIBRATOR CRYSTAL UNIT

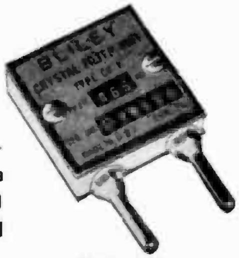


Type SMC100

A dual-frequency mounted crystal for calibration of receivers, signal generators, frequency monitors, etc. The 100kc. frequency is exact by adjustment; the 1000kc. is within ±0.05%.

Price	$7.75

CRYSTAL FILTER UNIT



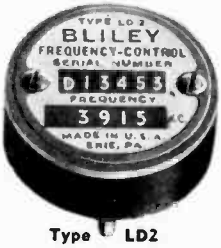
Type CF1

No modern communications receiver is complete without a quartz crystal filter. The CF1 Filter Unit is correctly designed and carefully manufactured.

Price, 456kc., 465kc. or 500kc. I-F	$5.50
Price, 1600kc. I-F	$9.50

80-160 METERS

±4 cycles/mc./°C.
(max.)



Type LD2

A precision-made, mounted, low-drift crystal. It is rigidly tested, highly active and thoroughly reliable.

Price, 80 or 160-meter band, ±5kc.	$4.80
Price, Exact integral kc.	$5.90

10-20 METERS

+20 cycles/mc./°C.
(20 meters)
+43 cycles/mc./°C.
(10 meters)

Type HF2

Simplifies the construction of stable 2½, 5, 10 and 20-meter transmitters. The crystal is rugged and easily excited.

Price, 14.0 to 14.4mc., ±15kc.	$5.75
Price, 14.4 to 15.0mc., ±30kc.	$5.75
Price, 28.0 to 30.0mc., ±50kc.	$5.75

20-40 METERS

±4 cycles/mc./°C.
(max.)

Type B5

This distinctive frequency control unit represents the best in a mounted low-drift high frequency quartz crystal.

Price, 7.0 to 7.3mc., ±5kc.	$4.80
Exact integral kc.	$5.90
Price, 14.0 to 14.4mc., ±15kc.	$7.50
Price, 14.0 to 14.4mc., ±15kc.	$7.50

40-80-160 METERS

– 23 cycles/mc./°C.

Type BC3

Fully dependable in every respect, this medium-drift mounted crystal offers stable frequency control at economical cost.

Price, 40 or 80-meter band, ±5kc.	$3.35
Price, 160-meter band, ±10kc.	$3.35
Bulletin E-6, FREQUENCY CONTROL WITH QUARTZ CRYSTALS (Canada & foreign, 15c)	$ .10
Catalog Circular, A-7	FREE

Bliley
ELECTRIC CO.
ERIE, PA.

Emergency Work

In many of the larger cities, various individuals and clubs have prepared themselves for any emergency that might arise by constructing and keeping in readiness self-powered communication equipment, for use in case of power failure. Such foresightedness is to be commended.

On the other hand, disaster is bound to strike at times in localities where no such methodical preparation has been made. In such an event, amateurs with a reasonable amount of technical training and experience should be able to establish communication within a couple of hours with no other facilities than an automobile tool kit, two or three auto radio receivers, and a couple of auto batteries. The latter are universally available, and a high percentage of the newer cars are now equipped with auto radios. If the supply of auto batteries is limited, they can be recharged as necessary by one of the autos from which they were commandeered.

One receiver can be torn up to provide parts and a power source for the transmitter. The output tube will make a good oscillator, either crystal or "t.n.t."

Another set can be torn into and the coils cut down until with the condenser plates entirely unmeshed they "hit" around 70 meters. Both the 80 and 160 meter bands can then be covered in grand style if a good outside antenna and a ground connection are used.

By wrapping a piece of insulated wire around both plate and grid leads of an i.f. tube (assuming the set is a superheterodyne, as most are), the stage can be made to oscillate, thus providing makeshift yet satisfactory heterodyne reception of c.w. signals. If the a.v.c. action bothers on c.w., either use a very short antenna or else ground the a.v.c. bus; either will effect a cure, the latter being the better method.

A microphone can be temporarily borrowed for the emergency from the nearest telephone. Two output transformers, of the type designed to match a pentode tube to dynamic speaker voice coil, can be connected with their corresponding windings in series (primaries in series; secondaries in series) and used backwards as a single, microphone transformer to feed directly into a pentode tube used as a class A modulator (Heising). It will be necessary to talk loudly and directly into the microphone, which incidentally should be fed from a separate 6 volt battery in order to avoid vibrator hash in the speech.

Home stations often can be kept on the air after a power failure by utilizing an auto radio and battery, feeding plate voltage to either the oscillator or exciter of your regular transmitter from the vibrator pack and deriving heater voltage direct from the battery. The oscillator or exciter should be originally designed with this in mind.

Any amateurs in the vicinity possessing battery-powered or auto-installed 5 meter gear can locate their equipment at strategic points and take care of short-haul traffic.

Amateurs not in the immediate disaster area usually can be of most service by doing lots of listening, and little or no transmitting until called upon.

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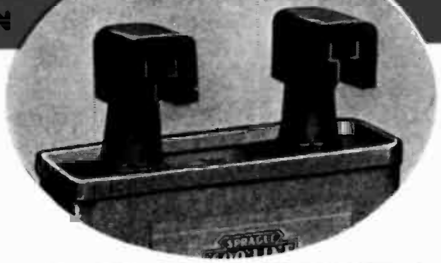

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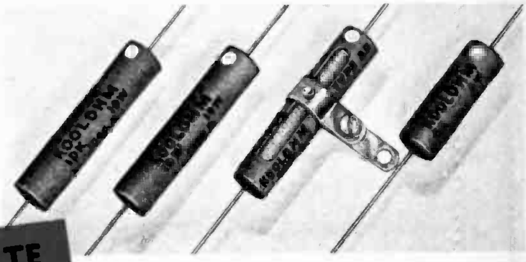

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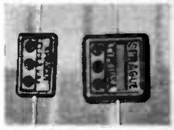

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GOOD ENGINEERING PRACTICE

The F. C. C. standards of good engineering practice, while intended by the commission to apply specifically to standard broadcast stations, contain recommendations that might be adopted advantageously in whole or part by stations of other classes, including amateurs. The present standards, enlarged from time to time as the state of the art improves, were designed to promote efficient station operation, as well as to safeguard operators and other persons from injury or death by electrocution.

Excerpts from the salient provisions of interest to amateurs are digested in the following paragraphs.

Protective Construction

Transmitters should be built either on racks and panels or in completely enclosed frames. The entire transmitter should be enclosed in a metal frame or grill or separated from the operating space by a barrier (or other equivalent means), all metallic parts of which are grounded.

High-powered final stages may be assembled in open frames provided the equipment is enclosed by a protective fence.

All external metallic handles and controls accessible to the operator must be adequately grounded. Tuning adjustments in circuits requiring voltages in excess of 750 must be made from the front of the panels with all access doors closed. All access doors must be provided with interlocks which will disconnect all voltages in excess of 750 when any such door is opened.

Meters having more than 1000 volts potential to ground on their movements must be protected by a cage or cover *in addition to the regular case* unless it can be shown by the manufacturer's rating that the meters will operate safely at the applied potential. No protective case is required on a plate voltmeter located at the low-voltage end of a multiplier resistor with one terminal of the meter at less than 1000 volts above ground. The commission considers it best practice to protect voltmeters subject to more than 5000 volts with suitable over-voltage protective devices across the instrument terminals in case the winding should open.

No circuit in excess of 150 volts shall have any parts exposed to direct contact. Dead front type of switchboard construction is preferred.

Proper bleeder resistors must be installed across all condenser banks to remove any charge which may remain after the circuit is opened. All plate-supply and other high-voltage equipment must be protected to prevent injury to the operator. Commutator guards must be provided on all high-voltage motor generators and similar machines. Exposed 220-volt switching equipment is not recommended; however it is not prohibited.

The antenna, lead-in, counterpoise, etc. must be installed so as not to present a hazard. It is not considered necessary to protect the equipment in the antenna tuning house and base of the antenna with screens and interlocks if doors to the tuning house and antenna are fenced and locked at all times with keys in the possession of the operator.

Wiring and Shielding

Transmitter panels or units must be wired in accordance with standard switchboard practice, either with cabled, insulated leads or with rigid bus bar properly insulated and protected. Inter-unit wiring in the transmitter (with the exception of circuits carrying r. f.) must be installed in approved fiber conduit or metal raceways to protect it from mechanical injury.

Circuits carrying low-level r. f. between units must consist either of concentric tubing, two-wire balanced lines, or be properly shielded to prevent the pickup of modulated r. f. energy from the output circuit.

Each stage preceding the modulated stage, including the oscillator, must be adequately shielded and filtered to prevent feedback. The commission requires that the crystal chamber, together with the leads to the oscillator circuit, be *totally* shielded. Lines running between the transmitter and monitors or similar devices must be thoroughly shielded.

(Continued on Page 600)

THORDARSON
AMATEUR TRANSFORMERS

"Thordarson"—a name which hams have regarded as a hall-mark of quality since radio's earliest days. Today, more than ever, it stands as the name on which hams rely for every transformer need. Only a representative group of Thordarson transformers is listed below. For information about the complete line ask your parts distributor or write the factory for your FREE copy of Catalog No. 400-D.

"19" SERIES UNIVERSAL DRIVER TRANSFORMERS

Through the use of five ratios on each transformer, this series will handle all driver transformer requirements usually encountered in amateur transmitter circuits. All of them are encased in mounting style 4-D.

Type No.	Ratio Primary to ½ Secondary	Amateur Net Price
T-19D01	1:1, 1.2:1, 1.4:1, 1.6:1, 1.8:1	$3.60
T-19D02	2:1, 2.2:1, 2.4:1, 2.6:1, 2.8:1	3.60
T-19D03	3:1, 3.2:1, 3.4:1, 3.6:1, 3.8:1	3.60
T-19D04	4:1, 4.5:1, 5:1, 5.5:1, 6:1.	3.60
T-19D05	1:3.15, 1:2.75, 1:2.5, 1:2.25, 1:2, 1:1.75, 1:1.4, 1:1.25, 1:1.85, 1:.75	3.60

"19" SERIES UNIVERSAL MODULATION TRANSFORMERS

Tapped coils enable the experimenter to match any modulator tubes to any Class C R.F. load. All except T-19M17 are in case style 2N.

Type No.	Cap. Watts	Pri. M.A. Per Side	Secondary M.A. Series	Secondary M.A. Par.	Amateur Net Price
T-19M13	15	50	50	100	$2.40
T-19M14	30	75	75	150	4.20
T-19M15	60	125	125	250	6.00
T-19M16	100	175	175	350	9.00
T-19M17	250	225	225	450	14.40

"19" SERIES TRANSMITTER INPUT AND FILTER CHOKES

Matched input and smoothing chokes for amateur, amplifier or experimental applications. Inductance values are measured under full load conditions and adequate insulation is provided for recommended service.

INPUT OR SWINGING CHOKES

Type No.	Cap. D.C. M.A.	Inductance Henries	D.C. Res. Ohms	Volts Insulation	Mtg. Fig.	Amateur Net Price
T-19C39	150	5-20	215	3000	2F	$1.95
T-19C35	200	5-20	130	3000	2D	2.40
T-19C36	300	5-20	105	5000	2D	3.90
T-19C37	400	5-20	90	5000	2J	6.00
T-19C38	500	5-20	75	5000	2J	8.40

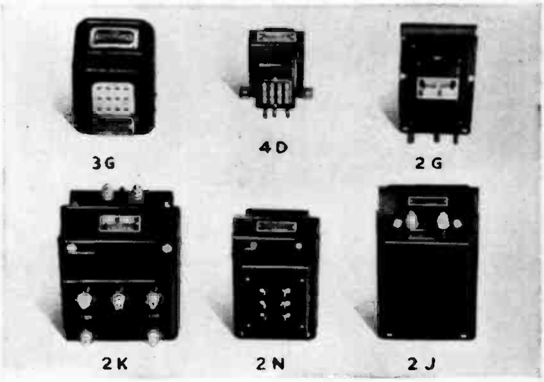
SMOOTHING CHOKES

T-19C46	150	12	215	3000	2F	$1.95
T-19C42	200	12	130	3000	2D	2.40
T-19C43	300	12	105	5000	2D	3.90
T-19C44	400	12	90	5000	2J	6.00
T-19C45	500	12	75	5000	2J	8.40

MULTI-MATCH MODULATION TRANSFORMERS
with Plug-in-Jack Terminal Board

The only modulation transformer built with this unique feature—see mounting figure 3G. Enables quick and accurate matching of tube loads without soldering. The experimenter is thus assured of peak transformer performance while testing new tubes or circuit changes.

Type No.	Cap. Watts	Pri. M.A. Per Side	Secondary M.A. Series	Secondary M.A. Par.	Amateur Net Price
T-11M74	40	100	80	160	$5.40
T-11M75	75	145	145	290	7.50
T-11M76	125	210	160	320	11.70
T-11M77	300	250	250	500	18.00
T-11M78	500	320	320	640	36.00



"19" SERIES PLATE SUPPLY TRANSFORMERS

These plate transformers are rated in D.C. voltages from a two section filter, including the voltage drop through the rectifier tubes. Designed especially for Amateur Short Wave or experimental equipment. Electrostatic shield between primary and secondary. Primary 115 volts 50-60 cycles. Listings below through T-19P69 are case style 2G. The balance are 2K.

Type No.	Sec. A.C. Load Volts	D.C. Volts	D.C. M.A.	Pri. V.A.	Amateur Price
T-19P54	560-0-560	400	150	115	$3.45
T-19P55	660-0-660 550-0-550	500* 400	250	200	4.50
T-19P56	900-0-900 800-0-800	750 600	225	260	4.80
T-19P57	1075-0-1075 507-0-507	1000** 400	125 150	245	6.00
T-19P58	1200-0-1200 900-0-900	1000** 750	200 150	500	7.80
T-19P69	1180-0-1180 900-0-900	1000 750	300	430	7.80
T-19P59	1560-0-1560 1250-0-1250	1250 1000	300	550	9.60
T-19P60	1875-0-1875 1560-0-1560	1500 1250	300	620	11.10
T-19P61	2125-0-2125 1875-0-1875	1750 1500	300	745	12.00
T-19P62	2420-0-2420 2125-0-2125	2000 1750	300	860	13.50
T-19P63	1560-0-1560 1265-0-1265	1250 1000	500	925	13.80
T-19P64	1875-0-1875 1560-0-1560	1500 1250	500	1130	17.10
T-19P65	3000-0-3000 2420-0-2420	2500 2000	300	1195	17.70
T-19P66	2125-0-2125 1875-0-1875	1750 1500	500	1185	21.00
T-19P67	2450-0-2450 2125-0-2125	2000 1750	500	1380	25.50
T-19P68	3000-0-3000 2450-0-2450	2500 2000	500	1760	30.00

*This transformer has a bias tap at 30V. **These transformers designed for double rectifiers and will deliver both secondary ratings simultaneously. If only the lower voltage taps are used the current rating is equal to the current rating of both windings.

COMBINATION PLATE AND FILAMENT
For Transmitter Application Mtg. Fig. 2G

T-19R30	560-0-560	400	150	$4.65

Filament Windings: 5V at 3A; 6.3V at 3A Ct.; 7.5V at 2.5A Ct.

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Good Engineering Practice

(Continued from Page 598)

Meter Specifications

All meters used in the final stage must have a minimum scale length of 2.3 inches and be accurate to two per cent of the full-scale reading. The maximum deflection must be such that the meters do not read off scale during modulation. No instrument, the accuracy of which is questionable or which has had its seal broken, should be employed.

Meters indicating plate voltage or plate current in the final r. f. stage must have a scale length of at least forty divisions. The full-scale reading must be not more than five times the minimum normal indication.

Antenna ammeters with *logarithmic* or *square law* scales should have a full-scale deflection not greater than three times the minimum normal indication. No scale division above one-third full scale (amperes) shall be greater than one-thirtieth of the full-scale reading.

Antenna ammeters with *expanded* scales should have a full-scale deflection not greater than five times the minimum normal indication. No scale division above one-fifth the full-scale reading (amperes) should be greater than one-fiftieth of the full-scale reading.

Tower Lighting and Painting

Where antenna masts and towers are high enough to constitute a hazard to aviation, they must be painted and illuminated. Each tower must be painted throughout its height with alternate bands of white and international orange (orange-yellow No. 5 of the color card supplement to the U. S. Army Q. M. C. Specifications No. 3-1) terminating with orange bands at both top and bottom. The width of the orange bands must be one-seventh of the height of the structure; the white bands, one-half the width of the orange ones. If the towers are over 250 feet high, bands should be from thirty to forty feet wide.

Specifications for lighting are issued by the Commission; details depend upon the degree of hazard presented by the particular installation.

Spare Equipment

A spare tube of every type employed in the transmitter and associated equipment must be kept on hand.

EL

"Radio"

Handbook

Edicion Espanol

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Editorial Pan America
Perú 677
Buenos Aires, Argentina

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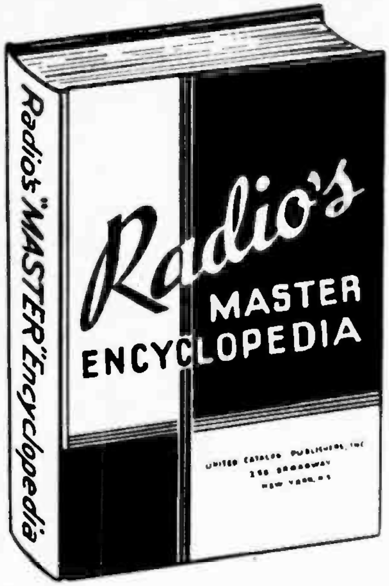

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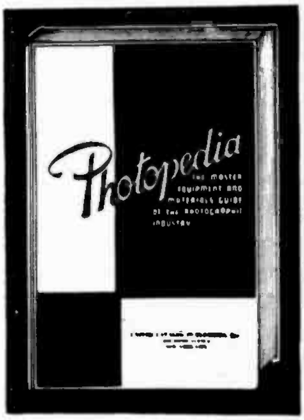

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Buyer's Guide

Parts Required for Building Equipment Shown in This Book

The parts listed are some of those actually used by "Radio's" laboratory in constructing the models shown. Other parts of equal merit and equivalent electrical characteristics may usually be substituted without materially affecting the performance of the units.

CHAPTER 6
RADIO RECEIVER CONSTRUCTION

Figure 3, page 135
Two-Tube Autodyne

C_1—Hammarlund SM-15
C_2—Hammarlund SM-100
C_3, C_5—Solar type MT
C_4, C_6—Solar "Sealdtite"
R_1—Centralab 710
R_2—Centralab "Radiohm"
R_3, R_4—Centralab 514
BC—Mallory 1.25 v.
CH_1—Stancor type C-2300
Panel—Bud PS1201
Tuning dial—Bud D-103B

Figure 7, page 138
Three-Tube Simple Super

C_1, C_2—Hammarlund MC-50-S
C_3—Hammarlund MC-140-S
C_4, C_8, C_{11}, C_{14}—Cornell-Dubilier DT-4P1
C_5, C_9—Cornell-Dubilier DT-4T1
C_6, C_7, C_{12}—Cornell-Dubilier DT-4S1
C_{10}—Cornell-Dubilier DT-4D1
C_{13}—Cornell-Dubilier BR-252
C_{15}—Cornell-Dubilier EDJ-9040
R_1, R_2, R_4, R_7, R_9—Centralab 516
R_3, R_5—Centralab 514
R_6—Yaxley L
R_8, R_{10}—Ohmite Brown Devil
IFT—Meissner 16-8092
CH—Stancor C-2300
J—Mallory-Yaxley 705
Dial—Crowe 123M

Figure 12, page 143
Super Gainer

C_1—Bud 833
C_2, C_{13}—Bud 913
C_3—Bud 900
C_4—Bud 905
R_3, R_5—Centralab "Radiohm"
Tubular condensers—Cornell-Dubilier "Shielded Mike"
Carbon resistors—Centralab 514
Dials—Crowe 296
IFT—Meissner 1600 kc. 16-8092

Figure 15, page 145
Six-Tube Super

Mica by-passes—Sprague type FM
Tubular by-passes—Sprague type TC
C_{11}, C_{12}—Sprague "Atoms"
T_1, T_2—Meissner 16-8096
T_3—Meissner 17-8175
Tubes—RCA
T_5—Stancor P-4076
CH—Stancor C-1003
C_1, C_2—Bud MC-913
C_3—Bud MC-323
C_4—Bud MC-905
R_6, R_{11}, R_{17}—Mallory-Yaxley Standard Universal
Dial—Bud D-103-B

Figure 20, page 148
Advanced Bandswitching Receiver

C_1, C_2, C_3—Hammarlund MC-35-S
C_4, C_5, C_6, C_7, C_{14}, C_{15}, C_{17}, C_{22}, C_{33}—Solar MW
C_8, C_9, C_{11}, C_{12}, C_{16}, C_{18}, C_{19}, C_{20}, C_{21}, C_{23}, C_{24}, C_{29}, C_{30}, C_{35}—Solar S-0238
C_{10}, C_{13}—Solar S-0228
C_{25}, C_{27}, C_{28}—Solar S-0219
C_{26}—Solar M-010
C_{31}, C_{32}—Solar DBB-669
C_{34}—Hammarlund SM-15
C_{36}—Meissner 22-7028
C_{1A}, C_{2A}, C_{1B}, C_{2B}—Hammarlund CTS
C_{1C}, C_{2C}—Hammarlund MEX
C_{3A}—Hammarlund APC-100
C_{3B}—Hammarlund APC-75
C_{3C}—Hammarlund APC-50
R_1 to R_{10}, inclusive, R_{13}, R_{16}, R_{18} to R_{22}, inclusive, R_{24} to R_{30}, inclusive, R_{32}, R_{33}, R_{36}, R_{38}—IRC BT-½
R_{11}, R_{12}—Mallory-Yaxley E
R_{14}, R_{34}, R_{35}—IRC AB
R_{15}—Mallory-Yaxley C1MP
R_{17}—IRC BT-2
R_{23}—Mallory-Yaxley E12
R_{31}—Mallory-Yaxley N
R_{37}—Mallory-Yaxley Y10MP
T_1—Meissner 16-8091
T_2, T_3, T_4—Meissner 16-8095
T_5—Meissner 16-5728
T_6—Meissner 16-5730
T_7—Meissner 17-6747
Shield cans for T_5, T_6—Meissner 25-8272
S_1—From Centralab "Switchkit"
S_2, S_3—Mallory-Yaxley 8
S_4—Centralab 1461
S_5—Centralab 1462
S_6—Mallory-Yaxley 6-9
S_7—Centralab 1460
Tubes—RCA
Dial—Crowe 525
Control Knobs—Meissner 25-8222

Figure 21, page 152
Power Supply for Advanced Receiver

T—Stancor P-6014
CH_1, CH_2—Stancor C-1001
C_1, C_2—Solar DA-0616
R—IRC DG

Figure 22, page 154
Superselective Phone Receiver

C_1, C_6, C_{25}—One Bud type 886
C_2—Hammarlund APC-25
C_{26}—Hammarlund SM-25
Potentiometers—Yaxley Universal
Wirewound resistors—Ohmite
Carbon resistors—Centralab

Tubular condensers—Cornell-Dubilier "Dwarf Tiger"
T_1, T_2—Meissner 16-6123
Tuning dial—Crowe type 296
RFC—Hammarlund CH-X
Tubes—RCA

Figure 30, page 159
Compact Long-Wave Receiver

C_1, C_4, C_5, C_9, C_{10}, C_{11}, C_{13}—Solar "Sealdtite"
C_2, C_3—Meissner 21-5216
C_{12}—Solar MO-25
C_{14}, C_{15}, C_{16}—Solar "Minicap"
C_{17}—Solar S-0283
R_1, R_2—Mallory-Yaxley "MR"
Vibrator—Mallory 501-P
T—Thordarson 14-R-34
CH—Thordarson T-13-C-27

Figure 34, page 161
UHF R/C Superhet

C_1—Hammarlund HF-15
L_1—Ohmite Z1
L_2—Hammarlund RFC-85
Mica condensers—Cornell-Dubilier type 1W or 5W
Tubular condensers—Cornell-Dubilier type DT
Tuning dial—Bud type D-103-B
R_2, R_3—Mallory-Yaxley Standard Universal
Tubes—RCA

Figure 37, page 164
High Gain Preselector

C_1, C_2—Bud type 903
Cabinet—Bud 870
Coil sockets—Hammarlund S5
Tuning dial—Crowe 124
Tubular condensers—Cornell-Dubilier "Dwarf Tiger"
Shaft coupling—Bud 795
Tube—RCA

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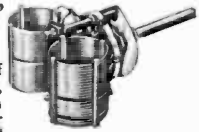

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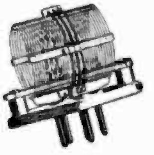

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Figure 40, page 167
6SA7 Mobile Converter

C_1, C_3—Cardwell ER-15-AD
C_2—Hammarlund MEX
C_4—Hammarlund APC
C_7—Mallory type BB-60
C_8—Meissner 22-7002
C_9—Mallory BB-15
L_3—Meissner 14-1006
R_1, R_2—IRC type BT
Tuning dial—Crowe 180

Figure 42, page 168
Five and Ten Meter Converter

L_1—Meissner 14-1006
C_1, C_2—Rebuilt Cardwell ER-25-AD, see text
C_3, C_9—Cornell-Dubilier 1W-5S1
C_4, C_5—Cornell-Dubilier 5W-5T5
C_6—Meissner 22-7002
C_7—Hammarlund APC-25
C_8—Hammarlund HF-15
C_{10}—Cornell-Dubilier EDJ-9080
R_1, R_5—IRC BT-½
R_2, R_3, R_4—IRC BT-1
Chassis and cabinets—Bud 870-A
Tubes—RCA

Figure 44, page 171
DeLuxe 10-Meter Converter

C_1, C_2—Bud 1641
C_3—Bud 1642
C_4, C_5—Meissner 22-5255
C_6—Bud 1673
C_7, C_8, C_9, C_{10}, C_{11}—Solar MP-4143
C_{12}, C_{14}, C_{15}—Solar S-0238
C_{13}—Solar MW-1216
R_1, R_2, R_3, R_4, R_6, R_7—IRC BT-1
R_5—Ohmite Brown Devil
L_4—Meissner 22-7002
S_1—Mallory-Yaxley 3242-J
Tubes—RCA
Dial—Crowe 123-M

CHAPTER 11
EXCITERS AND LOW POWERED TRANSMITTERS

Figures 2 and 3, page 281
One-Tube Exciter

C_1, C_6—Cardwell ZR-50-AS
C_2, C_3—Aerovox 1450
C_4, C_5, C_7—Aerovox 684

(Continued on Page 608)

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THE "STANDARD" INSTRUCTOGRAPH

The "Standard" as illustrated is strongly constructed, enclosed in an attractive case and is built for years of usefulness. Ten tapes and the book of instructions are supplied with this machine. Can be furnished either with an electric 110 volt 60 cycle AC motor or a spring wound motor. Priced $25.50 for the electric motor and $18.50 for the spring wound motor. These prices are delivered to any point in the United States or possessions. $1.00 additional to points in foreign countries. May be purchased on convenient monthly payments if desired.

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The "Junior" operates just as efficiently as the larger machine and also comes in an attractive case. The difference being mainly in size and construction. Five tapes and the book of instructions are supplied with this machine. Priced $12.00 delivered to any point in the United States or possessions, and $13.00 to points in foreign countries. Sold on easy monthly payments if desired.

RENTAL PROPOSITION

The "Standard" machine only is used in Rental service and rentals apply only to the United States proper. Instructograph, 10 tapes and book of instructions: For the 110 volt 60 cycle AC motor; First month $3.50, each additional month $2.75. For the Spring wound motor; First month: $3.00 each additional month $2.25.

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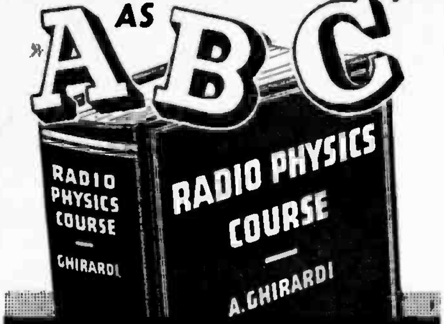

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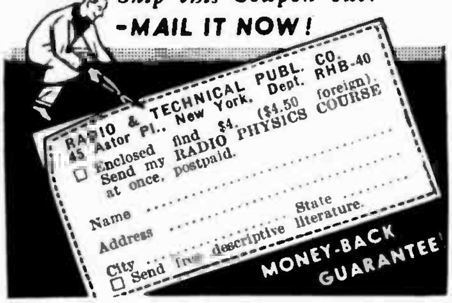

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CH_1, CH_2—Stancor C1421
Tube—RCA

Figure 18, page 298
"421" Exciter

C_1, C_2, C_3—Bud type 903
C_4—Bud type 912
C_N—Meissner 22-5255
Mica by-pass condensers—Solar MW
Coil D—Barker & Williamson type BVL
R_1, R_3, R_5, R[illegible]—Ohmite Brown Devil
S_1—Mallory 3223-J
M_1, M_2—Triplett 227-A
RFC_1—Bud 920
RFC_2—Bud 876
42's—RCA
T21's—Taylor
X—Bliley B-5

Figure 19, page 299
"421" Power Supply

T_1—Kenyon type T-246
T_2—Kenyon T-376
CH_1—Kenyon T-512
CH_2—Kenyon T-166
C_1, C_2—Sprague CR-46
R—Ohmite Brown Devil

Figure 24, page 302
814 Bandswitching Exciter

R_4, R_7, R_{14}—Ohmite "Brown Devil"
R_{13}, PC—Ohmite P-300
C_1—Cardwell EU-140-AD
C_2—Cardwell EU-100-AD
C_3—Cardwell MT-100-GS
C_4 to C_{13}—Solar MO and MW
C_{14}—Solar XM-25-22
C_{15}—Cardwell JD-50-OS
M_1, M_2—Triplett 227-A
T_1—Kenyon T-351
T_2—Kenyon T-365
Coil turret—Barker & Williamson type 2-A
S_1—Centralab 1461
S_2—Centralab 1460
S_3—Heintz & Kaufman 892
S_4—Mallory-Yaxley 151-L
Crystals—Bliley B5 and LD2
Tubes—RCA

CHAPTER 12
MEDIUM AND HIGH POWER AMPLIFIERS

Figures 1 and 2, pages 306 and 307
Breadboard P.P. 35-T's

C_1—Cardwell MT-70-GD
C_2—Cardwell XG-50-KD
Tank coils—Decker Mfg. Co.
Tubes—Eimac 35T's

Figures 1 and 3, pages 306 and 308
Breadboard 810's

C_1—Cardwell MT-100-GD
C_2—Cardwell XG-50-KD
C_3, C_4—Aerovox 1450
NC—Bud 1519
RFC—BUD 568
R_1—Ohmite 0577
Grid coil form—Bud 594
Tubes—RCA 810's

Figures 1 and 5, pages 306 and 310
Rack Mounted HK54's

C_1—Cardwell MT-70-GD

(Continued on Page 612)

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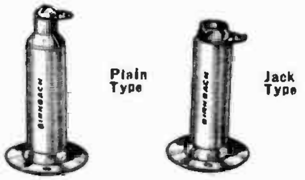
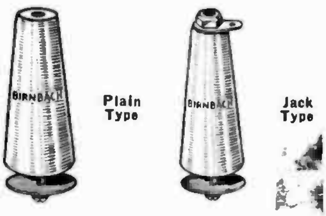
* STEATITE PILLARS



No.	Hgt.	Dia.	List Price	No.	Hgt.	Dia.	List Price
450	1"	½"	$ .25	450J	1"	½"	$.30
451	1½"	½"	.30	451J	1½"	½"	.35
452	2½"	½"	.35	452J	2½"	½"	.40
453	2½"	¾"	.90	453J	2½"	¾"	1.00
454	4"	¾"	1.10	454J	4"	¾"	1.20

CONE INSULATORS



No.	Hgt.	List Price	No.	Hgt.	List Price
430	⅝"	$.10	431J	1"	$.20
431	1"	.15	432J	1½"	.25
432	1½"	.20	433J	2¾"	.50
433	2¾"	.25			

* STEATITE BUTTON

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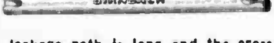
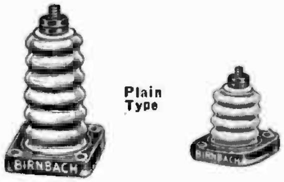


The leakage path is long and the cross section as small as consistent with the strength required and has a smooth white glaze overall.

No.	Length	List Price
470	7"	$.50
471	12"	.70

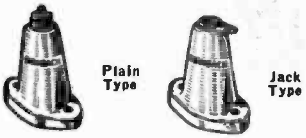
* METAL BASE INSULATORS



These metal base insulators are designed to eliminate breakage due to mounting. They have long leakage paths and are made of glazed low absorption porcelain.

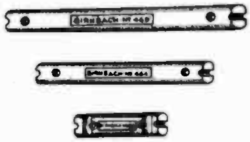
No.	Hgt.	List Price	No.	Hgt.	List Price
867	1⅜"	$.18	867J	1⅜"	$.23
4176	2¾"	.34	4176J	2¾"	.46
4451	4½"	.50	4451J	4½"	.65

STANDOFF INSULATORS



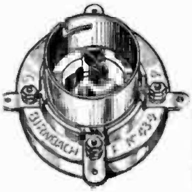
No.	Hgt.	List Price	No.	Hgt.	List Price
405	⅝"	$.06½	966J	1"	$.10
966	1"	.07½	866J	1½"	.15
866	1½"	.12	866SJ	1½"	.35
4275	2¾"	.30	4275J	2¾"	.55
4450	4½"	.50	4450J	4½"	.75

FEEDER SPREADERS



No.	Length	List Price
462	2"	$.12
464	4"	.15
469	6"	.20

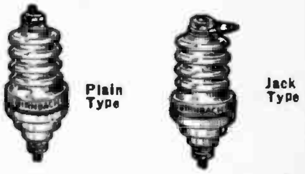
SOCKETS



They have double wiping phosphor bronze springs and nickel-plated brass shells. Bases of highly vitrified low absorption porcelain.

No.		List Price
434	50 watt	$1.25
435	10 watt	.85

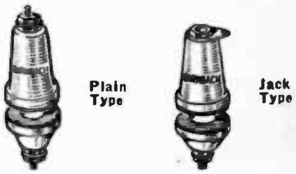
* CORRUGATED FEEDTHRU



These corrugated Feedthrus are designed to have a long leakage path and high surface insulation. They are made of highly vitrified porcelain with a smooth glaze.

No.	Hgt.	List Price	No.	Hgt.	List Price
479	1⅜"	$.35	479J	1⅜"	$.40
4276	2¾"	.65	4276J	2¾"	.80
4452	4½"	.95	4452J	4½"	1.10

FEEDTHRU INSULATORS



No.	Hgt.	List Price	No.	Hgt.	List Price
458	⅝"	$.12	478J	1"	$.25
478	1"	.20	4125J	1¼"	.30
4125	1¼"	.25	4175J	2¾"	.75
4234	2¾"	.55			
4175	2¾"	.50			

LEADIN INSULATORS

Each cone is 2¾" high and is made of low absorption, highly vitrified glazed porcelain. All brass nickel-plated hardware and lead and cork washers are used.

No.	Length	List Price
4235	10"	$.90
4236	15"	1.00
4237	10"	1.20
4238	15"	1.50

other BIRNBACH PRODUCTS

JACKS AND PLUGS
FLEXIBLE SHAFTS
FLEXIBLE COUPLINGS
EO1 *(GENUINE)* CABLE
INSULATED AND METAL
PIN TIP JACKS AND PLUGS
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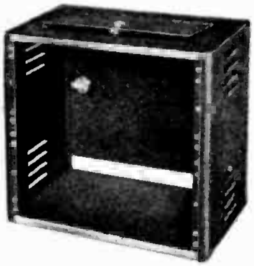
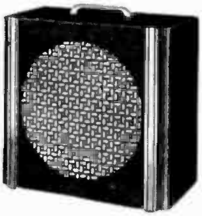




C_2—Cardwell XG-50-KD
C_3, C_4—Hammarlund N-10
Tank coils—Decker Mfg. Co.
Tubes—Heintz & Kaufman HK54's

Figures 1, 6 and 7, pages 306 and 311
"Accordion Coil" Amplifier

C_1—Hammarlund MCD-35-MX
C_2—Eimac vacuum type
T—Thordarson T-74-F23
Fil. meter—Triplett 237
Tubes—Eimac
R_1—Ohmite 50W

CHAPTER 13
SPEECH AND MODULATION EQUIPMENT

Figure 2, page 316
25-Watt Modulator

Tubular condensers—Aerovox 484
C_2, C_6—Aerovox PRS450 12 µfd.
C_3—Aerovox 1467 mica
C_5, C_7—Aerovox PB-10-10 25 volt
C_9—Aerovox 600-LU 4 µfd.
C_{10}—Aerovox GL-475 8 µfd.
Carbon resistors—Centralab 1 watt
Wirewound resistors—Ohmite "Brown Devil"
R_5—Mallory-Yaxley M control
T_1—Stancor A-4721
T_2—Stancor A-3892
T_3—Stancor P-3005
CH—Stancor C-1001
Bias cell—Mallory-Yaxley
Tubes—RCA

Figure 5, page 319
60-Watt T-21 Modulator

C_1, C_4—Solar S-0240
C_2—Solar S-0215
C_3, C_7—Solar S-0263
C_{13}-C_{14}, C_5-C_{15}—Solar LC5 8-8
C_{11}, C_{12}—Solar M116
C_8—Solar M010
R_1—Centralab 72-116
All ½-watt resistors—Centralab 710
All 1-watt resistors—Centralab 714
R_{15}, R_{16}, R_{21}—Centralab 516
R_{17}, R_{18}, R_{19}, R_{20}—Ohmite "Brown Devil"
BC—Mallory-Yaxley Bias Cell
T_1—Thordarson T-84D59
T_2—Thordarson T-11M75
T_3—Thordarson T-79F84
T_4—Thordarson T-84P60
CH_1—Thordarson T-75C49
CH_2—Thordarson T-75C51
CH_3—Thordarson T-68C07
Tubes—RCA 6J5, 6L7, 83, 45. Taylor T-21

Figure 9, page 322
6-Watt 6L6 Grid Modulator

C_1, C_4, C_7—Cornell-Dubilier EDJ-3100
C_2, C_8, C_9—Cornell-Dubilier BR-845
C_3—Cornell-Dubilier DT-681
C_5—Cornell-Dubilier DT-4P1
C_6—Cornell-Dubilier SM-6S5
1-watt resistors—Centralab 714
½-watt resistors—Centralab 710
R_{12}, R_{13}, R_{14}—Ohmite "Brown Devils"
R_6—Centralab 72-105 potentiometer
T_1—Stancor A-4406
T_2—Stancor P-3005
CH—Stancor C-1421

(Continued on Page 614)

RADIO SUPPLY'S

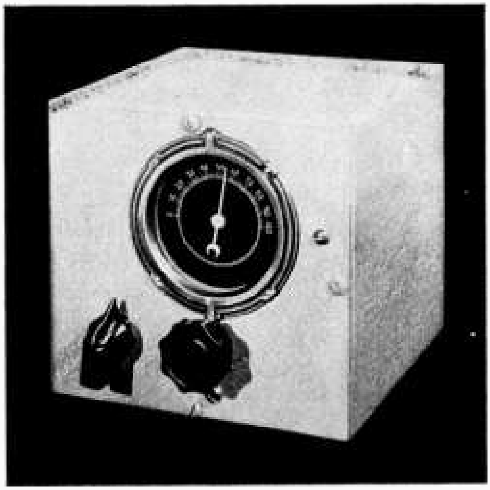
famous "X" Kits

—FIRST WITH LATEST—

RADIO SUPPLY places its entire facilities at the disposal of the amateur radio field. For this reason it is able to offer quality merchandise in the radio trade at a price reasonable to all.

The famous "Gonsett Converter" (XCI) has made a name for itself during the past year as being one of the most sensational pieces of radio equipment ever offered the amateur.

We use only first grade parts and thus the purchaser is assured of utmost performance.



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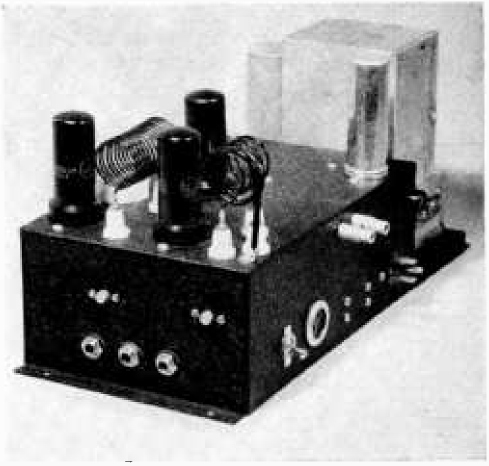
"XCI"
—THE TALK OF HAMDOM—

"XCI" complete kit	*$9.95*
6K8 tube	*.90*
Total	*$10.85*
Wired and tested	*$4.00*
Complete ready to operate	*$14.85*
"XMI" complete kit	*$18.50*
Tubes for same	*3.15*
Mallory Vibropak	*11.10*
Total	*$32.75*
Wired and tested	*12.50*
Complete, ready to go	*$45.25*



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Feed-thru insulators—Bud I-436
Chassis—Bud CB-1194
Pilot light—Mallory-Yaxley 310R
Tubes—RCA

Figure 11, page 324
Push-Pull 2A3 Amplifier-Driver

C_1, C_3, C_5—Aerovox 484
C_2, C_6—Aerovox PBS-25 10
C_4, C_7—Aerovox PBS-5 8-8
C_8 C_9—Aerovox WG-5 8
R_1, R_2, R_3, R_4—Centralab 710
R_5—Centralab 72-105
R_6—Centralab 710
R_7, R_8—Ohmite Brown Devil
Input trans.—Stancor A-82-C
T Stancor P-4049
CH—Stancor C-1421
Tubes—RCA

Figure 13, page 325
Class B 809 Modulator

T_1—Stancor A-4762
T_2—Stancor A-3894
T_3—Stancor P-3064
M—Triplett no. 221A
Tubes—RCA

Figure 14, page 325
8-Watt A.C.-D.C. Amplifier

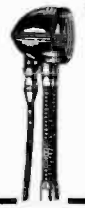
C_1—Aerovox MM50
C_2, C_4—Solar TT-35
C_3, C_5, C_6, C_9—Solar type S
C_7, C_8—Solar TT-36
C_{10}, C_{11}, C_{12}, C_{13}—Aerovox GLS-250
R_1 to R_6 incl.—Centralab 510
R_7—Centralab 72-105
R_8 to R_{12} incl.—Centralab 510
R_{13}—Ohmite "Brown Devil"
R_{14}, R_{15}—Centralab 510
R_{16}—Centralab 514
Tubes—RCA

Figure 17, page 327
TZ-40 Modulator

T_1—Thordarson 81D42
T_2—Thordarson 15D79
T_3—Thordarson 11M77
T_4—Thordarson 70R62
T_5—Thordarson 16F13
CH_1—Thordarson 74C29
CH_2—Thordarson 13C28
All tubular condensers—Cornell-Dubilier DT
All filter condensers—Cornell-Dubilier EDJ
Tubes—RCA. TZ-40's Taylor

Figure 21, page 332
203Z Modulator

All tubular condensers—Cornell-Dubilier DT
All resistors—I.R.C. BT-½ and BT-1
R_7—Mallory-Yaxley O control
R_{14}—Mallory-Yaxley Y50MP
T_1—Thordarson T-57A41



T_2—Thordarson T-75D10
T_3—Thordarson T-11M77
T_4—Thordarson T-19F96
M—Triplett 221A
203Z—Taylor

CHAPTER 14
POWER SUPPLIES

Figure 13, page 344
Voltage Regulated Supply

T—Kenyon T-206
CH—Kenyon T-154
C_1, C_2—Sprague type TC
C_3, C_4—Sprague UT-16
R_3—Centralab W-32

Figure 25, page 348
350-Volt Power Supply

T—Thordarson T-13R14
CH—Thordarson T68C07
C—Cornell Dubilier EH-9808
R—Ohmite Brown Devil

Figure 26, page 348
550-Volt Power Supply

Transformers and Chokes—Thordarson "19" type
Filter Condensers—Cornell Dubilier TLA-6040

Figure 27, page 349
250-Volt Bias Pack

T—Stancor P-4078
CH—Stancor C-1355
C—Solar type D-800
R—Ohmite "Dividohm"

Figure 29, page 350
850-Volt Power Supply

T_1—Kenyon T-668
T_2—Kenyon T-360
CH—Kenyon T-512
C—Aerovox 1005
R—Ohmite "Brown Devil"
Tubes—Taylor

Figure 31, page 352
High Voltage Power Supply

Transformers—Thordarson CHT
Chokes—Thordarson CHT
Condensers—Aerovox

CHAPTER 15
TRANSMITTER CONSTRUCTION

Figure 3, page 362
TZ40 250-Watt Amplifier

R_1, R_3, R_5—Ohmite "Brown Devil"
C_1—Bud 903
C_2—Bud 911
C_3—Bud 1533
C_4, C_5, C_6, C_8, C_9, C_{10}, C_{12}, C_{13}—Cornell-Dubilier "DT"
RFC_1, RFC_2—Bud 920
RFC_3—Bud 876
M_1, M_2—Triplett 227-A
L_4—Bud type MCL
TZ40's—Taylor
6L6's—RCA
X—Bliley VF-1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THE "400"

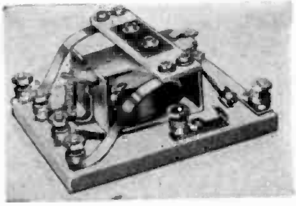

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Figure 9, page 368
35-T Cathode-Modulated Phone

Carbon resistors—Centralab Insulated
Wirewound resistors—Ohmite "Brown Devil" and "Dividohm"
R_{19}, R_{31}—Mallory-Yaxley Standard Universal
C_3—Bud 903
C_4, C_5, C_9, C_{10}—Cornell-Dubilier type 9
C_6—Bud type 1540
C_7—Bud type NC-890
C_{11}—Bud type 1559
C_{12}—Bud types 780 and 781
C_{15}—Mallory-Yaxley TX808
T_1—Thordarson T-70R78
T_2—Thordarson T-19F83
T_3—Thordarson T-19F90
T_4—Thordarson T-19P60
T_5—Thordarson T-70R62
T_6—Thordarson T-19F84
T_7—Thordarson T-17S15
CH_1—Thordarson T-16C07
CH_2, CH_3—Thordarson T-75C51
CH_4—Thordarson T-17C00-B
35T's—Eitel McCullough
Other tubes——RCA
X—Bliley type VF-1
RFC_1 to RFC_4—Bud type 920
RFC_5—Bud type 568
Cabinet, chassis and panels—Bud

Figure 21, page 376
400-Watt Phone Transmitter

All variable condensers—Bud
All mica fixed condensers—Cornell-Dubilier type 9
All paper by-pass condensers—Solar Domino
Electrolytic condensers—Mallory-Yaxley
Ceramic sockets—Hammarlund type S
All wirewound resistors—Ohmite
All carbon resistors—Centralab insulated type
Tubes—Heintz & Kaufman HK254's or Eimac 100TH's, Heintz & Kaufman HK54 or Eimac 35T, Taylor 203Z's. All others RCA
RFC—Bud type 920
RFC_1—Bud type 569
R_{13}, R_{21}—Yaxley universal type
Tuning dials—Bud type 165
Coil Forms—Bud type 126
C_{33}, C_{34}, C_{35}—Mallory oil type
All a.f. and power transformers and chokes—Thordarson
Crystal—Bliley LD2 or B5

CHAPTER 16
U.H.F. AND MOBILE COMMUNICATION

Figure 5, page 386
2½-Meter 10-Watt Transmitter

T_1—Thordarson type T-86A02
T_2—Thordarson T-17M59
T_3—Thordarson T-70R62
CH—Thordarson T-57C53
C_1—Cornell-Dubilier type EDJ2250
C_2,C_3—Cornell-Dubilier EH 9808 (one)
R_1, R_2, R_3—Centralab 514
R_4, R_5—Centralab 516
Tubes—RCA
M—Triplett 221

Figure 9, page 388
35-T Concentric Pipe Oscillator

C_1—Solar type MW
C_2, C_3—Solar type XM-6
C_4—Solar type XM-25
C_5—Bud 567

R—Ohmite "Brown Devil"
35-T—Eimac
Ceramic socket—Hammarlund S-4

Figure 13, page 390
5-Meter C.C. Transmitter

C_1, C_2, C_4—Cornell-Dubilier type W
C_3, C_5—Hammarlund MC-20-S
C_6—Cornell-Dubilier type 9
RFC—Hammarlund type CHX
R_1, R_2—Centralab 516
Crystal—Bliley HF2
Tubes—RCA
M—Triplett 221

Figure 16, page 392
56-Mc. Transmitter Exciter

C_1, C_2—Solar MP-4119
C_3—Cardwell ZU-75-AS
C_4—Solar MW-1239
C_5—Solar MW-1216
C_6—Solar MW-1210
C_7—Cardwell ZR-50-AS
C_8, C_{10}, C_{11}, C_{13}—Solar MW-1227
C_9—Solar MW-1233
C_{12}—Cardwell ZT-15-AS
R_1, R_4, R_7—IRC "BT"
R_2, R_5, R_6—Ohmite Brown Devil
RFC—Bud 920
Crystal—Bliley B-5
Tubes—RCA 6L6, Taylor T21

Figure 18, page 395
125-Watt Amplifier

C_1—Cardwell ET-30-ADI
C_2—Cardwell NP-35-ND
R_1—Ohmite Brown Devil
J_1, J_2—Yaxley 702
RFC—Ohmite Z-1
T—Thordarson, T-19F98
Sockets—Hammarlund S-4
Tubes—Heintz & Kaufman type 24's
Bar knobs—Crowe

Figure 20, page 396
HK54 U.H.F. Amplifier

C_1—Hammarlund MCD-35-MX
C_2—Aerovox 1467
R_1—Ohmite 25W
M_1, M_2—Triplett 321
T—Kenyon T-357

Figure 23, page 399
112-Mc. Transceiver

C_1—Cardwell ZR-10-AS with mounting bracket
C_2—Solar type MT
C_3, C_6—Solar type S-0256
C_4—Solar type S-0212
C_5—Solar type DT-879
C_7—Solar type S-0219
C_8—Solar type DJ-364
R_1, R_4, R_5, R_6—Centralab 516
R_2—Mallory-Yaxley "Universal"
R_3—Centralab 514
RFC—Ohmite type Z1
S_1—Mallory-Yaxley 3142-J
CH_1—Thordarson T-43C92
T_1—Thordarson A-3833

Figure 27, page 403
28-Mc. T21 Mobile Transmitter

Carbon resistors—Centralab 516

Fixed mica condensers—Solar MW
C_4, C_5—Hammarlund "APC"
C_{11}, C_{12}—Mallory FPD 410
C_{14}, C_{15}, C_{16}—Mallory FPB 410
Relay 1—Guardian series 115 single pole single throw
Relay 2—Guardian series 115 double pole double throw
C_9—Cardwell ZR25AS
CH_1, CH_2—Thordarson T-53C19
Vibrator packs—Mallory 552
X—Bliley B-5

CHAPTER 18
TEST AND MEASURING EQUIPMENT

Figure 5, page 489
Frequency Spotter

C_1, C_2—Hammarlund Star SM-100
C_4, C_5—Solar type MW
C_6, C_7—Solar type MP "Domino"
C_8, C_9 C_{10}—Solar type MW
C_{11}, C_{12}—Solar type MP "Domino"
C_{13}—Solar type MW
C_{14}, C_{15}—Solar D-820 electrolytic
R_1, R_2, R_3, R_4—IRC BT-1 and BT-2
R_5, R_6—Ohmite Brown Devil
S_1—Centralab 1465 switch
L_1—Meissner 17-6753 b.f.o. coil
T_1—Thordarson T-13R11

Figure 8, page 491
Dual Crystal Calibrator

X—Bliley SMC-100
L—Hammarlund CH-8
L_1—Hammarlund CH-X (altered)
C_1—Meissner 22-7002
C_2, C_3, C_4—Solar "Sealdtite"
C_6—Hammarlund SM-25
C_7, C_8—One Solar LGS-44
R_1 to R_5—IRC type BT
T—Thordarson T-13R01
Tubes—RCA

Figure 11, page 494
Frequency Standard

L, X—Bliley SOC100 crystal unit
All resistors—IRC insulated BT½-BT1
R_{12} R_{20}, R_{25}—IRC wirewound potentiometers
All mica and tubular condensers—Aerovox 1467 and 284
C_2—Meissner 21-5214
All tubes—RCA
Output jacks—General Radio type 274-J
C_{25}, C_{26}—Aerovox "Dandee" 40-μfd. midget electrolytic
C_{19}—Aerovox PR50 10 μfd.

Figure 14, page 497
Field Strength Meter

Variable condenser—Hammarlund "Star"
Coil form—Bud type 906
Tube—RCA

Figure 23, page 502
Frequency Meter-Monitor

C_1, C_2—Hammarlund MC-150-B
CH—Thordarson midget
C_{11}, C_{12}—Aerovox PBS type
Resistors—Centralab insulated type
Mica condensers—Cornell-Dubilier type W
Tubular condensers—Solar "Sealdtite"
Tubes—RCA

Figure 29, page 505
C.W. Monitor

C_2—Hammarlund SM-50
RFC—Hammarlund CH-X
S_1—Centralab selector type
R_1, R_2—Centralab
Tube—RCA
Dial—Bud D103B

Figure 32, page 507
Phone Test Set

S_1—Yaxley selector type
C_1—Bud type 906
Dial—Crowe type 292
Tube—RCA
M—Triplett 321

Figure 35, page 508
Ohmmeter

Resistors—Ohmite
Meter—Triplett 221
Switch—Mallory-Yaxley 3100-J

Figure 45, page 511
R.F. and A.F. Power Meter

R—Ohmite D-100
M—Weston 425

Figure 52, page 516
Cathode-Ray Modulation Checker

Resistors—Centralab carbon
T—Thordarson T-92R33
C_2—General Electric Pyranol type
R_2, R_3, R_7—Yaxley universal type
C_1—Solar "Domino"
Tubes—RCA

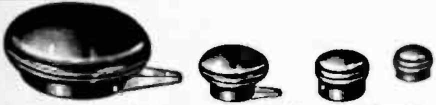
Figure 56, page 519
902 Oscilloscope with Sweep

R_6, R_{22}—Yaxley Y50MP
R_7—Yaxley UC506
R_{13}—Yaxley UC504
R_{20}—Yaxley Y500MP
R_{21}—Yaxley Y25MP
R_{29}, R_{30}—Yaxley Y100MP
All tubulars—Solar "Sealdtite"
Filter condensers—Solar DE908
SW_2—Yaxley 3215J
SW_4, SW_5—Yaxley 3234J
Resistors—IRC type BT
All tubes—RCA
T_1—Thordarson T-92R33

CHAPTER 20
RADIO THERAPY

Figure 3, page 534
200-Watt Portable Diathermy

C_2, C_3—Solar type
C_4—Cardwell MT-100-GS
C_5, C_7—Solar type
C_6—Solar type
R_1—Ohmite type
RFC_1—National R-154-U
RFC_2—National R-154-U
M—Triplett type 326
T_1—Thordarson T-74F23
T_2—Thordarson T-19P58
T_3—Thordarson T-19F90
Overload relay—Guardian
75-T's—Eitel McCullough
866's—Taylor



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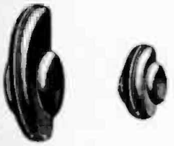
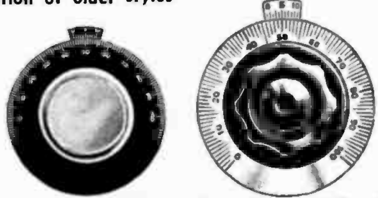
Crowe Call-Letter Transmitter Emblem. Illuminated from rear. Translucent letters—clear, no-glare visibility. Frame adjustable for 3, 4 or 5 characters. Adaptable to either panel or wall mounting.

NEW!
—Knobs in Colors
—Transmitter Dials
—Call-Letter Emblems
for the Amateur—
Experimenter—Set Builder



New Crowe Bar Knobs. Distinctive designs. Available in 3 colors—red, ivory and black.



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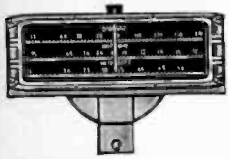

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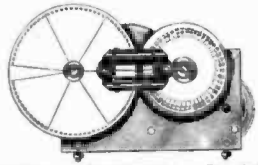

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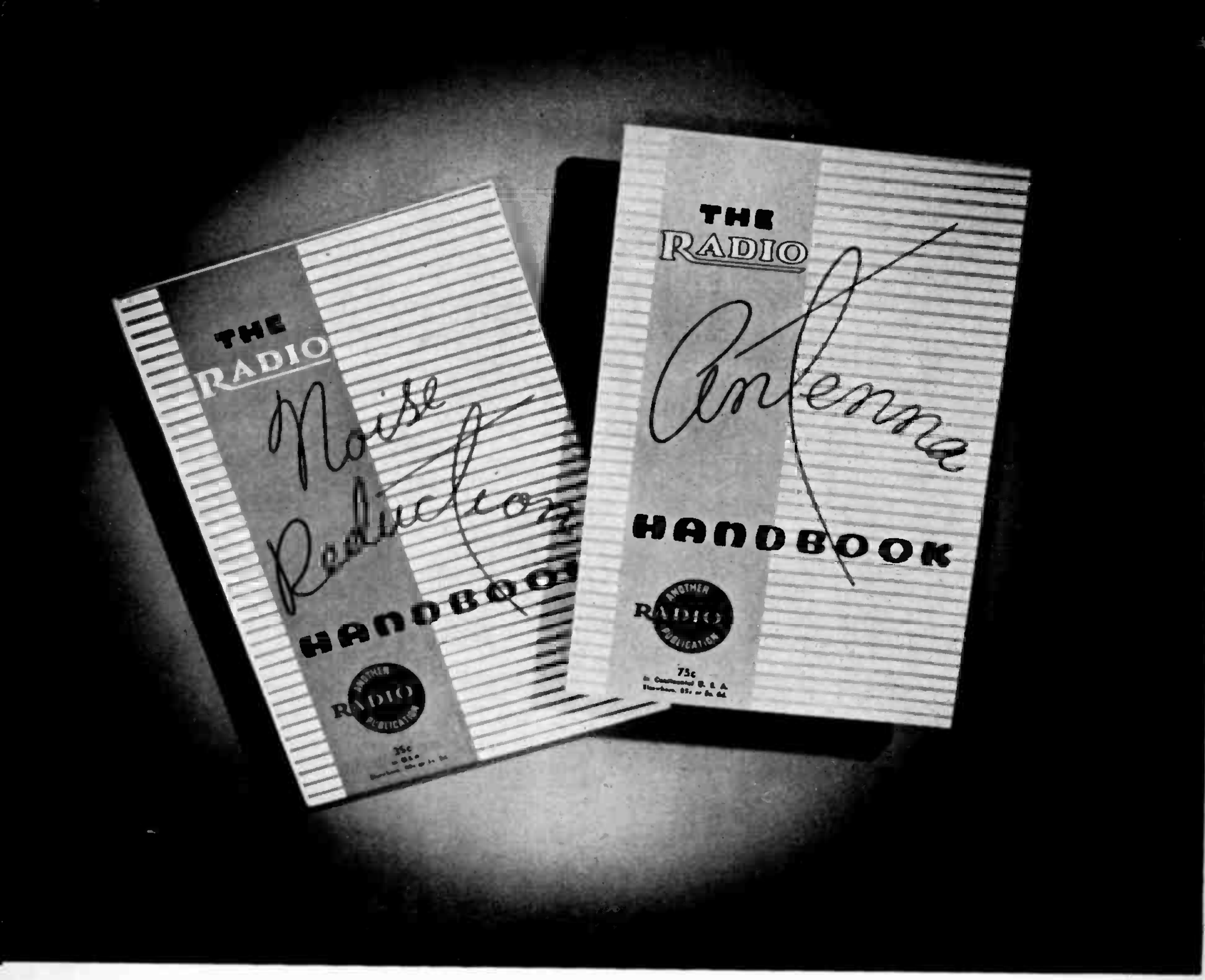

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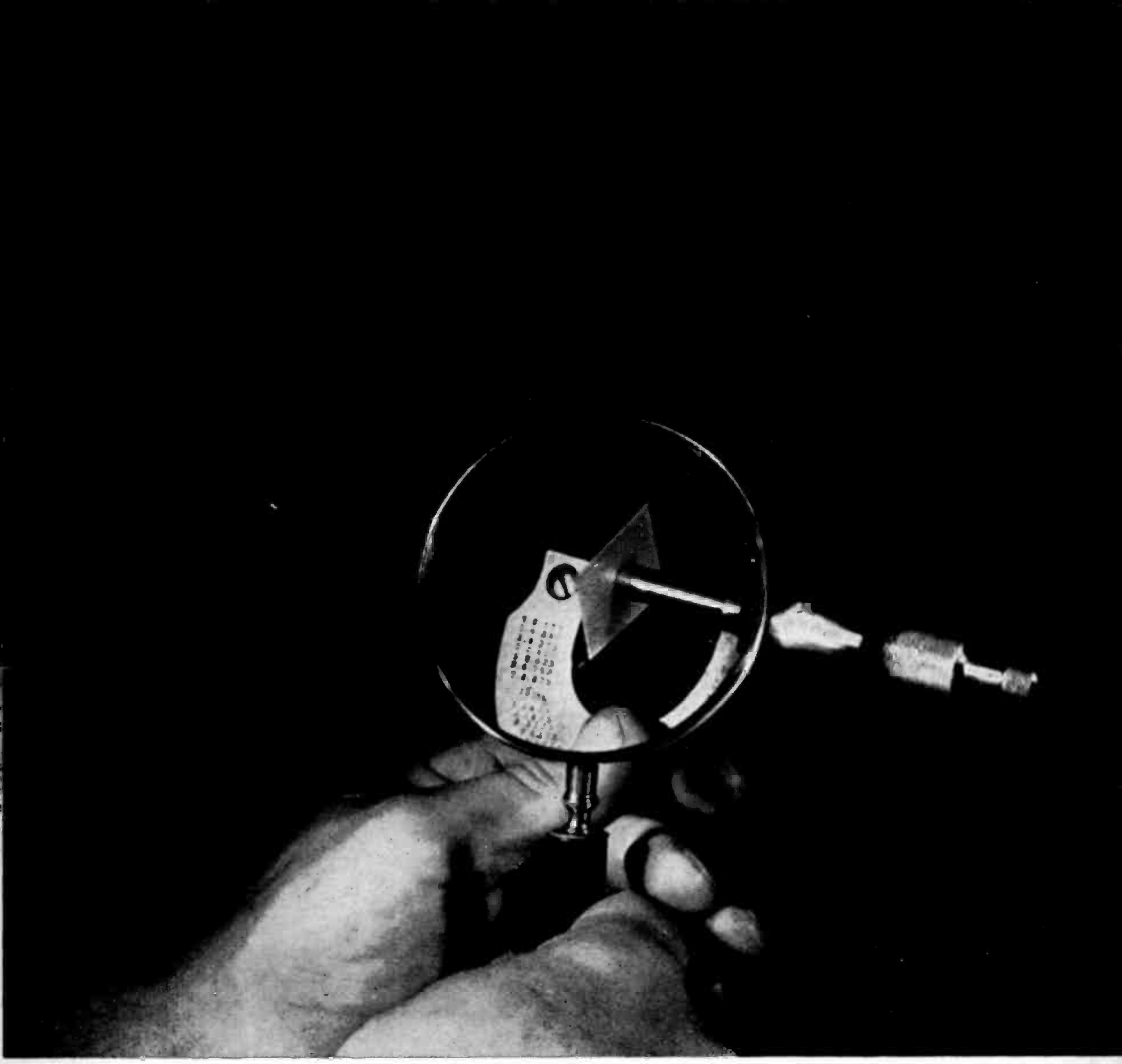

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