The RADIO AMATEUR'S HANDBOOK

A Manual of
Amateur High-Frequency
Radio Communication

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Published by
THE AMERICAN RADIO RELAY LEAGUE

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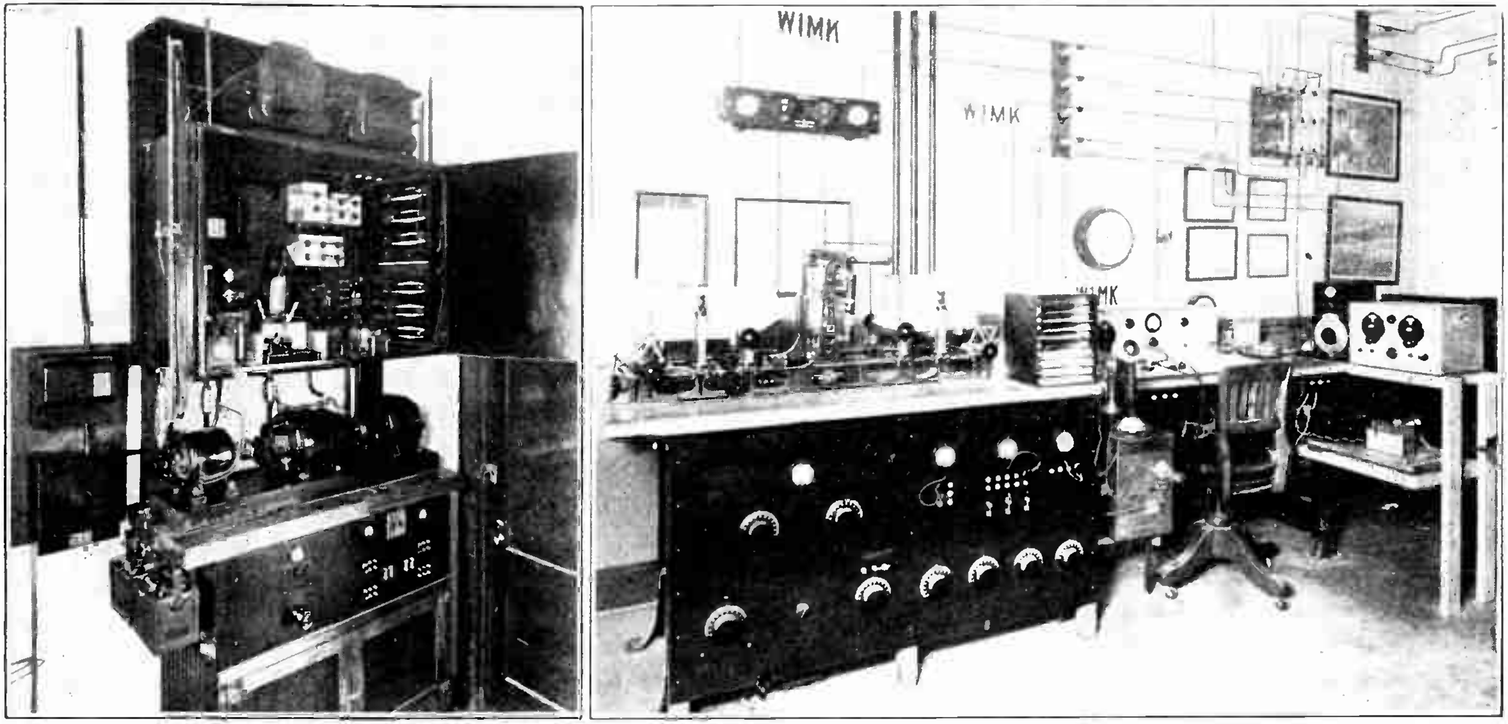

W1MK, THE HEADQUARTERS STATION OF THE A.R.R.L. AT HARTFORD, CONN.

These views of power supplies and operating position show good station arrangement. Note the neatness and accessibility of every piece of apparatus. High voltage d.c. is obtained from a motor-generator and a mercury-arc rectifier and filter, with facilities also available for using mercury-vapor rectifiers. Fuses, relays, batteries, and charging equipment are all in the power-supply room. The single-signal receiver is in front of the operator, key and controls at his right hand, message file box and telephone at his left. At his right side are monitor, electron-coupled frequency meter, and an automatic tape transmitter for sending Official Broadcasts to A.R.R.L. members. On the table is the 3500-4000-kc. band transmitter using two Type 04-A tubes in a self-excited T.P.T.G. circuit. The panel transmitter below works on the 7-mc. and 14-mc. bands. This is a controlled-temperature crystal-excited set terminating in a Type 61 tube. Two-wire voltage (Zeppelin) feed is used to separate antennas for the two transmitters, and a separate receiving antenna facilitate "break-in" work. W1MK is a busy station but is always ready for a call from any "ham." See page 17 for the schedule of regular transmissions of addressed information to A.R.R.L. members.

The
RADIO AMATEUR'S HANDBOOK

A Manual of Amateur High-Frequency Radio Communication

By

THE HEADQUARTERS STAFF
of the
AMERICAN RADIO RELAY LEAGUE

Tenth Edition

WEST HARTFORD, CONN.
THE AMERICAN RADIO RELAY LEAGUE, INC.
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FOREWORD

IN PRESENTING a tenth edition of *The Radio Amateur's Handbook* the publishers can only hope that it will be found as helpful as previous prints of this book and enjoy as wholehearted a reception at the hands of the amateur fraternity.

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

This book is made available by the American Radio Relay League, the radio amateur's own organization. Written by amateurs, for anyone and everyone interested in amateur work, it is hoped that it will continue to be a helpful manual to those active in amateur work and instrumental in assisting beginning and prospective amateurs to get into the game and get the maximum of enjoyment out of it by directing their efforts along the lines that bring results most quickly, surely and inexpensively.

In 1925 Mr. Francis Edward Handy, for many years the League's communication manager, commenced work on a small manual of amateur operating procedure, at the direction of the A.R.R.L. Executive Committee. It was deemed desirable to include a certain amount of "technical" information, since an amateur's results are so greatly influenced by the disposition and adjustment of his apparatus. When Mr. Handy completed his manuscript he had written a considerable-sized book of great value. It was published in 1926 and enjoyed an instant success. Produced in the familiar format of the League's magazine, *QST*, unusual as that is for a publication of this nature, it was possible to distribute for a very modest charge a work which in volume of subject-matter and profusity of illustration surpassed most available radio texts selling for several times its price — and which, because it was written by an eminently practical amateur, was of the greatest possible value as a guide to other amateurs. Three successive editions were revised by Mr. Handy as reprinting became necessary.

Throughout the year 1928 the League conducted a technical development program at its headquarters laboratory for the purpose of developing new apparatus and methods which would overcome the handicaps of reduced space in the radio spectrum which were to become effective upon the radio amateur at the beginning of 1929, by virtue of the then newly-signed international radio treaty. The modified technique and equipment which resulted from this technical development program naturally called for a complete revision of the technical chapters of the *Handbook*. Indeed, the rapid technical progress during that and the succeeding years demanded constant re-writing and revision of the technical material.

In the headquarters establishment of the League at West Hartford there are many technically skilled amateurs, each a specialist in his own field. It is only natural that the preparation of the technical chapters of the *Handbook* should have fallen into their hands and that the publication should have become the family affair which it now is.

To a total of fourteen printings the fame of the *Handbook* has echoed around the world. Its success has been really inspiring. Quantity orders have come from many a foreign land; schools and technical classes have adopted it as a text; but most important of all, it has become the right-hand guide of practical amateurs in every country on the globe. But amateur radio moves with amazing rapidity and the best practices of yesterday are quickly superseded by the developments of to-day. The very success of the book as a publication brings a new responsibility to us, the publishers — the *Handbook* must be kept up to date.

We present, then, a tenth edition, again modernized in the light of current amateur practice. The edition represents the collaboration of many members of the A.R.R.L. staff. Mr. Handy, our communications manager, has prepared the chapters on the A.R.R.L. Communications Department, on operating a station and on message handling. Mr. James J. Lamb, the technical editor of *QST*, is the author of the chapters on electrical and radio fundamentals. The opening chapter is from the pen of Mr. A. L. Budlong, the assistant secretary of the League. The ten chapters constituting the remainder of the book are the work of Mr. George Grammer, assistant technical editor of *QST*, and the undersigned.

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

ROSS A. HULL
EDITOR

WEST HARTFORD, January, 1933

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The Amateur's Code

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

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

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

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

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

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

THE RADIO AMATEUR'S HANDBOOK

Chapter One

THE STORY OF AMATEUR RADIO

AMATEUR radio to-day is an established institution. Thousands of people pursue it as a hobby; a powerful and prosperous organization bonds together these followers and protects their interests; an internationally-respected radio magazine is published solely for their benefit. The Army and Navy seek the coöperation of the amateur in developing communication reserves; the public depends on amateur services in major emergencies; the countries of the world recognize him as one of the established branches of the radio art and provide space on the air for him when writing up international radio treaties.

Thirty odd years ago amateur radio did not exist — the name, had it been used, would have meant nothing. All the development just mentioned, then, has taken place within the comparatively short time represented since the opening of the present century.

It is the purpose of this chapter to trace, briefly, this development.

Prior to the advent of radio telegraphy there existed a class of young fellows whose hobby centered around "electrical experiments." They built electric motors and wet cells to run them; they assembled Wimshurst static machines; they constructed backyard telegraph lines.

When Marconi announced that it was possible to send messages without wire and proved it by transmitting the letter "S" across the Atlantic Ocean, the older heads murmured in awe and consulted their "Bibles". Our youthful electrical experimenters, on the other hand, perceived immediately that here was something a hundred-fold more engrossing than "electricity." With one voice they asked, "How does he do it?" and with one purpose of mind they proceeded to find out for themselves.

So early in the radio picture, then, we see the beginning of *amateur* radio — the pursuit of radio, not as a business or means of profit, but as a hobby to be indulged during one's spare time for the love of the work and the pleasure it returns to the individual. It blossomed independently in the minds of hundreds of American youths and men who saw in the new scientific marvel a means for personal enjoyment and a new agency for personal inter-communication. Once begun, it grew and grew. Nothing has stopped it yet.

It is difficult to clamp a definite date on the beginning of any widespread movement, but we may regard the year 1901 as the one in which Amateur Radio received its start in this country.

▶For ten years progress was slow, crude and fraught with difficulties. There were few books on the subject, none of a popular nature. There were no radio magazines. Much of an amateur's transmitting and receiving equipment was homemade, of necessity, the glorious era of ten-cent-store radio being some twenty years in the future. Only a few concerns in the country carried radio equipment of any kind.

But progress was made and by 1912 ranges had increased to the point where the fellow with several kilowatts was sometimes heard three and four hundred miles, in favorable sections of the country. The average radio amateur, however, contented himself with more moderate distances, and used his set for the most part in conversing with friends on the other side of the city.

At this point it is well to remember that there was as yet no governmental regulation of any kind when it came to "wireless." Anyone who wanted to put a radio transmitter on the air — they were all sparks, of course — could do so. He could use any power he chose, assign himself a call of his own, pick his own wavelength (most amateurs at this time operated on wavelengths from 250 to as high as 800–1000 meters), and operate either as an amateur or a commercial when and as he pleased.

There were probably in the neighborhood of six hundred amateurs in active operation by the end of 1911, with the total naval and commercial stations coming to only some 25 per cent of this figure.

▶ The law came for the first time in 1912. Government representatives returned from an international radio meeting in London armed with detailed regulations to govern the newly-arrived industry and sundry announcements were immediately made to all amateurs as follows: Every amateur operator must henceforth take out a license for himself and his station. Amateurs would have to keep their power down to a maximum of one kilowatt. They could not operate above two hundred meters. Commercial and Navy stations now had definite rights, and their traffic was to be accorded priority. Official call letters would be issued to each station and were to be used by it when transmitting. A few special licenses would be issued to operate on 375 and 425 meters.

Initial alarm in the amateur ranks at these pronouncements was soon allayed when it was found by experiment that if the matters of obtaining licenses and of showing consideration to the commercial and government stations were complied with, observance of the other features was not particularly necessary. "Two hundred meters" would cover anything from 250 to 375. "One kilowatt" could be stretched to two without much fear of government admonishment. Regulation, in a word, was not accompanied by enforcement beyond the bare essentials, either in the amateur ranks or in any other branch of radio, in those first early days.

Under this happy state of affairs the amateur grew and prospered, and by the first part of 1914 had increased in number to about 2000. Except, however, for a slight increase in transmitting range to four or five hundred miles for the big fellows, and the use of audion bulbs — non-regenerative — by some of the more advanced stations for receiving detectors, the art remained in about the same state.

▶ In the early part of 1914, Hiram Percy Maxim, an ardent amateur in addition to being a world authority in the field of sound, desired to send an amateur radiogram from his home in Hartford, Connecticut, to another station in Springfield, Massachusetts. His own transmitter not having sufficient range to reach Springfield he conceived the idea of having it relayed by an intermediate station at Windsor Locks, Connecticut.

It was done.

Now it is not claimed that this in itself was unusual. Ships were using the relay principle to get messages from mid-ocean to shore with the assistance of other ships. It is reasonable to assume that amateurs themselves had previously relayed messages beyond the limits of their own particular sets.

The act itself, therefore, had no particular significance. The application of the act, however, had all the significance in the world. Maxim had for many months thought of starting a national amateur organization. He had not carried it further than the idea state because he could think of no prime moving force, no basic principle around which to rear the structure. Americans have always been great "joiners," but if an amateur organization were ever to progress beyond the paper stage it must offer something more than one's name on the rolls. In short, unless he could find something definite for such an organization to do, he could not justify its existence.

The morning after the Hartford-Springfield relay while his thoughts were harking back to the previous evening's success, the old ideas about the national organization wandered through his mind — something clicked — and the problem was solved!

For here, without a doubt, was the idea around which the organization could be successfully and strongly built. The missing block in the puzzle had been found and fitted. The organization would be a *relay* organization. It would have as its object the developing of relay routes over all the country among all the amateurs, so that by this means an amateur in one part of the country could send a message hundreds of miles to an amateur in another part; perhaps even send a message from one coast to another!

▶ Within a week, a name had suggested itself suitable for this new organization, and a month later it was decided to start the ball rolling. Witness, then, in May, 1914, H. P. Maxim and another Hartford amateur, C. D. Tuska, sitting down and writing a letter to each one of the amateurs listed at that time in the government call-book, announcing the formation of the *American Radio Relay League*, outlining its purposes, and soliciting membership. There were no dues; membership was free on application.

Response was immediate and enthusiastic. Applications came back in every mail. In the early summer of 1914 was issued the first publication of the American Radio Relay League — a little blue-bound call-book listing the names, addresses, calls, power, range, receiving speed and operating hours of three hundred League members. This sold for 50 cents.

By letter and radio the word was spread. Membership increased rapidly. In January, 1915, the League was incorporated under the laws of the State of Connecticut as a non-commercial organization with no capital stock. In March, 1915, a second call-book was issued, listing some six hundred members. In the meantime, through radio contacts and correspondence, attempts were being made to build up the relay routes for which the organization had been formed. Some success was being had in this line. In late summer of 1915, however, a serious difficulty loomed and demanded attention. It was proving a real task to acquaint the growing membership with the plans and schedules by means of letters only. Increasingly it became evident that a bulletin of some kind was necessary. The League, however, had no funds; membership was still free and the call-books were sold at cost.

What to do?

The answer came in December of 1915 when each member of the League received in his mail a sixteen-page magazine called *QST*. This, it was announced, was being published privately at the expense of Maxim and Tuska and was thenceforth to be the official publication of the League. League membership continued to be free. Any League member who wanted to get the magazine could have it by sending in $1.00 for a year's subscription.

Response was again immediate; *QST* continued, and, except for a period during the War, has since been published monthly as the official organ of the League. Since the War the League has owned it.

▶ Having now a journal in which to chronicle the activities of the membership, Amateur Radio rolled up its sleeves, hitched its belt and settled down to business. A member, discovering some new improvement for his apparatus, would write an article on the subject, and within a month everyone was benefiting by it. Manufacturers, invited to advertise, found a new and responsive field for their wares. Some of them began to manufacture apparatus peculiarly suited to amateur needs.

In February, 1916, occurred the first attempt at a nation-wide relay test when Kirwan, 9XE, of Davenport, Iowa, inaugurated the first Washington's Birthday Relay with a message from Col. W. P. Nicholson, of the Rock Island Arsenal, addressed to the governors of every State in the Union. The Pacific Coast got the message fifty-five minutes after it had been started at 9XE; the Atlantic Coast, sixty minutes after; New Orleans had it in twenty minutes and Canada had it in twenty minutes. The success of this test, though far from 100 per cent, created the greatest enthusiasm.

It was during the summer of this year, too, that Charles E. Apgar, an amateur at Westfield, N. J., copied on phonograph records all the transmissions of the supposedly neutrality-observing German radio station at Sayville, and thereby provided evidence for the Government to take it over.

As a fitting close to the year, two manufacturers brought out special amateur regenerative receivers — instruments which so marvelously increased the sensitivity and range of receiving apparatus that a transcontinental relay was immediately proposed.

▶ The year 1917 had no more than dawned when an amateur message did cross the country. On January 27th three messages were started from the station of the Seefred brothers, 6EA, on the Pacific Coast, and passing by quick jumps through three intermediate stations ended up at Maxim's station, 1ZM. But this accomplishment was almost immediately over-shadowed by a greater one. On February 6th a message was started from the East Coast, relayed to the West Coast, and an answer returned in the record time of one hour, twenty minutes!

In this same month an important change took place in the A.R.R.L. For nearly three years Maxim and Tuska had been acting as self-appointed president and secretary, respectively. By 1917 the League had grown to such an extent that a more business-like organization was deemed advisable. On February 28, 1917, then, a group of amateurs met at the call of Mr. Maxim in New York. When they dispersed, after a two-day session, they had written and adopted a constitution that outlined the policies of the League, specified the machinery for the election of officers, divided the country into six divisions, to be supervised by division managers and assistants, and had elected by vote twelve A.R.R.L. directors and four officers.

With a real organization now behind it, with transcontinental relays a reality, with manufacturers at last catering whole-heartedly to amateur wants, with the trunk lines beginning to move traffic regularly, with a report of a west coast station hearing an east coast station direct and with a League membership of nearly 4000, organized amateur radio in early 1917 was poised for tremendous strides in development.

▶ It was two years before those strides were taken, however.

For, coincidentally with its declaration of war on Germany in April, 1917, the United States Government placed a ban on the operation of all amateur apparatus. Amateur antennas were lowered; amateur transmitters were sealed; amateur receiving apparatus was ordered dismantled.

But wait a moment —

A representative of the Navy Department met with President Maxim and Vice-President Hebert in New York and requested the aid of the A.R.R.L. in enlisting its skilled relayers as radio instructors and operators for the duration of the war. The need, it was explained, was desperate; five hundred operators were needed immediately.

A last broadcast went out over the League's relay routes. Within ten days the Navy had its five hundred operators!

Thereafter, deprived of its basis of existence and steadily losing members to the armed forces of the United States, the League kept on as best it could for the benefit of those who were too old or too young to enlist and to bring the able-bodied members into the service. Everything possible was done to keep going. Hope was held out during the summer of 1917 that the war ban would not prevent experimental work with dummy antennas. It was a vain hope. Further orders were issued, strictly prohibiting the use of radio apparatus for any purpose whatsoever. The order was a death-blow. *QST* stopped publication with the issue of September, 1917, after having been run for several months at a loss.

The League closed its desk, locked the office, hung a "Not In" sign on the door knob, and went to war.

Before it was over, three thousand additional A.R.R.L. members had followed those first five hundred pioneers.

▶ The war ended on November 11, 1918. Eleven days later the old Board of Direction met in New York, authorized President Maxim to attend a hearing on a proposed radio bill in Washington, and adjourned after agreeing to meet again for the purpose of getting the League started.

In February, 1919, the Board met again and listened to a report by Vice-President Hebert on the condition of the League. This report stated that all membership dues had lapsed, and that there was but $33 in the treasury. It ended by recommending that if the League were reorganized, a paid secretary should be employed, and that *QST* should be bought from its owner, Mr. Tuska, and become the property of the League.

That Board had nerve and determination. On the first of March it again met, and voted to reorganize the League. Further, it voted to purchase *QST* for the A.R.R.L. The fact that there was only $33 in the treasury and that the purchase price of *QST*, including several months' unpaid printing bills, was close to $5000, did not deter it one whit. It appointed a committee to devise a financing plan, told them to go to it, and adjourned.

Before the month was up, another meeting was held, attended this time by several of the old members of the League temporarily in New York. It was immediately determined to advise as many former League members as could be reached of the reorganization plans. Orders were given to the secretary to print up a miniature two-page *QST* and send it out. When it was pointed out that to send out such a bulletin would cost nearly $100, the eleven men present stopped the meeting temporarily, dug down in their pockets, and in a few minutes had placed $100 on the table.

When they met two weeks later, applications were beginning to come in. It was voted to resume publication of *QST*, and K. B. Warner, formerly of Cairo, Illinois, was elected the paid secretary of the League.

On May 3, 1919, the Board again met to listen to a plan proposed by the Finance Committee. Briefly, it was to borrow $7500 from former League members, issuing in return certificates of indebtedness payable in two years with interest at 5 per cent per annum. The proposal was approved. It was also voted to purchase *QST*. Secretary Warner was instructed to lay plans immediately for the first issue of the magazine.

In June the first post-war issue of *QST* was printed with money loaned for the purpose by the printer himself, and the A.R.R.L. bond issue was advertised to the members. It was stated that if the League were to continue, $7500 must be subscribed by the membership. No security could be offered — the League had no assets. The loan would be a loan on faith only.

Amateur spirit is a very wonderful thing. If you don't believe it, consider this: as one man the old League members subscribed to that bond issue. The League went on.

▶ The A.R.R.L.'s first job was to get the ban on transmitting lifted. Eight months had passed since the termination of hostilities but transmitting was still prohibited. The League sent protests, appeals and entreaties to Washington, but month dragged after weary month with no results. Amateur radio fumed, swore and turned to building long-wave receivers for diversion. It was a poor sop, at best.

October, 1919 — and the ban was lifted! An immediate headlong rush to get on the air took place. Manufacturers were hard put to supply apparatus fast enough. Each night saw additional dozens of stations joyously crashing out over the air.

Those who operated amateur stations during this period will never forget it. Every evening heard scores of distinctive notes booming and echoing from one end of the country to the other. It was a time of extreme competitive effort, pitched to the nervous tempo of post-war tension.

In all fairness, however, it must be chronicled that the interference was terrible!

▶ But it was an era of progress. Records were made and broken, and broken again. A message was relayed from Hartford to Los Angeles and an answer returned in 6½ minutes. 6ZK in California was heard in New York City. 9ZN in Chicago was heard in Panama. 2RK in New York was reported by a ship operator at Gibraltar. Relay routes grew over night; traffic mounted higher and higher. It became necessary to make the position of Traffic Manager a paid job. The League paid off its bonded indebtedness, and began to put money in the bank. An official emblem was adopted — the now-familiar diamond. At the request of Canadian amateurs, A.R.R.L. operating territory was extended to include Canada, and four Canadian divisions were created. The Bureau of Standards at Washington requested and secured the coöperation of League members in a nation-wide fading test. A convention was held in 1921, at Chicago, and was attended by four hundred amateurs from all over the United States.

▶ One of the principal characteristics of amateur radio is the rapidity with which current practice, regardless of how good it may be, is thrown aside — lock, stock and barrel — for something that is proved to be better. No more conclusive demonstration of this can be cited than the despatch with which tube (C.W.) transmission replaced spark transmission in the amateur stations of this country.

An undercurrent of C.W. experimentation began with the resumption of post-war transmission in 1919. It was confined to a small group for one very excellent reason: power tubes were not yet commercially available. Only a favored few were in a position to acquire government war-time tubes. The acquiring, it may be said, was done by devious methods.

Those experimenters made some highly interesting discoveries. C.W. traveled incredibly long distances with low power. It was sharp. It did not create vicious local interference. It cut through static.

Such decided advantages could not be overlooked. When power tubes became available commercially early in 1921, the A.R.R.L. started a campaign advocating the adoption of C.W. for amateur use. Conversion, at first, proved a slow process. The rank and file remained loyal to the spark pending what it considered definite proof of the superiority of the tube transmitter.

This proof, as we shall see, was not long forthcoming.

▶ In December, 1921, thirty American amateur stations were heard in Europe! It electrified the amateur world — but it was not an accident. All but three of those thirty stations were logged with American amateur equipment operated by an American amateur who had been sent to England at the expense of the League solely for that purpose. Not that we doubted the ability of our British cousins to do a good job on the receiving end, but — well, safety first. They had had little experience with 200 meters. So Paul Godley was sent over, and put up an antenna at the very edge of the sea on a bleak moor in Scotland. For ten bitter cold rainy days he made his home in a drafty tent with the receiving equipment, while every American amateur who could get a set on the air shot signals at him. When he dismantled his apparatus at the conclusion of the tests it had been demonstrated for all time that amateur signals on 200 meters could span the Atlantic.

Something else had been accomplished, too. More than two-thirds of the signals that got across were from C.W. stations. Here was an argument that could not be laughed off. The spark contingent thought it over, sighed resignedly, and began poring through catalogues of C.W. equipment. From that time on, the future of tube transmission was assured.

If further proof of the merits of C.W. were needed, another transatlantic test the following year supplied it. Three hundred and fifteen American calls were logged in Europe. What was more, one French and two British stations were heard on this side. Two-way communication with Europe loomed as a possibility.

Hardly had the year 1923 opened when, too, New Zealand amateurs reported logging stations from every district in the United States. In midsummer of the same year this news was eclipsed by reports from Australia that they were hearing many American amateur signals from all but the eastern districts, and coincident with these reports word came that several ships in Chinese and Japanese waters had logged West Coast amateurs.

▶ Inertia is more than a name in the physics text book and a factor in mechanical problems. It is something to be reckoned with in many lines of activity — including amateur radio.

When Marconi began his communication experiments he chose long wavelengths because spark apparatus was easier to handle at long wavelengths. Followed a natural inference on the part of the radio world: long waves are best. The 1912 London Conference fostered this belief by doling out the longest waves to the long-distance services. As wavelengths got down around 1000 meters, they were apportioned to services with more limited range requirements. When it came to our resulting United States law, the amateur was limited to a maximum of 200 meters. It was the firm conviction of most folks that this would effectually prevent him from getting out any farther than his backyard.

To a certain extent, then, the amateur must be forgiven if for the first twenty years of his existence he persisted in a belief that the only way to get DX was to boost the wave as high as possible. Even after the law made its appearance in 1912 the majority continued on the high side of 240 meters. Nor did the overwhelming success of the 1922 transatlantics suggest to the amateur world generally that there might be a catch in this matter of wavelength. The transatlantic success was a success in spite of the wavelength, and that was all there was to it. To-day we say it was indeed in spite of the wavelength, but we mean it differently.

As is always the case, however, the experimentally-minded class of amateur was at work, and was seriously interested in the business of determining the real value of the traditionally worthless wavelengths below 200 meters. It started in to find out. During the first part of 1922, *QST* carried an account of successful communication between Boston and Hartford on 130 meters. Results were excellent. Early in 1923, under the leadership of the League's technical staff, a systematic effort was made to determine the communications possibilities of wavelengths in the vicinity of 100 meters. Three separate transmitters in various parts of the country transmitted alternately on pre-arranged schedules, starting at 200 meters and going down in jumps of ten meters until 90 meters was reached. Listening stations recorded the results at various distances. In every case better signals were logged as the wavelength dropped, and articles on the possibilities of short-wave transmission began to appear in *QST*.

▶ On November 27, 1923, was accomplished the first amateur two-way work across the Atlantic, when Schnell, 1MO, and Reinartz, 1XAM, worked for several hours with 8AB, Deloy, in France! It was a great accomplishment, but the significant fact was this: all three stations used a wavelength in the vicinity of 110 meters.

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

In early 1924 the Hoover Radio Conference assigned amateurs bands at 20, 40 and 80 meters. It must be admitted that the move from 100 to 80 was made with misgivings by many. There was magic in 100! It speedily developed that there was just as much magic in 80 — perhaps a little more. Many other European countries were worked, two-way.

Thought turned to 40 meters. A pretty low wavelength, to be sure — but you never could tell about those short waves. What had worked once might work again. Forty was given a whirl, and responded instantly by enabling two-way communication with Australia, New Zealand and South Africa.

Surely this must stop somewhere! It stood to reason that 20 was too low for any use. But — it was given a try-out. No good? Almost immediately it showed undreamt-of possibilities by enabling an east coast station to work a west coast station direct at high noon. The dream of amateur radio — Daylight DX!

This capped the climax. Downward, ho! A year later, as far as the average amateur was concerned, a plugged cent would have bought the entire wavelength spectrum above 100 meters.

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

▶ It is usually difficult to conceive of improvement on the latest developments. The perspective, of course, is too close. Wherefore, each year in amateur radio sees some who are convinced that at last the ultimate has been reached, and that further improvement or development is impossible.

It was this class that decided there were no more worlds to conquer after spark had attained its peak of development in 1921. Yet, within a year, the introduction of tube transmission had opened unlimited fields for endeavor. C.W. development on 200 meters represented an "ultimate" until we uncovered the 100-meter region, and that in turn was regarded as a stopping point by the pessimists until the majority had shown what could be done with 80 meters, and 40, and 20. Twenty meters, at the present time, represents the lowest of the amateur wavelength assignments that is useful for DX communication purposes with any degree of dependability, but this has not kept enterprising amateurs from exploring the still higher frequencies. At the amateurs' own request, the international radio treaty of 1927 assigned them narrow bands in the vicinity of five and ten meters.

Five-meter experimentation in 1924 showed that band to be practically worthless for distance transmission; signals at those wavelengths could be heard only to "horizon range." But the amateur turns even these disadvantages to use; five-meter sets, particularly five-meter 'phone sets, are being built in increasing numbers for local rag-chewing and short-distance work, the comparative freedom from static and complete absence of out-of-town interference making them nearly ideal for this purpose. During 1931 and 1932 tremendous activity in five-meter work was manifested by thousands of amateurs all over the country, and a complete new line of transmitters and receivers developed to meet the special conditions incident to communicating at these ultra-high frequencies.

A belief that there are no more fields to conquer is merely proof of mental stagnation on the part of the believer. History alone furnishes us sufficient assurance of the fact that there will never be an "ultimate."

▶ Legislation has always been the arch enemy of the amateur. We have already seen that but for human erring on the part of the early lawmakers in 1912, the first encounter with this formidable antagonist would very likely have ended in virtual extinction.

Due to the intervention of the Great War, no further international threat was to be made until 1927. Meanwhile, however, plenty of trouble of this kind made itself felt within the borders of our own country. As the state of the art advanced, more and more attempts at radio legislation were fostered in Congress. Most of these in their original form were detrimental to the welfare of the amateur. To list the various bills and outline their histories would tire the reader and accomplish no useful end. Let this statement suffice: since the organization of the A.R.R.L. in 1914 there has never been presented in either House of Congress a single bill pertaining to radio legislation without the amateur cause being personally represented by one or more officers of the League.

A menace of another kind put in its appearance during 1926 and 1927. There appeared a tendency on the part of municipalities to create city ordinances restricting local amateur operation. For six months the League waged a battle in two States against the constitutionality of such ordinances, and in 1927 obtained a court opinion denying the right of municipalities to regulate or restrict amateur operation.

While the 1932 international radio congress just held at Madrid is probably foremost in the minds of amateurs, our greatest international legislative crisis — in fact, the greatest threat against amateur existence we have ever experienced — occurred five years before that in the fall of 1927, when world-delegates assembled in Washington for the first international radio gathering since the London conference of 1912. Such international meetings were supposed to be held every five years, but the Great War had caused their postponement. The Washington Conference was a critical one for the amateur. In 1912 he did not exist in sufficient numbers to be given consideration, from a world standpoint. In 1927 he did, but unfortunately our Government was practically the only one in the world that had actively sponsored amateur radio during the 15 years which had elapsed since London. Amateur representatives at the 1927 gathering, then, faced an overwhelming majority of hostile delegations — nations which not only did not wish to recognize the amateur but who, in many instances, wanted to see him forever ruled off the face of the earth. The short waves he had pioneered were proving very valuable for other purposes. Only sustained effort on the part of League representatives, backed by the consistent and splendid support of the United States and a few other friendly delegations, made it possible to emerge from that conference with the amateur privileges we enjoy to-day.

It must not be assumed that amateur radio is now past all legislative perils. It probably never will be.

The Madrid conference this past year developed spirited attacks on most of our Washington frequency allocations and on many of our general regulations and operating privileges. We know that our amateur representatives at these five-year conferences and at the smaller technical conferences held every two years must be prepared for continual attempts on the part of other interests to wrest territory from us or curtail our privileges.

But the fact above all others that is stressed with respect to the Washington Conference is that it resulted in the amateur, for the first time in history, being officially written into an international document and recognized as one of the classes entitled to space in the radio spectrum. Future international conferences may seek to restrict the amateur, but they cannot any longer deny his existence.

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

We have already seen 3500 amateurs contributing their skill and ability to the American cause in the Great War. After the war it was only natural that cordial relations should prevail between the Army and Navy and the amateur. Several things occurred in the next few years to strengthen these relations. In 1924, when the U. S. dirigible *Shenandoah* made a tour of the country, amateurs provided continuous contact between the big ship and the ground. In 1925, when the United States battle fleet made a cruise to Australia and the Navy wished to test out short-wave apparatus for future communication purposes, it was the League's Traffic Manager who was in complete charge of an experimental high-frequency set on the U. S. S. *Seattle*.

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

One of the most brilliant examples of amateur coöperation with the military was furnished in January of 1930 when, at the request of the War Department, League operators organized a communication net for contact with the "Arctic Patrol" flight of the Army's First Pursuit Group from Michigan to Spokane, Washington, and return. In 1931, when the Air Corps staged its spectacular movement of some 600 military aircraft, radio was an essential part of the maneuvers. Part of the movement involved a three-day mission over the New England area. Since the War Department's radio communication system did not maintain stations at any of the key cities where the Air Corps was to mobilize there, the A.R.R.L. was asked if it would organize a communication net of amateurs. It did so, and for the entire time during which the maneuvers were in New England, 24-hour 100%-effective communication was furnished by a network of amateur radio stations. Both this service and the "Arctic Patrol" incident elicited the highest praise from War Department and Air Corps officials.

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

Since 1919, amateur radio has been the principal, and in many cases the only, means of outside communication in more than thirty storm and flood emergencies in this country. The most noteworthy were the Florida hurricane of 1926, the Mississippi and New England floods of 1927, and the California dam break and second Florida hurricane in 1928. During 1931 there were the New Zealand and Nicaraguan earthquakes and the "Viking" explosion disaster in Labrador, and in 1932 the floods at Caliente, California and in the upper Guadelupe valley of Texas. In all of these amateur radio played a major rôle in the rescue work, and amateurs earned world-wide commendation for their resourcefulness in effecting communication where all other means failed.

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

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

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

When the Byrd Expedition went to the Antarctic, three of its four operators were amateurs, and amateur stations in the United States furnished a great part of the communication with this country.

Even in aviation the amateur contributes his services. Byrd utilized it in both his Arctic and Antarctic trips; Wilkins took along an amateur operator to the polar regions when he made his flights over the great wastes north of the American continent, and on both this and his Antarctic trip utilized communication with amateurs for the handling of traffic.

Service of a slightly different nature was furnished for the National Air Races at Los Angeles some years ago and for the past three years at Cleveland, when amateurs installed and operated the entire equipment necessary to maintain instantaneous communication between the judges' stand and the outlying pylons, checking planes in the races, reporting "down" planes, and furnishing immediate details of all fouls, etc.

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

▶ To-day the amateur's position is fixed forever in the radio world. He has a name for being a progressive, resourceful and capable type. He has a growing list of glorious accomplishments to his credit. He is, to-day, law-abiding to the extreme.

This outline of the growth of amateur radio has necessarily been brief. Yet we hope that through it all the reader has glimpsed that indefinite and elusive something which always has been and for all time will be an integral part of amateur radio, prized as one of its most cherished possessions — a something which casts aside all marks of rank, caste or creed and binds together amateurs the world over — a something which, for want of a better name, we call Amateur Spirit.

The American Radio Relay League

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

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

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

The president, vice-president, secretary, treasurer and communications manager of the League are elected or appointed by the Board of Directors. These officers constitute an Executive Committee to act in handling matters that come up between meetings of the Board, their authority subject to certain restrictions.

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

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

Headquarters

From the humble beginnings recounted in the story of amateur radio, League headquarters has grown until now it occupies an entire floor in a new office building and employs more than two dozen people.

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

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

W1MK

For many years it was the dream of the League's officers that some day Headquarters would be able to boast a real "he-station" and a permanent operator to run it. In 1928 this dream became an actuality, and the League to-day owns and operates the station shown in the frontispiece, operating under the call W1MK. The principal duty of one of the members of Headquarters is to operate this station day and night.

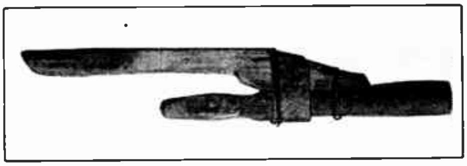
The current operating schedules of W1MK may be obtained by writing the Communications Department at Headquarters or by consulting the current issue of *QST*. While much of the operating time is devoted to pre-arranged schedules, the station is always ready at other times for a call from any amateur.

Traditions

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

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

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



THE WOUFF-HONG

It is now framed and hangs on the wall of the Secretary's office at A.R.R.L. Headquarters.

Joining the League

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

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

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

Chapter Two

GETTING STARTED

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

Amateur radio is a tremendously fascinating hobby. There is lasting enjoyment in its many varied angles and worth-while possibilities. There is the enduring satisfaction that comes from doing things with the apparatus put together by our own skill. The process of designing and constructing radio equipment develops real engineering ability. Operating an amateur station with even the simplest equipment likewise develops operating proficiency and skill. Many an engineer, operator or executive in the commercial radio field got his practical background and much of his training from his amateur work. So, in addition to the advantages of amateur radio as a hobby, the value of systematic amateur work to a student of almost every branch of radio cannot well be overlooked. An increasing number of radio services, each expanding in itself, require additional personnel, technicians, operators, inspectors, engineers and executives and in every field a background of amateur experience is regarded as valuable.

Amateur radio makes it possible to develop friendships with other men who have stations in every part of the U. S. A. and Canada, or for that matter it may be said that friendships in every part of the world follow two-way amateur communication. With a low-power station it is possible to communicate all over the world and to keep in touch with the hundreds of fellows who have equipment similar to your own. We do not mean to say that the first contacts are going to be with foreign amateurs. Experience in adjusting the simple transmitter, in using the right frequency band at the right time of day when foreign stations are on the air, and practice in operating are necessary before you will communicate with your first foreign station. But there is nothing difficult about it. High power is unnecessary in an amateur transmitter. Simple transmitters using one or more receiving-type tubes are being used by dozens of amateurs every day to communicate with every continent on the globe.

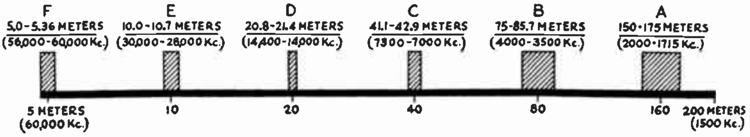
A high-frequency (short-wave) receiver alone will bring you hours of pleasure and will repay the little effort necessary to assemble it. Sooner or later, however, it is probable that you will build yourself either a radiotelephone or radiotelegraph transmitter. While many amateurs build 'phone transmitters,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

There is nothing difficult incident to taking your place in the ranks of licensed amateurs. The necessary steps are first, to learn the code, second, to build a receiver and a transmitter and third to get your amateur licenses and go on the air. Don't let any of these worry you. Thousands of men and women between the ages of 15 and 60 have mastered the code without difficulty by the exercise of a little patience and perseverance and these same thousands have found it an easy matter to pass the government examination for amateur operator license (there is no examination for amateur station license). We will treat of both of these subjects in detail later in this chapter.

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

Our Amateur Bands

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



RELATIVE POSITION AND WIDTH OF THE AMATEUR BANDS IN THE HIGH-FREQUENCY SPECTRUM

(There is also a band from 400 to 401 Mc., not shown in this drawing)

Sandwiched in among all these services are the amateurs, thousands of whose signals may be heard every night in the various bands set apart by International Treaty for amateur operation. These bands are in approximate harmonic relation to each other; their position in the short wave spectrum and their relative widths are shown in the sketch. Incidentally, while for the benefit of the newcomer to amateur radio we have designated these bands both by their wavelength and their frequency, the reader will do well to learn as quickly as possible to learn to talk in terms of *frequency*, rather than wavelength.

Many factors have to be considered in picking a certain frequency band for a certain job, especially the distance and the time of day when communication is desired. But in addition to daily changes, there are seasonal changes, and in addition a long-time change in atmospheric conditions which seems to coincide closely with the cycle of sun-spot or solar activity which is completed approximately each eleven years. The reliability of communication on a given frequency at a given time of day, the suitability of a given band for traffic or DX, the desires of the individual amateur in choosing his circle of friends with whom he expects to make contact on schedule, the amount of interference to be expected at certain hours, and the time of day available for operating — all influence the choice of an operating frequency. Many amateurs can use any one of the several available frequency bands at will. Let us now discuss briefly the properties peculiar to each of them.

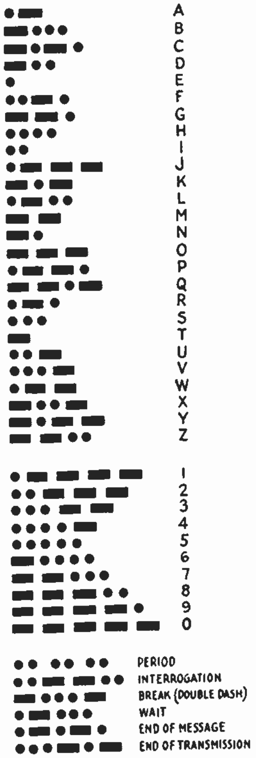
The 1750-kc. band, which carried all our activity before our experimenters opened the way to each of the higher frequency bands in turn, always served amateurs well for general contact between points all over the country. There was a short period, during the height of development of the higher frequencies, when activity in this band dwindled, but it is now again greatly on the increase.

The band is popular especially for radio-telephone work. The very fact that it is less congested and occupied makes it an extremely attractive band for the amateur operator who would communicate effectively and avoid interference. Code practice transmissions are made in this band for beginning amateurs and many beginners may be heard in this region making their first two-way contact with each other. The band is one of our "widest" from the standpoint of the number of stations that may be comfortably accommodated. In the next year or so, it may be expected to take more of the present properties of the 3500-kc. region, and its use by amateurs continue to increase. The band is open to amateur television and picture-transmission. If you are just getting on the air, plan to use this band. If you have been working on higher frequencies, include this band in your plans for 1933 and 1934 — or you will be missing an important part of amateur radio.

The 3500-kc. band has, in recent years, been regarded as best for all consistent domestic communication. It is good for coast-to-coast work at night all the year except for a few summer months. It has been recommended for all amateur message-handling over medium distances (1,000 miles for example). Much of the friendly human contact between amateurs takes place in the 3500-kc. band. It is the band from which we have made excursions to the higher frequencies on occasions when foreign contacts were desired. During the last year or so this band has exhibited some of its former DX properties, signals from amateur stations in this country being reported from South Africa, New Zealand and other remote points, and 'phone signals heard in Europe. As the winter evening advances, the well-known "skip effect" (explained in detail in Chap. Four) of the higher frequencies has made itself known, the increased range of the "sky wave" brings in signals from the other coast and the increased range also brings in *more* stations, so that the band appears busier. Apparently we are in a transition period, and it is just a matter of time to find a return to international DX working in the 3500-kc. band.

The 7000-kc. band has been the most popular band for general amateur DX work for some years. It is useful mainly at night for contacts with the opposite coast, or with foreign countries. Power output does not limit the range of a station to the same extent as when working on the lower frequency bands discussed above. However, the band is more handicapped by congestion in the early evenings and more subject to the vagaries of skip-effect and uncertain transmission conditions than are the lower frequency bands, but not limited in usefulness by these things to the same extent as the 14-mc. band. The 7000-kc. band is satisfactory for working distances of several hundred miles in daylight. It is generally considered the most desirable night band for general DX work in spite of difficulties due to interference. This band may be expected to take on better daylight DX characteristics in the next few years if predictions based on the sun-spot cycle are correct, and at the same time, while great possibilities will exist for evening work, it is likely to be more inconsistent and unreliable during the late evenings.

The 14,000-kc. or 14-mc. band is the very best frequency to use to cover great distances in daylight. In fact it is the *only* band generally useful for daylight DX contacts (QSO's) over coast-to-coast and greater distances. Communication over long distances will usually remain good during the early evenings and surprising results can be obtained then, too. Using these higher frequencies there is often difficulty in talking with stations within three or four hundred miles, while greater distances than this (and very short distances within ten or twenty miles of a station) can be covered with ease. The reason that 14-mc. signals are less useful for general amateur DX late evenings is because the "skip" increases during darkness until the "sky wave" covers greater than earthly distances. The band, while one of the very best for the amateur interested in working foreign stations without much difficulty from domestic interference, is sometimes subject to sudden fluctuations in transmitting conditions, and this characteristic will become more important perhaps as we return to the general conditions for radio communication that obtained back in 1923 and 1924, a condition now estimated to be due by 1934 or 1935.



THE CONTINENTAL CODE

The 28,000-kc. (28-mc.) band, opened for amateur work by the Federal Radio Commission in early 1928 at the request of the A.R.R.L. is principally an experimental band at the present time. It combines both the long-distance characteristics of the 14-mc. band and some of the local advantages of the 56-mc. band, but its long-distance characteristics are generally too "spotty" for reliable communication. The result is that few amateurs to-day operate in this territory, though it is probable that more attention will be given to its short-distance properties as the 56-mc. band fills up.

The 56,000-kc. or 56-mc. band, likewise made available for amateur experimentation at the request of the League, is strictly a local and short-distance band, but as such possesses many advantages. For distances of ten to thirty miles (and occasionally more, depending on the height of the apparatus) it is ideal; the apparatus is cheap, easily constructed, and extremely compact; operation is marked by freedom from interference and fading. The result has been a tremendous interest in this band by amateurs during the past year and a half, and hundreds of stations are now operating there with keen enjoyment.

Memorizing the Code

The first job you should tackle is the business of *memorizing* the code. This can be done while you are building your receiver. Thus, by the time the receiver is finished, you will know all the characters for the alphabet, the most-used punctuation marks, and the numerals, and will be ready to practice receiving in order to acquire speed. Speed practice, either by means of a buzzer, or by listening in on your receiver, can be indulged in in odd moments while the transmitter, in turn, is being constructed. The net result of such an organized program should be that by the time the transmitter is finished you will be able to receive the ten words a minute required by the government for your amateur operator license, and can immediately proceed to your license examination without loss of time.

Memorizing the code is no job at all if you simply make up your mind you are going to apply yourself to the job and get it over with as quickly as possible. The alphabet, numerals and punctuation marks are shown in the table given here. Start by memorizing the alphabet, forgetting the numerals and punctuation marks for the present. Various "trick" systems of learning the code have been suggested from time to time, but the job is really such a simple one that there is probably no better way to do than to take the first five letters, memorize them, then the next five, and so on. As you progress you should review all the letters learned up to that time, of course. When you have memorized the alphabet you can go to the numerals, which will come very quickly since you can see that they follow a definite system. The punctuation marks wind up the schedule — and be sure to learn them, too.

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

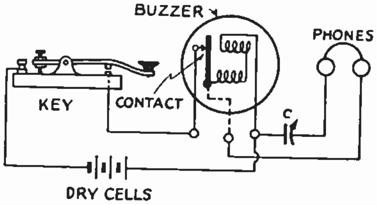
Don't think about speed yet. Your first job is simply to memorize all the characters and make sure you know them without hesitation. Good practice can be obtained, while building the receiver, if you try to spell out in code the names of the various parts you are working on at the time.

Acquiring Speed by Buzzer Practice

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

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

Another good practice set for two people learning the code with each other is that using an old audio transformer, a type 01-A tube (although almost any three-element receiving tube will work), a pair of 'phones, key, three No. 6 dry cells, tube-socket, and a 20- to 50-ohm filament rheostat. These are hooked up as shown in the diagram to form an audio oscillator. Since the "B" supply to the tube comes from the "A" battery it is important that the A-battery polarity be just as shown or the outfit will not work. If nothing is heard in the 'phones when the key is depressed, reverse the leads going to the two binding posts at either transformer winding. Reversing both sets of leads will have no effect.

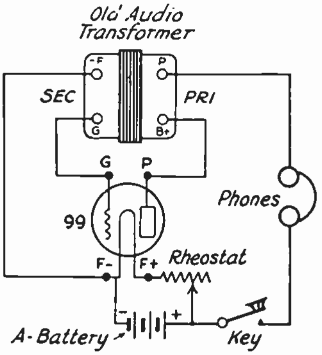


CONNECTIONS OF A BUZZER CODE PRACTICE SET WITH A TELEPHONE HEAD SET

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

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

After the practice set has been built, and another operator's help secured, practice sending turn and turn about to each other. Send single letters at first, the listener learning to recognize each character quickly, without hesitation. Following this, start slow sending of complete words and sentences, always trying to have the material sent at just a little faster rate than you can copy easily; this speeds up your mind. Write down each letter you recognize. Do *not* try to write down the dots and dashes; write down the letters. Don't stop to compare the sounds of different letters, or think too long about a letter or word that has been missed. Go right on to the next one or each "miss" will cause you to lose several characters you might otherwise have gotten. If you exercise a little patience you will soon be getting every character, and in a surprisingly short time will be receiving at a good rate of speed. When you think you can receive ten words a minute (50 letters a minute) have the sender transmit code groups rather than straight English text. This will prevent you from recognizing a word "on the way" and filling it in before you've really listened to the letters themselves.



CONNECTING AN AUDIO OSCILLATOR (HARTLEY) FOR CODE PRACTICE WORK

Learning by Listening

While it is very nice to be able to get the help of another person in sending to you while you are acquiring code-speed, it is not always possible to be so fortunate, and some other method of acquiring speed must be resorted to. Under such circumstances, the time-honored system is to "learn by listening" on your short-wave receiver. Nor should you make the mistake of assuming that this is a more difficult and less-preferred method: it is probable that the *majority* of amateurs acquire their code speed by this method.

With even the simplest of short-wave receivers a number of high-power stations can be heard in every part of the world. Many commercial high-frequency stations send on frequencies above 3,000 kilocycles and can be copied with the simple receivers described in this book. Formerly it was considered necessary to construct special low-frequency receivers to get code practice. To-day, however, there are powerful trans-ocean stations in operation on high frequencies. Many of them use tape transmission. The sending is perfectly regular. Often words are repeated twice. Both understandable English and secret code (most excellent for code practice) are used in the text of the messages. These stations send at speeds depending on the reception conditions at the time of transmission. It is usually possible to pick a station going at about the desired speed for code practice.

After building a receiver and getting it in operation, the first step in "learning by listening" will be to hunt for a station sending slowly. Listen to see if you cannot recognize some individual letters. Use paper and pencil and write down the letters as you hear them. Try to copy as many letters as you can.

Whenever you hear a letter that you know, write it down. Keep everlastingly at it. *Twenty minutes or half an hour is long enough for one session.* This practice may be repeated several times a day. Don't become discouraged. Soon you will copy without missing so many letters. Then you will begin to get calls, which are repeated several times, and whole words like "and" and "the." After words will come sentences. You now know the code and your speed will improve slowly with practice. Learning by this method may seem harder to some folks than learning with the buzzer. It is the opinion of the writer, who learned in this way, that the practice in copying actual signals and having real difficulties with interference, static, and fading, is far superior to that obtained by routine buzzer practice. Of course the use of a buzzer is of value at first in getting familiar with the alphabet.

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

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

Volunteer Code Practice Stations

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

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

Interpreting What We Hear

As soon as we finish our receiver and hook it up we shall begin to pick up different high-frequency stations, some of them perhaps in the bands of frequency assigned to amateurs, others perhaps commercial stations belonging to different services. The loudest signals will not necessarily be those from near-by stations. Depending on transmitting conditions which vary with the frequency, the distance and the time of day, remote stations may or may not be louder than relatively near-by stations.

The first letters we identify probably will be the call signals identifying the stations called and the calling stations, if the stations are in the amateur bands. Station calls are assigned by the government, prefixed by a letter (W in the United States, VE in Canada, G in England, etc.) indicating the country. In this country amateur calls will be made up of such combinations as W9GP, W8CMP, W3BZ, W1MK, etc., the number indicating the amateur call area (see map) and giving a general idea of the part of the country in which the station heard is located. The reader is referred to the chapter on "Operating a Station" for complete information on the procedure amateurs use in calling, handling messages, and the like. Many abbreviations are used which will be made clear by reference to the tables of Q Code, miscellaneous abbreviations, and "ham" abbreviations included in the Appendix. The table of international prefixes, also in the back of the book, will help to identify the country where amateur and commercial stations are located.

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

U. S. AMATEUR CALL AREAS

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

LCO and *LCD* in the prefix of commercial messages refer to the text as being "language of country of origin" or "language of country of delivery." *RP* means "reply prepaid." Also the prefix often shows the class of traffic and the station to whom the message is going. The low-frequency commercial stations number messages periodically. Ship and shore stations start a new series of message numbers each day and with each new station worked. The commercial stations use "de" for an intermediate. Army and naval stations will be observed to use "v" in place of the "de."

The communication laws specify that a call shall be made by sending the call letters of the station called three times, the intermediate "de" (meaning *from*) once, and following this with the call letters of the calling station three times. The full form of a call is like the following, "GBR GBR GBR de CKA CKA CKA." The answer, "CKA CKA de GBR K," signifies that GBR is ready for traffic.

Commercial traffic is classed as "ordinary"; "deferred"; "urgent"; and "rush." "Ordinary" messages have a straight prefix. *P* in the prefix of a message indicates that it is "paid" or "personal" traffic rather than business falling under some other classification. *TR* is the prefix to a position report. *SVC* shows that a service message is coming. The letters *GOVT* indicate that a government message will be sent. *GOVT S B*, *GOVT W B*, or *GOVT HYDRO* in the preamble indicate that the message to follow contains official business of the U.S. Shipping Board or Weather Bureau. *GOVT* is also transmitted as the first word in the address and is counted as one word. Other signs in the preamble indicate different classes of radiograms. A collated radiogram is indicated by *TC* sent in the preamble and as the first item of the address, and such messages must always be repeated back to the sending station for verification. The number is sent first in a commercial radiogram. *W*, *WDS*, *CK*, or *GR* refer to the number of words, the check or word groups in the message. A short commercial message with a "radio" check might be sent from WAX to RXC (Panama) as follows:

RXC WAX P 36 wll MIAMI FLA 317P 30 TO FRANK CLARK CARE SS HARBINGER BALBOA ——-——ADVISE NEW MACHINERY REQUIRED ——-——PATTERSON AR

When the receiving operator is uncertain of a word or part of a message because of poor reception of automatic transmission he asks a repeat from the transmitting station at the first opportunity. *RQ* is the prefix that tells what is meant. *RQ* is used when the "receiver questions" the message. "RQ WAX 36 CLARK THIRD" means, "What is the third word in the text of WAX's number 36 addressed to Clark?" The answer to an *RQ* is a *BQ* and in this case might be, "BQ WAX 36 THIRD MACHINERY."

League O.B.S. System

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

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

Day	*Time (E.S.T.)*	*Frequencies (kc.)*
Sunday	8:30 p.m.	3825 and 7150
	Midnight	3825 and 7150
Monday	8:30 p.m.	3575 and 7003
	10:30 p.m.	3575 and 7003
Tuesday	8:30 p.m.	3575 and 7150
	Midnight	3575 and 7150
Thursday	8:30 p.m.	3825 and 7003
	Midnight	3825 and 7003
Friday	8:30 p.m.	3825 and 7150
	10:30 p.m.	3825 and 7150

These transmissions are sent at a moderate rate of speed and are frequently used by advanced beginners for *code practice* work.

Using a Key

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

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

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

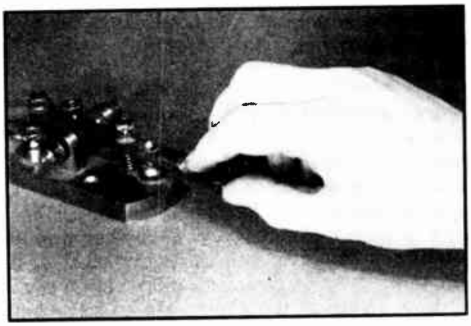
Sending

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

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

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

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



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

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

Individuality in sending should be suppressed rather than cultivated. Sending is something like writing, however. Individuality is bound to show in all hand-sending. Unless the spacing is even and regular, reception becomes guess-work. The operator who practices on a buzzer until he has developed a good "fist" is appreciated by everyone he works. His sending is legible and gets favorable attention.

A good rule is never to send faster than you can receive. Then you can tell what your signals sound like to the operator who must copy them. Speed needs to be held in check. "Copiability" is what we want. Repeats waste valuable time. When you find that you are sending too fast for the other fellow, slow down to his speed. Attempting to send dots nervously in as rapid succession as possible is the first step in acquiring a "glass arm."

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

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

Obtaining Government Licenses

As soon as you are able to copy ten words per minute and have mastered elementary theory you are ready to think about obtaining your amateur operator's license. It is well to be able to copy one or two words faster than ten-per, perhaps, to make up for the effect of any nervousness which may handicap you as it does most of us during any sort of examination. While you will need no license in the United States to operate any kind of a *receiver*, both an operator's and a station license are required before you can lawfully send a single dot or dash over the air with a *transmitter*. Happily, neither license costs anything to obtain. The first step toward getting them is to write to or call on your government radio inspector at his office in your inspection district, requesting application blanks for amateur station and operator's licenses.

The table in the Appendix shows the territory included in each of the twenty inspection districts, and gives the address for the inspector's office in each district.

Do not confuse these inspection districts with the amateur call areas shown in the map. There was a time when the amateur call areas corresponded with the nine inspection districts then designated. In 1932, however, the Federal Radio Commission reorganized the field department and created the twenty inspection districts shown in the table, although continuing to issue amateur calls according to the original old nine call areas.

Operators' Licenses

Amateur *operators'* licenses are issued in three grades. They are known as Amateur Extra First Class, Amateur First Class, and Temporary Amateur Operator Class.

The *Temporary Amateur License* is issued upon mail application to persons living too far away from a district inspection office to conveniently take the first-class examination. The general requirements and conditions in connection with the temporary license are outlined by the following quotation from the regulations:

"Application for this class of license (temporary amateur) will be accepted only from applicants residing more than 100 miles from examining point, which may be the district headquarters or a city visited by an examining officer. . . . The applicant must submit a sworn statement attesting to his ability to transmit and receive at a speed of not less than 10 words per minute in Continental Morse code, and complete a questionnaire pertaining to the operation of an amateur radio installation. Applications for examination for unlimited amateur phone privileges will not be accepted from holders of Temporary Amateur Class Operator License. Applicants for this examination must appear personally before an examining officer and pass a written examination.

"Renewal of Temporary Amateur Class Licenses. These are *not renewable*. Holders of this class of license will be expected to pass the regular amateur examination during the license term, which is for one year only. Failing to appear for examination when given an opportunity or failing to pass examination, the temporary amateur class license will be cancelled and holder will not be issued another license of this class (that is, another *temporary* license) upon subsequent application."

It may be mentioned that under exceptional circumstances (such as the holder of the temporary license being a permanent invalid) the non-renewal clause is not enforced, and the temporary license *is* renewed. This applies only in special cases, however; in general, as stated in the regulations, the first-class examination must be taken by the holder of a temporary license before the one-year term of the temporary ticket has expired. This first-class examination, incidentally, includes an actual code-speed test, given by the inspector.

The *Amateur First Class License* is the one held by the majority of amateurs and, as just mentioned, must be obtained by the holders of temporary licenses during the one-year term of the "temporary." The examination for the first-class license is not given by mail, but is given personally by the inspector or one of his assistants. A code-speed test is also given the applicant to determine that he is qualified on that score. The regulations regarding the first-class amateur license are quoted:

"Applicants for this class of license must pass a code test in transmission and reception at a speed of not less than 10 words per minute in continental Morse code (5 characters to the word) and an examination similar to that given for amateur extra first-class license but not so comprehensive in scope. . . . Holders of this class of license, after at least one year's experience as a licensed operator at an amateur station, may be accorded unlimited phone privileges . . . after passing the supplemental examination and having their license so indorsed."

To be eligible for the examination for an *Amateur Extra First Class Radio Operator's License* the applicant must have had at least two years' experience as a licensed radio operator and must not have been penalized for violation of the radio laws. The code speed requirement is 20 words per minute receiving and transmitting plain language and a speed of at least 16 words per minute in handling coded groups. Applicants must pass a special examination which, incidentally, is sufficiently wide in scope to authorize the holder of the "extra-first" to operate under the unlimited 'phone privileges, if he so desires. The possession of one of these "extra first" operator's licenses is a special mark of distinction and proficiency. The superior grade of license is a stimulus to better operating and should be the goal of every operator. It is a mark of achievement and every amateur is urged to apply for this form of operator's "ticket" as soon as he can qualify.

Since mention has now been made several times of the *Unlimited 'Phone Privilege* it is in order to explain this. Briefly, four bands of frequencies are available for amateur radiophone operation. Two of these bands (1,875–2000 kc. and 56,000–60,000 kc.) may be used by the holder of any amateur operator license, whether it be temporary, first-class, or extra-first class.

The other two 'phone bands are 3,900–4,000 kc. and 14,150–14,250 kc. but only those amateur operators licensed for unlimited amateur 'phone operation may use them. The amateur extra-first class license carries this unlimited authorization with it, automatically. Amateurs possessing first-class operator licenses, and who have had at least one year's experience as licensed operators (any class) are permitted to take a special examination for unlimited 'phone operation; if successful in passing it, a certification to this effect is typed in on their license. The examination must be taken before the inspector, however; it is not given by mail.

Holders of temporary operator licenses are never permitted unlimited 'phone privileges.

The *terms of operator licenses* are three years for the amateur first-class and extra-first-class, and one year for the temporary amateur ticket. *Renewal* of the "first" and "extra first" is made without examination, upon application, providing proof is submitted indicating at least three amateurs with whom the applicant has communicated by code within the last three months of the license term. Lacking such proof a code test will be required. The temporary operator license, as has been mentioned, is not renewable.

Passing the Exam

The examination contains questions of two types: questions relating to the radio laws and regulations and operating procedure and those covering the candidate's technical knowledge and the apparatus he proposes to operate. This book contains all the information necessary to get an amateur license.

With the idea of indicating the type of questions asked and the general ground covered by the government examinations and to aid the prospective amateur, an article on *Passing the Government Examination for Amateur Operator's License* was published in two sections in *QST*, and later republished when these copies became exhausted. Reprints of this article are available from A.R.R.L. Headquarters and will be sent to any address on receipt of 20 cents to cover printing and mailing costs.

The requirements for passing the amateur operator's license examination are not difficult in any way. A written examination is necessary as proof of the ability of the operator and assurance of his understanding the equipment he proposes to operate. All amateurs are required to know the Continental code. Special attention and study should be given to the regulations which concern amateur stations, to the important international regulations, and to a number of the most-used "Q" signals. The full text of the regulations for amateur stations, and extracts from the radio law, the Radio Act of 1927, which explains the administration of the regulations and the penalties for certain violations, are included in the Appendix. Know the regulations for amateur stations and the various penalties prescribed in the Radio Act thoroughly. Be able to draw a complete schematic diagram of your transmitter and receiver and explain their operation briefly.

Applicants are expected to be familiar with amateur receiving and transmitting equipment. The construction and function of each part of the apparatus should be studied to make it easy to explain the operation and elementary theory.

In the examination the applicant is required to tell what apparatus he expects to use, to draw a simple diagram of connections, and to explain the operation. The diagram should show switches and ground connections just as they are in the station. The applicant must be able to identify a distress signal (SOS) and to understand the signal used telling him to stop sending (QRT) when he is causing interference (QRM).

Refer to the following chapters for explanations of how a vacuum tube oscillates in the receiver and transmitter, what might prevent oscillation (several reasons), schematic diagrams showing circuits similar to your own, including the source of power, the filter, oscillator, receiver, antenna and ground, etc. Be able to explain how regeneration is controlled and what other methods could be used, how the receiver is tuned and what is meant by tuning, how a vacuum tube detects and amplifies, how you determine whether your transmitter is operating in the amateur frequency bands, what frequency stability is and how it may be affected by different adjustments, types of power supply, etc. Then know the regulations regarding quiet hours, the powers of the Federal Radio Commission, the international regulations relative to the exchange of communications between the amateur stations of different countries, regarding superfluous signals, secrecy of messages, constancy of frequency and freedom from harmonics, meaning of SOS, CQ, QRT, etc., and the penalties for different violations.

Applicants who fail to qualify may be re-examined after three months from the date of taking their unsuccessful examination.

All of this sounds fearfully complicated but it really isn't — as many tens of thousands of licensed amateurs have proved. Progress is amazingly fast once you start.

Station Licenses

It is easy enough to give the matter a little study and pass the operator's license examination. As for the *station* license, there is no examination in connection with that. It is necessary to fill out the application blanks the Inspector sends you quite completely, however, answering all questions and returning the forms to the Federal Radio Commission at Washington, D. C.

In addition to entering the main facts concerning your proposed station, such as the location, power, etc., the name, age, and citizenship of the station owner are required. Aliens may not obtain station licenses. The F.R.C. has ruled that amateur stations, as a general class, are in the public interest so that detailed explanation on this point is not required. The station license allows the station to be operated. The man who holds the license is responsible for the proper operation of the station under the terms of the license.

The Federal Radio Commission licenses amateur telegraph stations to work in *any* or *all* of several frequency bands. If voice is to be used the station must be built to work in the 1875–2000 or 56,000–60,000 kc. (150–160 5–5.36 meter) bands, unless the operator holds the unlimited 'phone privilege in which case the station may also operate 'phone in the additional bands 3900–4000 and 14,150–14,250 kc. (75–76.9 and 21.05–21.2 meters).

Applications for renewal of station licenses (and operator licenses also, for that matter) must be filed so as to be received at the offices of the inspector in charge of the district in which the station is located at least *sixty* days prior to the expiration date of the license sought to be renewed, and failing this it is necessary for the license to cease operating until action has been taken on the application in due course.

Posting of Licenses

It is also ordered by the Federal Radio Commission that every station license shall be posted by the licensee in a conspicuous place in the room in which the transmitter is located, and the license of every station operator shall be posted in a conspicuous place in the room occupied by said operator while on duty.

Amateur Regulations

The full text of the amateur regulations is given in the Appendix including the basic definitions of an amateur and what constitutes commercial correspondence. In general the text of the regulations is self-explanatory but some of the more important points to be observed should be mentioned and discussed at this point.

An amateur is a person interested in radio technique solely with a personal aim and without pecuniary interest. Only individuals who can qualify as an amateur will be licensed. The right to use the amateur frequencies is extended only to amateurs and then only for amateur purposes. This provision protects us from the attempts of commercial enterprises to make use of amateur frequencies. *Bona fide* amateur clubs or organizations will have no difficulty in obtaining station licenses, providing an official individually accepts full legal responsibility for operation of the station.

Amateur stations shall not transmit or receive messages for hire nor engage in communication for material compensation, direct or indirect, paid or promised. This proviso gives further protection against commercial enterprises masquerading as amateurs, and defines the test of commercial traffic as that involving any sort of "compensation" for the handling thereof. Accordingly, insofar as this country is concerned, an amateur may handle any traffic he sees fit to handle, so long as he receives no compensation of any kind. It must be remembered, however, that the International Convention restricts the exchange of communications between different countries (internationally) so that messages must be in plain language relating to experiments in progress, or remarks must be limited to those of a personal nature and of such unimportance that they would not normally be transmitted by way of commercial telegraph, radio or cable.

Portable amateur stations will be licensed but the license holder must give the inspector advance notice of all points at which the station will be operated. Note that portable stations may not be used while in motion, since in this condition they fall under the classification of mobile stations. Amateur mobile stations are not at present licensed.

The licensee of an amateur station shall keep an accurate log of station operation, in which shall be recorded the time of each transmission, the station called, the input power to the last stage of the transmitter, the frequency band used and the personal "sine" or identification of the operator for each period of operation. Amateur stations are authorized to use a maximum power input into the last stage of a transmitter of one kilowatt. The Radio Act requires that the records of a station must be available to the radio authorities on demand. Such logs then assist the inspector in investigating interference cases, alleged off-frequency operation or other violations, determining when changes in frequency and power were made, which conditions interfere and which do not, etc. The A.R.R.L. has designed a log-book especially to take care of this government requirement which will be described when we come to the discussion of "Operating a Station." An accurate and complete station log is compulsory.

Amateur stations must use adequately filtered direct current power supply or arrangements that produce equivalent effects to minimize frequency modulation and prevent the emission of broad signals. The intent is to do away with a.c. signals and to prohibit transmitters with inherent frequency instability from producing "wobbly" signals on the air, using an unfair amount of the frequency territory to effect transmission. This parallels the regulation that requires that the minimum amount of power necessary to effect communication over a certain distance to be used. As will be seen in subsequent chapters, variations in plate voltage affect the frequency of an oscillator, so that it takes a d.c. power supply to comply with the regulations in every example of a self-controlled oscillator. Only oscillator-amplifier transmitters (crystal-controlled or self-excited oscillators) can be permitted to use a.c. plate supply, and even then only under the provisions (1) that they have a buffer stage so that the changing plate voltage on the amplifier has no opportunity to get back into the oscillator and affect its frequency and (2) that the oscillator and buffer stage are, of course, fed with d.c.

In general it is evident throughout the regulations that amateur stations should be judged by their external effects. Whenever general interference with broadcast reception on receiving apparatus of modern design exists, the Commission regulations regarding quiet hours must be observed, and these will continue in effect until it can be shown that adjustments or alteration of the transmitting arrangement or methods of treatment of the receivers to do away with the trouble have eliminated the difficulty. The quiet hours shall be eight to ten thirty p. m. local time, daily, and, in addition, quiet hours shall be observed on Sunday morning from 10:30 a. m. until 1 p. m. It should be noted that if use of one frequency band causes local interference but another band does not, the station remains free to operate on the bands that do not give rise to this difficulty. Even operation on a different frequency in the same band may be used for operation if it can be shown that it overcomes the trouble.

Amateur stations are not permitted to communicate with commercial or government stations unless authorized by the licensing authority except in an emergency or for testing purposes. This restriction does not apply to communication with small pleasure craft such as yachts and motor boats holding limited commercial station licenses which may have difficulty in establishing communication with commercial or government stations.

Amateur stations are not authorized to broadcast news, music, lectures or any other form of entertainment.

No person, firm, company or corporation within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto.

All persons who may have knowledge of the text or simply of the existence of radio telegrams, or of any information whatever, obtained by means of the radio service, shall be bound to maintain and insure the secrecy of correspondence.

All amateurs should be familiar with the laws and regulations, especially those provisions and penalties respecting violation of terms set forth in station and operators' licenses, secrecy of messages and malicious interference. A penalty of $500 fine for each and every offense is stipulated (in addition to other penalties provided by law) or conviction of a violation of any provision of the Radio Act or regulations made under that Act or of the provisions of treaties ratified and adhered to by the United States.

Operators' licenses may be suspended for a period of not more than two years upon satisfactory proof that the licensee (a) has violated any provision of any Act or treaty (or regulations made under such Act or treaty) binding on the United States which the Commission is authorized by this Act to administer; or . . . (d) has transmitted superfluous radio communications or signals or radio communications containing profane or obscene words or language; or (e) has wilfully or maliciously interfered with any other radio communications or signals.

Canadian Regulations

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

The form for application for station license may be obtained either from a local Radio Inspector's office or direct from the Department of Marine and Fisheries, Radio Branch, Ottawa. This consists of a blank form with spaces for details regarding the station equipment and the uses to which it is to be put. The applicant must also sign a declaration of secrecy which, as a matter of fact, is executed at the time of obtaining the operator's license. The annual fee for station licenses for amateur work in Canada is $2.50.

Chapter Three

ELECTRICAL FUNDAMENTALS

ALTHOUGH it is possible for the amateur unversed in electrical fundamentals to build and operate a station more or less successfully, better practical results and greater personal enjoyment of the game are in store for him who knows something of what it's all about. Amateur radio is really a part of the great field of electrical communication, both wire and radio, and hence has its foundations in the electrical fundamentals that have been in process of development for hundreds of years. To cover completely the basic principles involved is far beyond the scope of any one book, let alone a single chapter, so the aim here must be to present only those fundamentals that experience has shown to be of the greatest practical value to the amateur in the building and operating of his station. To the avid amateur whose appetite may be whetted for more, the books suggested in the Appendix are recommended for further study.

What Is Electricity?

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

"Electrons in motion constitute an electric current."

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

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

Electron Flow — Electric Current

It is considered likely that there is a continuous interchange of electrons between the atoms of a solid body, such as a piece of copper wire, but that the net effect under ordinary conditions is to make the average in any one direction zero. If, however, there is an electric field through the wire, as when the ends are connected to the terminals of a battery, there sets in a consistent drift of the negatively charged electrons, from atom to atom, towards the end of the wire connected to the positive battery terminal, somewhat as shown in Fig. 31. This drift of electrons constitutes an electric current. The rate at which the current flows will be determined by the characteristics of the conductor, of course, and by the strength of the electric field.

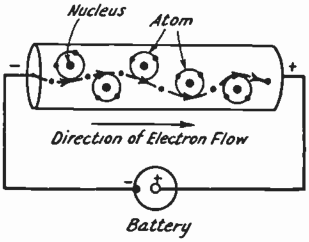


FIG. 31. — HOW CURRENT IS CONDUCTED IN A WIRE

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

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

A current of 1 ampere represents nearly 10^{19} (*ten million, million, million*) *electrons flowing past a point in 1 second; or a micro-ampere* (*millionth of an ampere*) *nearly 10 million electrons per microsecond* (*millionth of a second*).

Conductors and Insulators

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

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

Conduction in Liquids and Gases

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

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

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

Still another form of conduction very important in radio communication is pure *electronic conduction*. In the case of the copper wire we saw that the individual electrons did not make the complete trip from one end of the circuit to the other but that the flow was a sort of relay process. We also saw that the electrons could not leave the wire in random directions but, under the influence of the electric field, progressed only from the negative towards the positive end. They were restrained from leaving the surfaces of the conductor. But they can be made to fly off from the conductor when properly stimulated to do so, as is illustrated by the familiar radio vacuum tube. Here we have electrons being freed from the *cathode*, a conductor that would nominally retain them, and actually traveling through vacuum to the plate that attracts them because it is connected to the positive terminal of a battery, as illustrated in Fig. 32. The reason that the electrons are freed from the cathode is that it has been heated to a temperature that activates them sufficiently to enable them to break away. This is known as *thermionic electron emission,* sometimes called simply *emission*. Once free, most of the emitted electrons make their way to the plate, although some return, repelled from traveling farther by the cloud of negative electrons immediately surrounding the cathode. This electron cloud about the emitting cathode constitutes

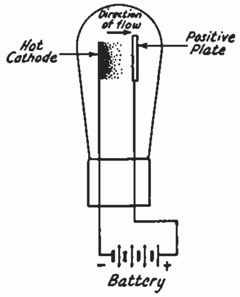


FIG. 32.—ELECTRONIC CONDUCTION BY ELECTRON EMISSION IN THE VACUUM TUBE

Stimulated by heat, electrons fly off from the cathode or filament and are attracted to the positive plate.

what is known as the *space charge*. A few electrons that reach the plate may have sufficient velocity to dislodge one or more electrons already on the plate. This dislodging of electrons from the plate by other fast moving electrons constitutes *secondary emission*. When it occurs there is actually simultaneous electron flow in two directions. The various phenomena connected with electronic conduction, briefly outlined here, are of such extreme importance in the operation of vacuum tubes that they cannot be emphasized too greatly.

Direction of Flow

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

Electromotive Force — Voltage

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

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

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

How Electricity Is Produced

The ordinary electric cell and the electric generator are the sources of current used in ordinary practice. The electric cell may take the form of a so-called dry cell, a wet cell or perhaps a storage cell. In any case, the current is derived by a chemical action within the cell. In the first two forms mentioned, the action of the fluid (there is a fluid even in a "dry" cell) tears down the structure of one of the elements or "poles" of the cell, producing an excess of electrons in one element and a deficiency in the other. Thus, when the elements are connected by a conductor, this unbalance of electrons results in a flow of electrons from one element to the other and the flow is what we know as an electric current. In the storage cell, the chemical change is reversible and the cell can be "recharged." The manner in which the electric generator produces a current is to be discussed at a later stage.

Direct and Alternating Current — Frequency

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

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

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

Resistance and Resistors — Ohm's Law

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

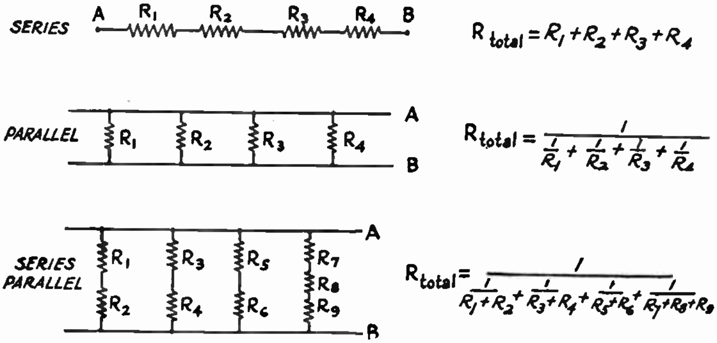


FIG. 33 — RESISTANCES CONNECTED IN SERIES, PARALLEL, AND SERIES-PARALLEL

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

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

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

The *resistance* of the circuit can therefore be found *by dividing the voltage by the current*; the *current* can be found *by dividing the voltage by the resistance;* the *electromotive force or e.m.f.* is equal to the *product of the resistance and the current*. At a later stage it will be shown just how valuable may be the practical application of this law to the ordinary problems of our radio work.

Series and Parallel Connections

The resistors used in electrical circuits to introduce a known amount of resistance are made up in a variety of forms. One common type consists of wire, of some high resistance metal, wound on a porcelain former. To obtain very high values of resistance the wire must be extremely fine. Because this introduces manufacturing difficulties, some of the high value resistors which are not required to carry heavy current are made up of some carbon compound or similar high resistance material. Resistors, like cells, may be connected in series, in parallel or in series-parallel. When two or more resistors are connected in series, the total resistance of the group is higher than that of any of the units. Should two or more resistors be connected in parallel, the total resistance is decreased. Fig. 33 shows how the value of a bank of resistors in series, parallel or series-parallel may be computed.

Heating Effect and Power

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

Power (watts) $= EI$

We already know that $E = IR$

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

Also, $P = \dfrac{E^2}{R}$

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

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

Part C of the diagram, showing the variation of output of a generator with different resistance loads, suggests how a voltmeter and ammeter may be connected for measuring the power output of the generator or the power dissipated in the resistor. The power will be $E \times I$ in all cases, but this product will be zero in either A or B where either I or E is zero. As shown by the sketch the maximum power in the load (but not maximum efficiency) is obtained when the load resistance equals the internal resistance of the battery or generator.

Alternating Current Flow

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

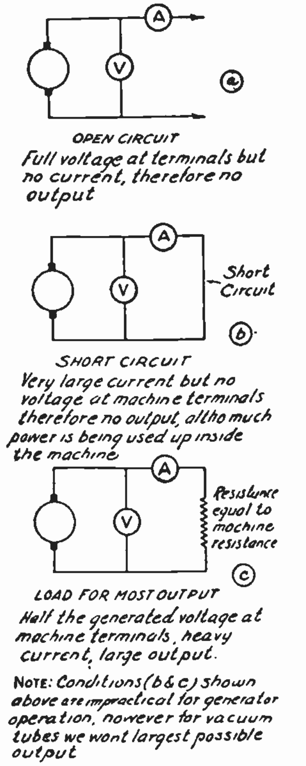


FIG. 34 — SHOWING THE VARIATION OF OUTPUT AS LOAD RESISTANCE IS CHANGED

Electromagnetism

When any electric current is passed through a conductor, magnetic effects are produced. *Moving electrons produce magnetic fields.* Little is known of the exact nature of the forces which come into play but it is assumed that they are in the form of lines surrounding the wire; they are termed *lines of magnetic force*. It is known that these lines of force, in the form of concentric circles around the conductor, lie in planes at right angles to the axis of the conductor.

The magnetic field constituted by these lines of force exists only when current is flowing through the wire. When the current is started through the wire, we may think of the magnetic field as coming into being and sweeping outward from the axis of the wire. And on the cessation of the current flow, the field collapses toward the wire again and disappears. *Thus energy is alternately stored in the field and returned to the wire.* When a conductor is wound into the form of a coil of many turns, the magnetic field becomes stronger because there are more lines of force. The force is expressed in terms of *magneto-motive force* (*m.m.f.*) which depends on the number of turns of wire, the size of the coil and the amount of current flowing through it. The same magnetizing effect can be secured with a great many turns and a weak current or with fewer turns and a greater current. If ten amperes flow in one turn of wire, the magnetizing effect is 10 *ampere-turns*. Should one ampere flow in ten turns of wire, the magnetizing effect is also 10 ampere-turns.

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

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

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

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

Permeability is the ratio between the flux density produced in a material by a certain m.m.f. and the flux density that the same m.m.f. will produce in air. Iron and nickel have higher permeability than air. Iron has a permeability some 3000 times that of air, is of low cost, and is therefore very commonly used in magnetic circuits of electrical devices. The permeability of iron varies somewhat depending on the treatment it receives during manufacture. Soft iron has low *reluctivity*, another way of saying that its permeability is extremely high. The molecules of soft iron are readily turned end to end by bringing a current-carrying wire or a permanent magnet near. When the influence is removed they just as quickly resume their former positions.

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

Inductance

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

The Reactance of Coils

As we have said, a coil tends to limit the amount of current which an alternating voltage can send through it. A further very important fact is that a given coil with a fixed amount of inductance will impede the flow of a high frequency alternating current much more than a low frequency current. We know, then, that the characteristic of a coil in impeding an alternating current flow depends both on the inductance of the coil and on the frequency of the current. This combined effect of frequency and inductance in coils is termed *reactance*, or *inductive reactance*.

The inductive reactance formula is:

$$X_l = 2\pi f L$$

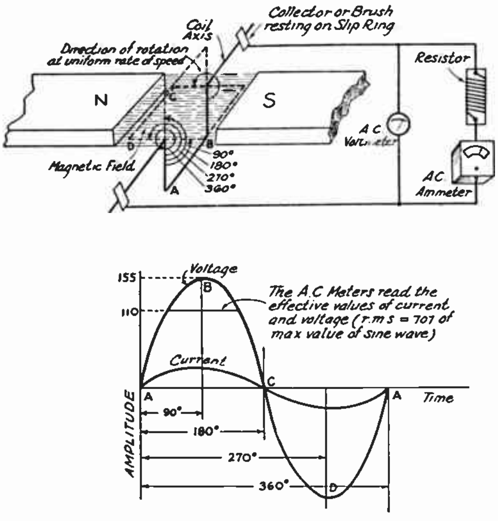
where X_l is the inductive reactance in ohms
π is 3.1416
f is the frequency in cycles per second
L is the inductance in henries

Transformers and Generators

We have stated that if a magnetic field passes through a coil, an electro-motive force is induced in the coil. Not only does this phenomenon provide us with an explanation of self-inductance in coils but it permits an understanding of how transformers and generators operate. Transformers are very widely used in radio work — their essential purpose being to convert an alternating current supply of one voltage to one of higher or lower voltage. In transmitters, for instance, there will be one or more transformers serving to step down the 110-volt supply voltage to 7.5, 10 or 11 volts for the filaments of the transmitting tubes. Then there will be another transformer to step up the 110-volt supply to 500, 1000 or perhaps several thousand volts for the plate supply of the transmitting tubes. These transformers will consist of windings on a square *core* of thin iron strips. The 110-volt supply will flow through a primary winding and the magnetic field created by this current flow, because it is common to all windings on the core, will induce voltages in all the windings. Should one of the secondary windings have twice the number of turns on the primary winding, the secondary voltage developed will be approximately twice that of the primary voltage. Should one of the secondary windings have one third of the primary turns, the voltage developed across the secondary will be one third the primary voltage. Direct current flowing in the primary of such a transformer would build up a magnetic field as the current started to flow but the field would be a fixed one. So long as the primary current remained steady there would be no voltages developed in the secondaries. This is the reason why transformers cannot be operated from a source of continuous direct current.

A somewhat similar arrangement is to be found in the alternating current generator — a simplified diagram of which is shown in Fig. 35. In one common form of alternator, the magnetic field is fixed and voltages are induced in the coil by its rotation in the field. The result is exactly similar to that which would be obtained if the coil was fixed and the field rotated around it. As the coil turns at a uniform rate from the vertical position, it is cut by an increasing number of magnetic lines of force and the induced voltage increases until it becomes a maximum when the coil is horizontal. As the coil continues to rotate towards the vertical position the induced voltage decreases until it becomes zero when the coil is again in the vertical plane. When the coil continues its rotation from this position, the direction of the field with respect to the turns of the coil has now been reversed and the voltage between the ends of the coil has therefore been reversed also. As the coil continues its rotation, the voltage again climbs to a maximum and falls to zero when the coil reaches its original vertical position. In the actual generator, of course, the rotation of the coil (the armature) is very rapid. The speed of rotation in the elementary machine shown in the diagram would directly govern the frequency of the alternating voltage produced.

In the practical alternator, of course, the arrangement is much more complex and the electro-magnet which produces the field may have many pairs of poles. A similar machine is used to generate direct current. The chief difference in it is that a commutator is provided on its shaft to rectify the output of the armature. This process involves changing the direction of every alternate half-cycle — so causing all the pulses of voltage generated to be in the same direction.



SIMPLE ALTERNATOR CIRCUIT

Diagram shows instantaneous values of current and voltage with electrical degrees of coil rotation — there are 360 electrical degrees for every pair of poles so that one complete mechanical revolution may correspond to more than one electrical revolution.

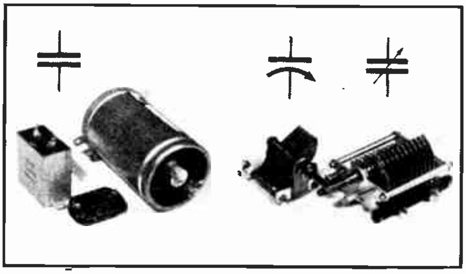
FIG. 35

Condensers — Capacitance

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

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

The unity of capacity is the *farad.* A condenser of one farad, however, would be so large that its construction would be impractical. A more common term in practical work is the *microfarad* (abbreviated μfd.) while another (used particularly for the small condensers in high-frequency apparatus) is the *micro-microfarad* (abbreviated $\mu\mu$fd.). The μfd. is one millionth of a farad; the $\mu\mu$fd. is one millionth of a microfarad.



FORMS OF CONDENSERS

The variable condenser symbols are interchangeable. Both are widely used.

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

Alternating Current in a Condenser

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

Capacitive Reactance

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

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

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

Where the capacitance is in microfarads ($\mu fd.$), as it is in most practical cases, the formula becomes

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

10^6 being 1,000,000.

Condenser Connections

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

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

$$C = C_1 + C_2 + C_3$$

The equivalent capacity of condensers connected in series is expressed by the following formula which can be simplified as shown when but two condensers are considered:

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

It is sometimes necessary to connect filter condensers in series. This increases the breakdown voltage of the combination although, of course, it decreases the capacity available. Condensers of identical capacitance are most effectively connected in series for this purpose. Voltage tends to divide across series condensers in inverse proportion to the capacity, so that the smaller of two series condensers will break down first if the condensers are of equal voltage rating. Before selecting filter condensers the operating conditions, voltage peaks and r.m.s. values should be carefully considered. For complete information on this matter the chapter on Power Supply should be consulted.

Distributed Inductance, Capacity and Resistance

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

Ohm's Law for Alternating Current

We start to realize the importance of these characteristics just as soon as we endeavor to apply Ohm's Law to circuits in which alternating current flows. If inductances did not have any resistance we could assume that the current through the coil would be equal to the voltage divided by the reactance. But the coil will have resistance, and this resistance will act with the reactance in limiting the current flow. The combined effect of the resistance and reactance is termed *impedance* in the case of both coils and condensers. The symbol for impedance is Z and it is computed from this formula:

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

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

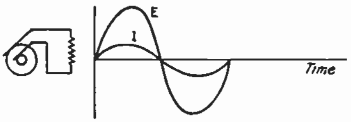
$$I = \frac{E}{Z} \qquad Z = \frac{E}{I} \qquad E = IZ$$

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

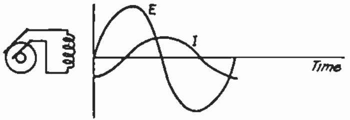
The Sine Wave

In Fig. 35, illustrating the action of the alternator in generating an alternating voltage, a curve indicating the voltage developed by the alternator during one complete cycle was shown. This curve, as obtained with a theoretically perfect alternator, is known as a *sine* curve. All the formulas given for alternating current circuits have been derived with the assumption that any alternating voltage under consideration would follow such a curve. It is evident that both the voltage and current are swinging continuously between their positive maximum and negative maximum values, and the beginner must wonder how one can speak of so many amperes of alternating current when the value is changing continuously. The problem is simplified in practical work by considering that an alternating current has a value of one ampere when it produces heat at the same average rate as one ampere of continuous direct current flowing through a given resistor. This *effective* value of an alternating current, if it truly follows a sine curve or has a *sinusoidal wave form*, is equal to the maximum or peak value divided by 1.41, the square root of 2. Similarly, the effective value of an alternating voltage is its peak value divided by 1.41.

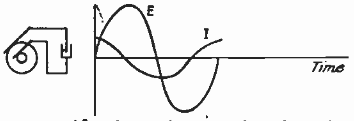
Another important value, involved where alternating current is rectified to direct current, is the *average*. This is equal to .636 of the maximum (or peak) value of either current or voltage. The three terms *maximum* (or *peak*), *effective* (or *r.m.s.*) and *average* are so important and are encountered so frequently in radio work that they should be fixed firmly in mind right at the start.



(a) Current and Voltage "in phase" with Pure Resistance in circuit



(b) Current "lagging" Voltage with Pure Inductance in circuit



(c) Current "leading" Voltage with Pure Capacitance in circuit

SHOWING AMPLITUDE-TIME RELATIONS OF CURRENT AND VOLTAGE FOR A COMPLETE CYCLE (360 Electrical Degrees)

FIG. 36

They are related to each other as follows:

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

The relationships for current are the same as those given above for voltage. The usual alternating current ammeter or voltmeter gives a direct reading of the effective or r.m.s. (root mean square) value of current or voltage. A direct current ammeter in the plate circuit of a vacuum tube approximates the average value of rectified plate current. Maximum values can be measured by a peak vacuum-tube voltmeter such as is described in the chapter on Radiotelephony.

Phase Angle

It has been mentioned that in a circuit containing inductance, the rise of current is delayed by the effect of electrical inertia presented by the inductance. Both increases and decreases of current are similarly delayed. It is also true that a current must flow into a condenser before its elements can be charged and so provide a voltage difference between its terminals. Because of these facts, we say that a current "lags" behind the voltage in a circuit which has a preponderance of inductance and that the current "leads" the voltage in a circuit where capacity predominates. Fig. 36 shows three possible conditions in an alternating current circuit. In the first, when the load is a pure resistance, both voltage and current rise to the maximum values simultaneously. In this case the voltage and current are said to be *in phase*. In the second instance, the existence of inductance in the circuit has caused the current to lag behind the voltage. In the diagram, the current is lagging one quarter cycle behind the voltage. The current is therefore said to be 90 degrees *out of phase* with the voltage (360 degrees being the complete cycle). In the third example, with a capacitive load, the voltage is lagging one quarter cycle behind the current. The *phase difference* is again 90 degrees. These, of course, are theoretical examples in which it is assumed that the inductance and the condenser have no resistance. Actually, the angle of lag or lead depends on the ratio of reactance to resistance in the circuit.

Power Factor

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

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

Practical Problems

It is surprising how many practical uses may be found for the fundamental information and formulas set forth in this chapter. A brief study of the equations and explanations with the few examples that will now follow will enable you to apply Ohm's Law and other electrical relations to determining practical things that arise in planning, building and operating even the simplest amateur station equipment. The problems which follow will serve as examples of some of the different things taken up in this chapter.

Plate Power Input

A certain transmitter has an output stage in which a single 203-A tube is employed. A high-voltage voltmeter is connected across the plate supply circuit and a milliammeter of suitable range used in the circuit so as to measure the current of this tube only. We have seen that $P = E \times I$. Therefore, assuming that the meters read 1125 volts and 125 milliamperes, the plate input power will be $1125 \times \frac{125}{1000} = 140.6$ watts.

Resistance of a Grid Leak

It is necessary to determine whether a resistor has a resistance which would make it suitable for a grid leak for a Type 10 transmitter, either used separately or in connection with other resistors of the same type. A 90-volt B-battery and a 0–50 ma. scale milliammeter are available. The battery is connected to the unknown resistor through the meter which is observed to read 10 milliamperes. The resistance is next calculated from Ohm's Law: $R = E/I$. $90 \div .010 = 9000$ ohms.

Measuring Grid Bias Voltage

When the grid-leak resistance is known, the current through the grid leak measured by a milliammeter of suitable range enables us to calculate the voltage drop across the resistor, which is the same as the bias between grid and filament. For example, 9000-ohm resistor is used biasing a Type 10 tube in the r.f. amplifier stage of a small oscillator-amplifier transmitter. A milliammeter connected in series with the resistors reads 21 milliamperes. Calculating the voltage drop by Ohm's Law ($E = RI$) we have the bias as $9000 \times .021$, which equals 189 volts (a high value).

Resistance Value for Dropping Plate Voltage

The transformer output goes to a tube rectifier through a filter which has a 70-henry choke in one lead. After keying in the negative lead the current passes through a 3-henry "keying" filter choke to the plates of two Type 10 tubes. There is some voltage drop in the rectifier tubes and in the resistance of the two choke-coil windings. In addition to this, a resistor may be added in series with the keying choke winding to drop the voltage further so our tube will operate normally with about 400 volts d.c. on its plate. The proper size of this resistor is quickly found by using Ohm's Law. If it is desired to produce a *drop in voltage* of about 100 volts, divide this value by the estimated plate current, let us say 100 ma. or .1 ampere. ($R = E/I$)

$$\frac{100}{.1} = 1{,}000 \text{ ohms.}$$

Size Resistor to Handle a Given Current

In purchasing resistors, be sure they are of ample size to dissipate the heat that will be produced by the current they will have to carry. The power that must be dissipated in heating is $W = I^2R$ (watts). $1000 \times .100^2 = 10$ watts, which must be dissipated by the resistor for dropping the plate voltage to two Type 10 tubes. Examining manufacturers' lists, this size can be used, but a 20-watt resistor is recommended to give long life and keep the maximum temperatures low. It is best to allow 40 per cent or 50 per cent factor of safety, since resistors are usually rated for their maximum allowable dissipation mounted in free space. Actually, the heat radiation is limited by mounting resistors near other apparatus. Heat also should be kept away from filter condensers or any other apparatus whose life varies inversely with temperature.

Transformer Output Current to Resistance Load

The transformer is rated at 100 watts (v.a.) which means that it will deliver

$$I = \frac{W}{E} = \frac{100}{1100} = 91.1 \text{ ma.}$$

Capacities

A fixed condenser of 250 $\mu\mu$fd. is connected in parallel with two variable air condensers having a maximum capacitance of 140 $\mu\mu$fd. and .0005 μfd., respectively. What is the total capacitance obtainable for any adjustment or setting of the condensers? First it is necessary to change the ratings to either microfarads or micro-microfarads to get the three units on the same basis. The answer will be either:

$250 + 140 + 500 = 890$ $\mu\mu$fd. (micro-microfarads)

or

$.00025 + .00014 + .0005 = .00089$ μfd. (microfarads).

Assume the three capacities to be connected in series. Let us determine the equivalent lumped capacity:

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{250} + \frac{1}{140} + \frac{1}{500} =$$

$$.004 + .00715 + .002 = .01315$$

$$C = 76.1 \ \mu\mu\text{fd. (micro-microfarads).}$$

Condenser Reactance

A high-voltage power-supply transformer may, under certain conditions, require protection of the windings from voltages built up due to leakage of high-frequency currents back through r.f. chokes and the filter, or due to r.f. induced in power-supply leads located in the field of the high-power stage of a transmitter. The same circumstances can cause break-down of insulation in filament transformers. At any rate it will be assumed that we have a 7200-kc. transmitter and that it is desired to connect a small condenser across the high-voltage winding to by-pass current of this radio frequency. Remembering that *the higher the frequency is, the lower the reactance of a condenser,* we judge that a small condenser will sufficiently by-pass the radio-frequency current, preventing the undesired r.f. voltage from building up across our transformer winding (or a choke coil, milliammeter or other piece of apparatus could be protected similarly).

Finding a .02-μfd. mica-insulated transmitting condenser available, rated to withstand 2000 volts, we decide to consider what may happen if we connect it across the transformer secondary.

First of all to see if it will be practical and accomplish the result we want, let's find (a) what the reactance of the condenser to the 7200-kc. (7,200,000-cycle) voltage which has strayed into the circuit will be; and (b) what the reactance will be to the 60-cycle source. In the formula the units are cycles and farads so we must remember to use the proper conversion factors.

$$
\begin{aligned}
\text{(a) } X_c &= 1 \div 2\,\pi f C \\
&= 1 \div 6.28 \times 7{,}200{,}000 \times .02 \times 10^{-6} \\
&= 1 \div 6.28 \times 7.2 \times .02 \\
&= 1/.905 \\
&= 1.105 \text{ ohms}
\end{aligned}
$$

reactance at this frequency. This is an extremely low value which will readily by-pass r.f. and prevent any harmful voltages building up across an inductance.

$$
\begin{aligned}
\text{(b) } X_c &= 1 \div 2\,\pi f C \\
&= 1 \div 6.28 \times 60 \times .02 \times 10^{-6} \\
&= 132{,}800 \text{ ohms}
\end{aligned}
$$

reactance at 60 cycles.

Current Through a Reactance

The transformer is a small one and so we cannot be sure until we figure it out whether the secondary current taken by the protective condenser and the set combined will be likely to overheat the transformer or not. The plate transformer we happen to have has a ratio of 10:1 and delivers 1100 volts (effective value) when run normally. The 60-cycle current through the condenser will be:

$$
I = \frac{E}{X_c} = \frac{1100}{132{,}800} = .0083 \text{ amperes}
$$

$$
= 8.3 \text{ ma.}
$$

Reading Diagrams — Schematic Symbols

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

The symbols used in schematic diagrams throughout this book will be easily understood at once by reference to Fig. 37. Most of the diagrams shown are plainly labelled or worded so that it is only necessary to know the general scheme which differentiates coils, condensers, and resistors to read the diagram. Reference to the text will help in understanding fully what is intended, since diagrams and text have been prepared to complement each other. In general, coils are indicated by a few loops of wire, resistances by a jagged line, and variable elements in the circuit by arrowheads. If a device has an iron core it is usually shown by a few parallel lines opposite the loops indicating coils or windings.

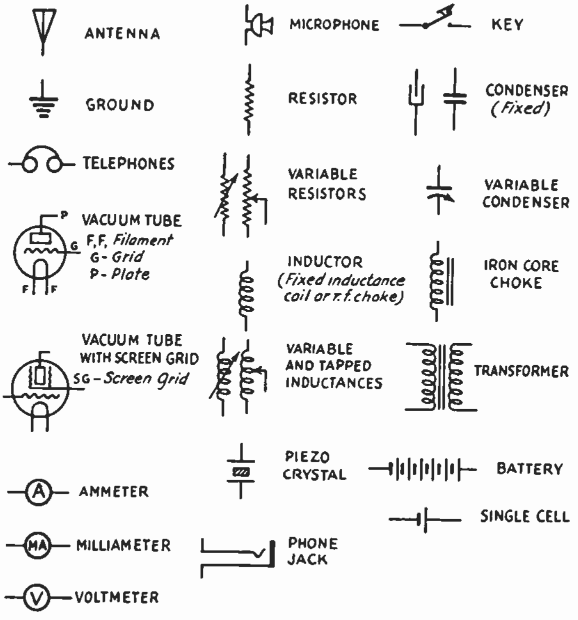


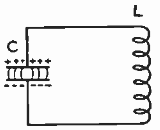
FIG. 37 — SCHEMATIC SYMBOLS USED IN CIRCUIT DIAGRAMS

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

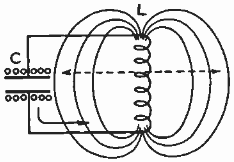
Chapter Four

RADIO FUNDAMENTALS

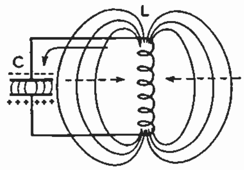
In our discussion of fundamental principles, we have seen how a flow of electrons through a wire constitutes an electric current, and how this current, under certain conditions, gives rise to electric and magnetic effects as changes in the current flow take place. In addition to the effect which resistance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



A - *Electrostatic Energy Stored In Condenser.*



B - *Electromagnetic Energy Stored In Coil. Magnetic Field Sweeps Outward.*



C - *Electromagnetic Field of Coil Collapses Energy returned to Condenser, charging it in reverse of initial polarity.*

FIG. 41 — A HALF-CYCLE OF OSCILLATION IN A RESONANT CIRCUIT

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

The Tuned Circuit

Let us assume that a condenser C and coil L are connected as shown in Fig. 41, and that the condenser is initially charged as indicated in A, one plate having a surplus of electrons and therefore being negative while the other plate, being correspondingly deficient in electrons, is positive. The instant that the condenser plates are connected together through the coil L there will start a flow of current as shown by the arrow in B. The rate of flow of current will be retarded by the inductive reactance of the coil and the discharge of the condenser will not be instantaneous even though the velocity of flow is constant. As the current continues to flow from the condenser into the coil, the energy initially stored in the condenser as an electrostatic field will become stored in the electromagnetic field of the coil. When substantially all the energy in the circuit has become stored in this field the lines of force about the coil begin to collapse, and thus cause a continued flow of current through the circuit, the flow being in the same direction as the initial current. This again charges the condenser *but in opposite polarity to the initial charge.* Then, when all the energy again has been stored in the condenser, the sequence is repeated in the opposite direction. The process is one of *oscillation.* During one complete cycle the energy is alternately stored in the condenser and in the coil twice, and there is one reversal in the direction of current flow. This represents a complete cycle of alternating current. The process would continue indefinitely were there only inductance and capacitance in the circuit but, as has been pointed out in Chapter Three, all circuits contain some resistance. Therefore during each cycle a part of the energy will be dissipated in the resistance as heat, each cycle will be of lesser amplitude than the preceding one and the process will finally stop because there is no longer energy to sustain it. This *damping* caused by resistance is overcome in practical circuits by continuously supplying energy to replace that dissipated in resistance of one form or another, as will be shown later.

Oscillation Frequency And Resonance

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

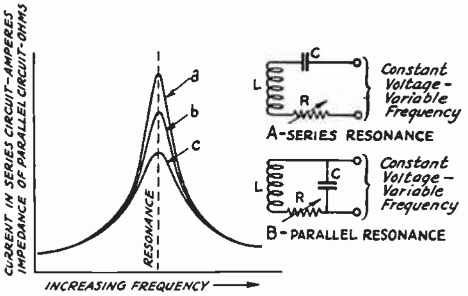


FIG. 42 — CHARACTERISTICS OF SERIES AND PARALLEL RESONANT CIRCUITS

The important practical aspect of all this is that in any circuit containing capacitance, inductance and not too much resistance, the introduction of a pulse of electrical energy will cause an alternating current oscillation of a frequency determined solely by the values of inductance and capacitance; and that for any combination of inductance and capacitance there is one particular frequency of applied voltage at which current will flow with the greatest ease. Recalling the explanations of inductive reactance and capacitive reactance given in Chapter Three, this becomes readily understandable. It has been shown that the inductive reactance of the coil and the capacitive reactance of the condenser are oppositely affected with frequency. Inductive reactance increases with frequency; capacitive reactance decreases as the frequency increases. In any combination of inductance and capacitance, therefore, there is one particular frequency for which the inductive and capacitive reactances are equal and, since these two reactances oppose each other, for which the net reactance becomes zero, leaving only the resistance of the circuit to impede the flow of current. The frequency at which this occurs is known as the *resonant frequency* of the circuit and the circuit is said to be *in resonance* at that frequency or *tuned* to that frequency.

In practical terms, since at resonance the inductive reactance must equal the capacitive reactance, then

$$X_l = X_c \text{ or } 2\pi fL = \frac{1}{2\pi fC}$$

The resonant frequency is, therefore,

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

Where

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

Series and Parallel Resonance—Effect of Resistance

In the simple tuned circuit just discussed the elements, inductance and capacitance, were considered with respect to each other but not in combination with other circuit elements as they are usually encountered in practical applications. In our radio transmitters, and in receivers as well, the tuned circuit is invariably associated with a source of electrical energy and also is usually coupled to still other circuits to which it transfers energy.

All practical tuned circuits can be treated as either one of two general types. One is the *series resonant* circuit in which the inductance, capacitance, resistance and source of voltage are in series with each other. With a constant-voltage alternating current applied as shown in A of Fig. 42 the current flowing through such a circuit will be maximum at resonant frequency. The magnitude of the current will be determined by the resistance in the circuit. The curves of Fig. 42 illustrate this, curve *a* being for minimum resistance and curves *b* and *c* being for greater resistances.

The second general case is the parallel resonant circuit illustrated in B of Fig. 42. This also contains inductance, capacitance and resistance in series, but the voltage is applied in parallel with the combination instead of in series with it as in A. Here we are not primarily interested in the current flowing *through* the circuit but in its characteristics as viewed from its terminals, especially in the *parallel impedance* it offers. The variation of parallel impedance of a parallel resonant circuit with frequency is illustrated by the same curves of Fig. 42 that show the variation in current with frequency for the series resonant circuit. The parallel impedance is maximum at resonance and increases with decreasing series resistance. Although both series and parallel resonant circuits are generally used in radio work, the parallel resonant circuit is most frequently found, as inspection of the diagrams of the equipment described in subsequent chapters will show.

High parallel impedance is generally desirable in the parallel resonant circuit and low series impedance is to be sought in series resonant circuits. Hence low series resistance is desirable in both cases. *At frequencies other than resonance frequency, the series resonant circuit has capacitive reactance for frequencies below resonance and inductive reactance for frequencies above resonance frequency, while the parallel resonant circuit offers inductive reactance at frequencies below resonance and capacitive reactance for frequencies above resonance.*

It is to be noted that the curves become "flatter" for frequencies near resonance frequency as the resistance is increased, but are of the same shape for all resistances at frequencies further removed from resonance frequency. The relative sharpness of the resonance curve near resonance frequency is a measure of the *sharpness of tuning* or *selectivity* (ability to discriminate between voltages of different frequencies) in such circuits. This is an important consideration in tuned circuits used for radio work. Since the effective resistance is practically all in the coil, the condenser resistance being negligible, the efficiency of the coil is the important thing determining the "goodness" of a tuned circuit. A useful measure of coil efficiency, and hence of tuned circuit selectivity, is the ratio of the coil's reactance to its effective resistance. This ratio will be recognized as an approximation of the reciprocal of the circuit property of power factor discussed in Chapter Three, and is designated by Q.

$$Q=\frac{2\pi fL}{R}$$

A Q of 100 would be considered high for coils used at the lower amateur frequencies, while the Q of coils for still lower frequencies may run into the hundreds.

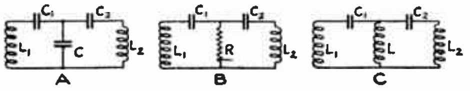
Coupled Circuits

Resonant circuits are not found in an isolated state in very many instances but are usually associated with other resonant circuits or are *coupled* to other circuits. It is by such coupling that energy is transferred from one circuit to another. Such coupling may be *direct*, as shown in A, B and C of Fig. 43, utilizing as the common coupling element, capacitance (A), resistance (B) or inductance (C). These three types of coupling are known as *direct capacitive*, *direct resistive* or *direct inductive*, respectively. Current circulating in the L_1C_1 branch flows through the common element (C, R or L) and the voltage developed across this element causes current flow in the C_2L_2 branch. Other types of coupling are the *indirect capacitive* and *magnetic* or *inductive* shown below the others. The coupling most common in high-frequency circuits is of the latter type. In such an arrangement the coupling value may be changed by changing the number of active turns in either coil or by changing the relative position of the coils (distance or angle between them). The arrangement then performs in a manner similar to the transformer described in the previous chapter.

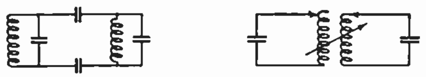
All of the above coupling schemes may be classified as either tight or loose. Coupling cannot, however, be measured simply in "inches" separation of coils. The separation between the coils (distance and angle between axes) and the inductance in each determines the coefficient of coupling. Many turns in two coils very close together give us tight coupling and a big transfer of power. Few turns at right angles or far apart give us loose coupling with little actual energy transfer. "Tight" coupling is not necessarily the best coupling, it should be kept in mind. Too-tight coupling will give a double-humped resonance effect and should be avoided.

Radio Frequency Resistance — Skin Effect

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



Direct coupling with condenser, resistor, or coil.



Indirect Capacitive Coupling *Magnetic Coupling*

FIG. 43 — COMMON TYPES OF COUPLED CIRCUITS

Circuits with Distributed Constants — The Antenna

In addition to resonant circuits containing lumped capacitance and inductance, there are important tuned circuits in which no condensers and coils are to be found. Such circuits utilize the distributed capacitance and inductance that are inevitable even in a circuit consisting of a single straight conductor. Our transmitting and receiving antennas are such circuits and depend on their distributed capacitance and inductance for tuning. A peculiarity of such a "linear" circuit is that when it is excited at its resonant frequency the current or voltage, as measured throughout its length, will have different values at different points. For instance, if the wire happens to be one in "free space" with both ends open circuited (in other words, a Hertz antenna), when it is excited at its resonant frequency *the current will be maximum at the center and zero at the ends.* On the other hand, *the voltage will be maximum at the ends and zero at the center.* The explanation of this is that the traveling waves on the wire are reflected when they reach an end. Succeeding waves traveling toward the same end of the wire (the *incident* waves) meet the returning waves (*reflected* waves) and the consequence of this meeting is that currents add up at the center and voltages cancel at the center; while voltages add up at the ends and currents cancel at the ends. A continuous succession of such incident and reflected waves therefore gives the effect of a *standing wave* in the circuit.

Frequency and Wavelength — Harmonic Operation

Instead of specifying the properties of a linear circuit such as the antenna in terms of inductance and capacitance it is customary to do so simply in terms of length. This is possible because the length of such a circuit will be inversely proportional to its resonant frequency, since the velocity of the waves is practically identical for conductors of various materials, lengths and diameters. This velocity is given as three hundred million meters per second, corresponding to 186,000 miles per second. The *wavelength* is equal to the velocity divided by the frequency, and is usually expressed in meters and designated by the Greek letter λ. In practical terms,

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

where $f_{kc.}$ is the frequency in kilocycles.

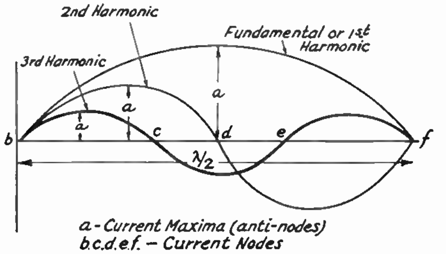


FIG. 44 — CURRENT DISTRIBUTION IN AN ANTENNA OPERATING AS A LINEAR OSCILLATORY CIRCUIT AT ITS FUNDAMENTAL, AND SECOND AND THIRD HARMONICS

The length of an antenna is specified in terms of the wavelength corresponding to the lowest frequency at which it will be resonant. This is known as its *fundamental* frequency or wavelength. As will be shown in the chapter on Antennas, this length is (very nearly) a half-wavelength for an ungrounded (Hertz) antenna and a quarter-wavelength for a grounded (Marconi) antenna. Therefore it is common to describe antennas as *half-wave, quarter-wave,* etc., for a certain frequency ("half-wave 7000-kc. antenna", for instance).

Although a coil-condenser combination having lumped constants (capacitance and inductance) resonates at only one frequency, linear circuits such as antennas containing distributed constants resonate readily at frequencies which are integral multiples of the fundamental frequency (or wavelengths that are integral fractions of the fundamental wavelength). These frequencies are therefore in *harmonic* relationship to the fundamental frequency and, hence, are referred to as *harmonics.* In radio practice the fundamental itself is called the *first harmonic,* the frequency twice the fundamental is called the *second harmonic,* and so on. For example, a Hertz antenna having a fundamental of 1790 kc. (in the amateur 1750-kc. band) also will oscillate at the following harmonic frequencies: 3580 kc. (2nd), 5370 kc. (3rd), 7160 kc. (4th), 8950 kc. (5th), 10,740 kc. (6th), 12,530 kc. (7th) and 14,320 kc. (8th). Hence the one antenna can be used for four amateur bands, resonating at its first, second, fourth and eighth harmonics. A "free" antenna (Hertz) may be operated at the fundamental or any harmonic frequency, odd or even; a grounded (Marconi) type only at its fundamental or harmonics that are *odd* multiples of the fundamental frequency.

Fig. 44 illustrates the distribution of the standing waves on a Hertz antenna for its fundamental, second and third harmonics. There is one point of maximum current with fundamental operation, there are two when operation is at the second harmonic and three at the third harmonic; the number of current maxima corresponds to the order of the harmonic and the number of standing waves on the wire. As noted in the figure, the points of maximum current are called *anti-nodes* (also known as "loops") and the points of zero current are called *nodes.*

Because the velocity of the waves on the conductor (antenna) is essentially the same as that for the radio waves in space, wavelength is used interchangeably with frequency in describing not only antennas but also for tuned circuits, complete transmitters, receivers, etc. Thus the terms "high-frequency receiver" and "short-wave receiver", or "75-meter fundamental antenna" and "4000-kilocycle fundamental antenna" are synonymous. A chart showing the relationship between frequencies and wavelengths, including those of the amateur bands, is given in the Appendix. The resonance equation of a tuned circuit, previously given for frequency, is expressed in terms of wavelength as follows:

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

where

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

Radiation By Antennas

So far we have discussed the antenna with respect to its ability to perform as a resonant circuit. We now come to the practical use that is made of the energy that oscillates in the antenna. It will be remembered that in the preceding chapter it was shown that current flow in a conductor was accompanied by a magnetic field about the conductor; and that with an alternating current the energy was alternately stored in the field in the form of lines of magnetic force and *returned to the wire*. Now this is quite true when the alternating current is of low frequency, such as the 60-cycle kind commonly used. But when the frequency becomes higher than 15,000 cycles or so (radio frequency) all the energy stored in the field is not returned to the conductor but some escapes in the form of electro-magnetic waves. In other words, energy is radiated. This we know. Just how radiation occurs is not clearly understood at the present time. But we know enough for practical purposes about what happens in the antenna and about how the waves behave after leaving the antenna.

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

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

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

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

The Vacuum Tube — Rectification

The most universally used device in radio communication is the vacuum tube. It works to change alternating to direct current in our power supplies, to amplify sound from a whisper to a roar, to generate the radio-frequency power used in transmission and to amplify and detect weak radio waves in our receiver. Vacuum tubes appear in many sizes and in a variety of structures. But all operate on the same principle. Most commonly, the vacuum tube has a glass bulb from which practically all air and other gas has been removed, and within which there are two or more elements, ranging from a filament (cathode) and plate on up to these two in combination with three, four and even more elements.

The simplest type of vacuum tube is that shown to illustrate electronic conduction in Chapter Three. It has but two elements, cathode and plate, and is therefore called a *diode.* As was explained, the hot cathode emits electrons which flow from cathode to plate within the tube *when the plate is positive with respect to the cathode.* The tube is a conductor in one direction only. If there should be a battery connected with its negative terminal to cathode and positive to plate, this flow of electrons would be continuous. But if a source of alternating current is connected between the cathode and plate, then electrons will flow only on the positive half-cycles of alternating voltage. There will be no electron flow, and hence no current flow, during the half cycles when the plate is negative. Thus the tube can be used as a *rectifier,* to change alternating current to pulsating direct current. This alternating current can be anything from the 60-cycle kind to the highest radio frequencies, making it possible to use the diode as a rectifier in power supplies furnishing direct current for our transmitters and receivers, as described in Chapter Ten, or even to use it as a rectifier (detector) of radio-frequency current in receivers.

How Vacuum Tubes Amplify — Tube Characteristics

If a third element, called the *control grid* or simply the *grid*, is inserted between the cathode and plate of the diode, the tube becomes a *triode* (three-element tube) and acquires utility for more things than rectification. This grid is usually in the form of an open spiral or mesh of fine wire. With the grid connected externally to the cathode and with a steady voltage from a d.c. supply applied between the cathode and plate (the positive of the plate or "B" supply is always connected to the plate), there will be a constant flow of electrons from cathode to plate, through the openings of the grid, much as in the diode. But if a source of variable voltage is connected between the grid and cathode there will be a variation in the flow of electrons from cathode to plate (a variation in plate current) as the voltage on the grid changes about a mean value. When the grid is made less negative with respect to the cathode there will be an increase in plate current; when the grid is made more negative with respect to the cathode there will be a decrease in plate current. This occurs because the electron flow to the plate is encouraged when the grid swings positive, while electrons leaving the cathode are repelled from traveling to the plate when the grid swings negative. The important thing about this is that when a resistance or impedance is connected in the plate circuit, the variation in plate current will cause a variation in voltage across this load that will be a magnified version of the variation in grid voltage. In other words there is *amplification* and the tube is an *amplifier*.

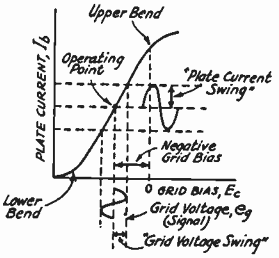


FIG. 45 — OPERATING CHARACTERISTICS OF A VACUUM TUBE AMPLIFIER

The measure of the amplification of which a tube is capable is known as its *amplification factor*, designated by μ (mu), an important *tube characterictic*. Another important characteristic involving plate current change caused by grid voltage change over a very small range is a tube's *mutual conductance*, designated by g_m and expressed either in milliamperes plate current change per volt grid voltage change (ma. per volt), or as the current to voltage ratio in *mhos* (inverse of ohms). Since the plate current changes involved are often very small, the mutual conductance is also expressed in *micromhos*, the ratio of amperes plate current change to volts grid voltage change, multiplied by one million. Still another important characteristic used in describing the properties of a tube is the *plate resistance*, designated r_p. This is the ratio of a small plate voltage change to the plate current change it effects. It is expressed in *ohms*. These tube characteristics are inter-related and are different with tubes of different types, being dependent primarily on the tube structure (spacing between elements, spacing and size of wires in grid, etc.).

Amplifier Operation

The operation of a vacuum tube amplifier is graphically represented in Fig. 45. The sloping line represents the variation in plate current obtained at a constant plate voltage with grid voltages from a value sufficiently negative to reduce the plate current to zero to a value slightly positive. It should be kept in mind that grid voltage is with reference to the cathode or filament. This is known as the *static grid-voltage plate-current characteristic*. Notable things about this curve are that it is essentially a straight line (is *linear*) over the middle section and that it bends towards the bottom (near *cut off*) and near the top (*saturation*). In other words, the variation in plate current is directly proportional to the variation in grid voltage over the region between the two bends. With a fixed grid voltage (*bias*) of proper value the plate current can be set at any value in the range of the curve.

With negative grid bias as shown in Fig. 45 this point (the *operating point*) comes in the middle of the linear region. If an alternating voltage (*signal*) is now applied to the grid in series with the grid bias, the grid voltage swings more and less negative about the mean bias voltage value and the plate current swings positive and negative about the mean plate current value. This is equivalent to an alternating current superimposed on the steady plate current. With this operating point it is evident that the plate current *wave shapes* are identical reproductions of the grid voltage wave shapes and will remain so as long as the grid voltage amplitude does not reach values sufficient to run into the lower- or upper-bend regions of the curve. If this occurs the output waves will be flattened or be *distorted*. If the operating point is set towards the bottom or towards the top of the curve there will also be distortion of the output wave shapes because part or all of the lower or upper half-cycles will be cut off. This kind of distortion may be undesirable or desirable, as will be shown later.

The major uses of vacuum tube amplifiers in radio work are to amplify at audio frequencies (approximately 100 to 10,000 cycles per second) and to amplify at radio frequencies (up to 60,000 kc. or higher). The audio-frequency amplifier is generally used to amplify without discrimination at all frequencies in a considerable range (say from 100 to 3000 cycles for voice communication), and is therefore associated with non-resonant or untuned circuits. The radio-frequency amplifier, on the other hand, is generally used to amplify selectively at a single radio frequency, or over a small band of frequencies at most, and is therefore associated with resonant circuits tunable to the desired frequency.

The circuit arrangement of a typical audio-frequency amplifier using a triode is shown at A in Fig. 46. The alternating grid voltage is applied through the transformer T_1 to the grid circuit, in series with the grid bias furnished by a battery. The alternating current component in the plate circuit induces an alternating voltage in the secondary of the output transformer T_2. This output might go on to another similar audio amplifier for further amplification. In lieu of the output transformer, a pair of 'phones could be connected in place of the primary in the plate circuit, in which case the alternating component in the plate current would be reproduced immediately as sound.

In B of Fig. 46 is shown the circuit arrangement of an amplifier for radio frequencies. In this case the tube is of the screen-grid type, the extra element being placed between the control grid and plate to prevent the feed-back and oscillation that will be discussed in the next section. Its operation, however, is similar to that shown in Fig. 45. The input and output circuits in this case are resonant circuits, tuned to the radio frequency that is to be amplified. The grid bias, instead of being furnished by a separate battery, is furnished by the voltage drop across the cathode resistor resulting from the steady plate current flowing through the plate circuit (which includes the "B" supply). Since this flow of current is from plate to cathode in the external circuit, the supply side of the cathode resistor will be negative with respect to the cathode and thus apply negative bias to the grid. Methods of obtaining grid bias are explained further in Chapter Five.

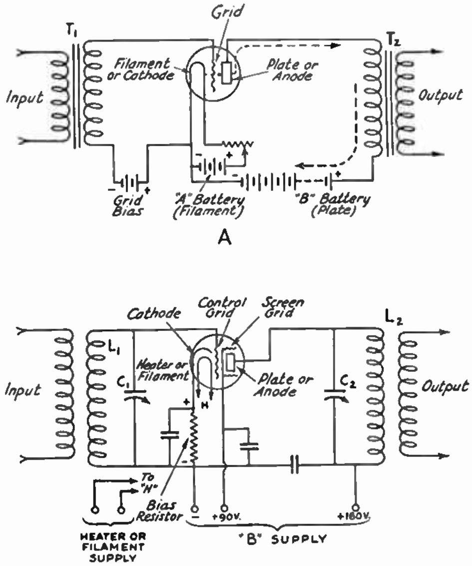


FIG. 46 — CIRCUITS OF TYPICAL VACUUM TUBE AMPLIFIERS

Generating Radio Frequency Power — Oscillators

Because of its ability to amplify, the vacuum tube can oscillate or generate alternating current power. To make it do this, it is only necessary to couple the plate (output) circuit to the grid (input) circuit so that the alternating voltage supplied to the grid of the tube is opposite in phase to the voltage on the plate. Typical circuits for this condition are shown in Fig. 47. In A the feedback coupling between the grid and plate circuits is inductive (by means of coils), while in B the coupling is capacitive (through a condenser). In the circuit of A the frequency of oscillation will be very nearly the resonant frequency of the tuned circuit L_1C_1, while in B the frequency of oscillation will be determined jointly by L_1C_1 and L_2C_2. To insure the proper phase relationship between plate and grid voltage, with the inductive feed-back of A the grid and plate should be connected to the opposite ends of the plate and grid coils when these coils are wound in the same direction; while in the arrangement of B the plate circuit should be tuned to a slightly higher resonant frequency than the grid circuit. (Plate circuit reactance inductive with respect to the grid circuit). At the high radio frequencies used in amateur work the inherent plate-grid capacitance of the usual triode tube is sufficient for feed-back in the tuned-grid tuned-plate type circuit of B and the feed-back condenser shown connected between grid and plate is not necessary.

There are many other arrangements of oscillator circuits but all utilize either the inductive or capacitive feed-back typified in the two shown here. Several of these other types are treated in Chapter Seven. A special type of oscillator of exceptional frequency stability that is becoming increasingly popular is the piezo-electric or crystal-controlled type. Most commonly it resembles the tuned-grid tuned-plate circuit of B with the exception that the tuned grid circuit is replaced by a plate of quartz crystal mounted between metal electrodes. This crystal acts like a tuned circuit, its electrical equivalent being that shown at B of Fig. 48. As shown, it consists of a very high inductance (L) in series with a very small capacitance (C) and resistance (R). The shunt capacitance C_1 is that of the electrodes between which the crystal is mounted, with the quartz as the dielectric. Its exceptional stability is attributable to its high ratio of inductive reactance to resistance; in other words, to its high Q. This property also makes the crystal useful as a very selective tuned circuit or filter for radio reception, as it is used in the Single-Signal receiver outlined in Chapter Five. Power type oscillators and amplifiers are used in combination in radio transmitters, both for radiotelegraphy and radiotelephony, and later chapters will describe practical aspects of these applications.

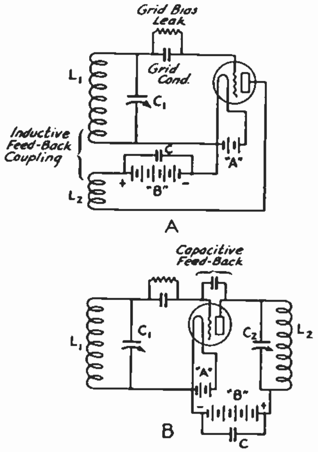


FIG. 47 — TWO GENERAL TYPES OF OSCILLATOR CIRCUITS

Modulation

In addition to generating radio-frequency energy in the transmitter and radiating it from the antenna, it is necessary to do something to utilize this energy for communication of intelligence. This is accomplished by *modulating* the transmitter's output either to form the dots and dashes of the telegraph code (by keying) or by varying the amplitude of the radio-frequency current to conform with the variations in intensity of the voice. Radio-frequency currents modulated by these two methods are represented in Fig. 49, a wave modulated for telegraphy by keying the transmitter's output into dot and dash form being shown in A, and one modulated with a sine-wave of audio-frequency current being shown in B. The outline of the modulation is referred to as the *envelope* and it is to this that the useful output of the receiver must conform. Detailed descriptions of modulation methods for both telegraphy and telephony are given in later chapters.

Detection of Radio Signals

After the modulated radio-frequency current has made its way into the receiver and perhaps through one or more radio-frequency amplifiers, it must be *demodulated* or *detected* to bring out the useful modulation envelope just described. To do this it is necessary to rectify the radio-frequency current. This might be done with the simple diode, as mentioned previously. However, the triode is more commonly used in amateur receivers because it gives much greater output in proportion to its radio-frequency input (is more *sensitive*) than the diode. Triode detectors are of two types, one giving what is known as *plate detection* and the other what is known as *grid detection*.

The circuit arrangement of a typical *plate detector* is shown in A of Fig. 410 and its operating characteristics are illustrated in A of Fig. 411. The circuit L_1C_1 is tuned to resonance with the radio frequency and the voltage developed across it is applied between the grid and cathode, in series with the grid bias battery. A telephone headset (or the primary of a transformer feeding an audio amplifier) is connected in the plate circuit, a small fixed condenser C being connected across the plate load circuit to by-pass radio frequency. As shown in A of Fig. 411, the negative grid bias voltage is such that the operating point is in the lower-bend region of the curve, near cut-off. Hence only the positive half-cycles of the signal voltage are completely effective in causing plate current change. With a modulated signal as shown there will be a variation in plate current conforming to the average value of the positive half-cycles of radio frequency. This variation corresponds to the envelope, representing an audio-frequency current superimposed on the steady plate current of the tube, and constitutes the useful audio output of the detector. When this pulsating current flows through the 'phones their diaphragms vibrate in accordance with it to give a reproduction of the modulation put on the signal at the transmitter. This type of detection is called plate detection because the rectification takes place in the plate circuit after radio-frequency amplification from grid to plate.

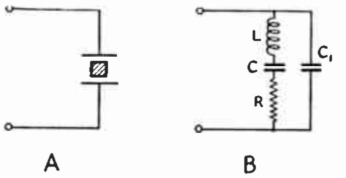


FIG. 48 — EQUIVALENT CIRCUIT OF PIEZO-ELECTRIC QUARTZ CRYSTAL

The circuit arrangement of a triode used as a *grid detector* (also called *grid leak detector*) is shown in B of Fig. 410. Here again we have an input circuit tuned to the frequency of the radio wave and connected so that the r.f. voltage developed across it is applied between the grid and cathode. However, there is no fixed negative grid bias, as in the case of the plate detector, but instead a small fixed condenser (*grid condenser*) and resistor of high value (*grid leak*) in parallel are connected between tuned circuit and grid. The plate circuit connections are the same as for the plate detector.

As shown in B of Fig. 411, the operating point is near the upper bend of the curve because the grid bias is near zero when there is no signal on the grid. A modulated radio-frequency voltage applied to the grid swings it alternately positive and negative about the operating point. The grid attracts electrons from the cathode, the consequent grid current increasing more during the positive half cycles than it decreases during the negative half cycles of grid swing. Hence there is a rectified grid current flow at modulation frequency whose average value develops a voltage across the grid leak. This audio-frequency variation in voltage across the grid leak causes corresponding variations in plate current which are reproduced in the 'phones. In contrast to plate detection, with grid detection the rectification takes place in the grid circuit and there is audio-frequency amplification to the plate circuit. Grid detection is generally used in amateur receivers of limited r.f. amplification because grid detectors are capable of greater sensitivity for small signals than plate detectors using similar tubes. Plate detection is more commonly used where detector sensitivity is of minor importance.

Regenerative Detectors

With both the grid and plate detectors just described it will be noted that a condenser is connected across the plate load circuit to by-pass radio-frequency components in the output. This radio-frequency can be fed back into the grid circuit, as shown in C of Fig. 410, and re-amplified a number of times. This *regeneration* gives a tremendous increase in detector sensitivity and is used in most amateur receivers. If the regeneration is sufficiently great the circuit will break into oscillation, which would be expected since the circuit arrangement is almost identical with that of the oscillator shown in Fig. 47-A. Therefore a control is necessary so that the detector can be operated either regenerating to give tremendous amplification without oscillation, or to oscillate and regenerate simultaneously. Methods of controlling regeneration are given in Chapter Five.

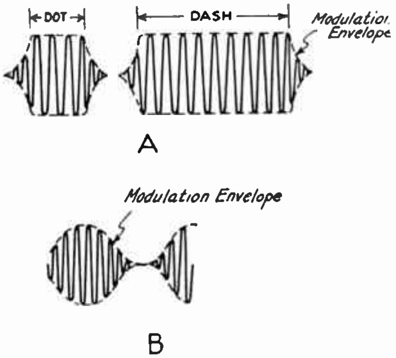


FIG. 49 — RADIO WAVES MODULATED FOR C. W. TELEGRAPHY AND TELEPHONY

Heterodyne or Beat-Note Reception

In discussing the detection of signals it has been pointed out that the detector output is a replica of the modulation applied at the transmitter. In the case of radiotelephony this modulation is at audio frequency and the methods of detection that have been described will reproduce it satisfactorily. But in the case of c.w. radiotelegraphy the variations in detector plate current, while they correspond with the dots and dashes of the code, will not cause an audio-frequency tone in the 'phones unless they are actually modulated with a tone of audible frequency. The most satisfactory method of giving this tone to c.w. signals is by *heterodyne* action, a form of modulation. The idea is illustrated in Fig. 412. When two alternating voltages of different frequencies are simultaneously applied to a detector, there appear in the detector output circuit current variations of both the original frequencies, of their sum frequency and of their difference frequency. This difference frequency is the *beat note*, and if the difference between the two original frequencies is an audio frequency, the beat note will be of audio frequency. One of the original frequencies is, of course, that of the radio signal. The other is that of a local oscillator. This local oscillator may be separate from the detector or a separate heterodyne. In most cases, however the detector itself also serves as the local oscillator to give the beat

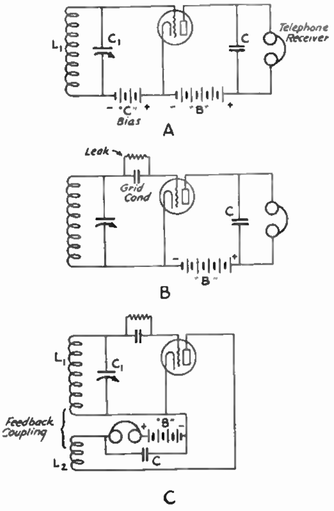
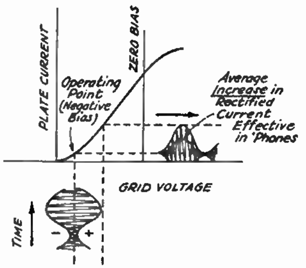


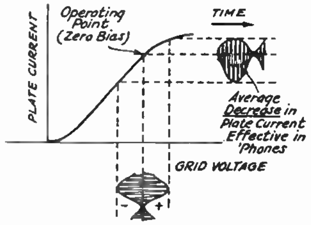
FIG. 410 — DETECTOR CIRCUITS OF THREE TYPES

A — Plate detection; B — Grid detection; C — Regenerative grid detection.

note. When so used, such a detector is known as an *autodyne*. A regenerative detector circuit like that shown in Fig. 410-C, with the regeneration adjusted so that the detector oscillates, is commonly used for amateur c.w. reception.



A – PLATE DETECTION



B-GRID DETECTION

FIG. 411 — OPERATING CHARACTERISTICS OF, A — PLATE DETECTOR, B — GRID DETECTOR

Superheterodyne Reception

As was mentioned in the section on series and parallel resonance, the selectivity of tuned circuits is relatively poor at even the lower amateur frequencies. At the higher amateur frequencies it becomes worse. Therefore it is impracticable to obtain really high selectivity in tuned amplifiers resonant to frequencies in the amateur bands. On the other hand, both higher selectivity and greater amplification per stage can be obtained in radio-frequency amplifiers operating at intermediate frequencies of 500-kc. or so. Such amplifiers can be utilized for amateur reception by converting the amateur frequency signals to the lower *intermediate frequency*. This also is possible by the heterodyne method.

Both the incoming signal and the local oscillator signal are introduced in a detector, with the local oscillator frequency either intermediate frequency higher or lower than the signal frequency. Since the difference between the two frequencies is quite great in this case, it is advisable to use a separate oscillator rather than to use the detector as an autodyne. The output of the detector is coupled to the i.f. amplifier stages by a radio-frequency transformer tuned to the intermediate frequency, thus filtering out the difference frequency component in the detector output and eliminating the other components. After amplification in the intermediate-frequency (i.f.) stages, the signal is detected in normal fashion by the *second detector*. If the incoming signal is modulated at audio frequency, the intermediate-frequency signal will be identically modulated and the audio-frequency output of the second detector will be normal. For c.w. reception it will be necessary to use a second heterodyne oscillator at the second detector or to operate this detector as an autodyne, as with the detector in the usual amateur receiver. A receiver operating in this fashion is a *superheterodyne*. Several types of modern superheterodyne receivers especially designed for high-frequency work are shown in Chapter Five.

Generation of Harmonic Frequencies

Distortion in vacuum tube amplifiers causes harmonics and we often purposely adjust vacuum tube circuits to give us maximum distortion when we desire output at a frequency that is a harmonic of the exciting frequency. High input voltage amplitude or grid swing and high negative bias are favorable for the production of harmonics. Because of curvature in the plate-current plate-voltage characteristic curves and because there is a different plate-voltage plate-current (static characteristic) for each value of impressed grid voltage, the current wave-form in the plate circuit becomes distorted, resulting in the generation of harmonic frequencies. A low plate-load (external) resistance or impedance will emphasize such distortion. Even with a high grid bias, large inputs to the grid circuit will also cause the grid to become positive during part of the input cycle, causing grid current to flow, thus decreasing the grid-filament resistance of the tube. This results in an uneven load and produces further distortion and harmonics. The way in which distortion in the output wave-form introduces a harmonic impulse or component is indicated in Fig. 413.

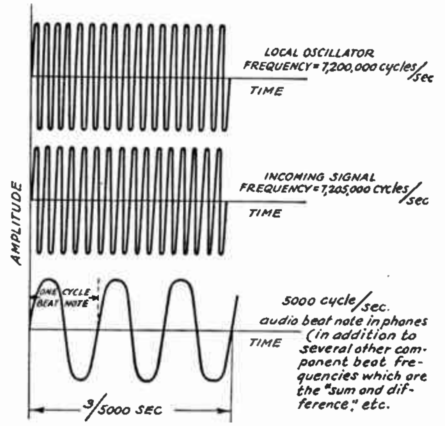


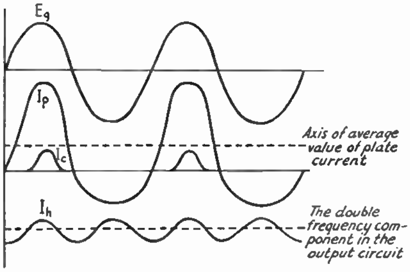
FIG. 412 — ILLUSTRATING HETERODYNE ACTION

Harmonics cannot be generated at frequencies below the fundamental but always occur at higher frequencies. When we pick up a radio signal with the receiver tuned to half the frequency of the transmitting station it is because our oscillating detector generates a harmonic *in the receiver*. In this case the harmonic is beating with the fundamental frequency of the transmitter.

By properly biasing tubes and tuning the output circuit to a desired harmonic frequency, a vacuum tube may be operated as a frequency doubler or frequency tripler, etc.

How Radio Waves Travel in Space — Fading and Skip Distance

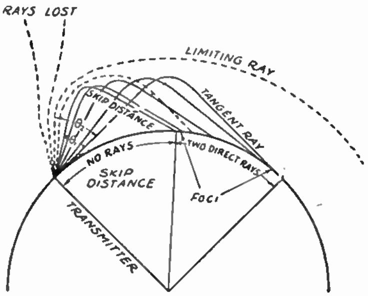
No discussion of amateur radio or of high-frequency phenomena can be complete without something about the commonly accepted theory advanced in explanation of the things that have been observed in connection with high-frequency transmission. It appears that just as light waves can be reflected and refracted so it is with radio waves. The behavior of radio waves is harder to understand because these waves are not visible or audible except by artificial means of detection. The frequency spectrum used for radio communication is a wide one and the determination of what happens is further complicated by the continuous variations taking place in the medium traversed by the radio waves. The bending or refraction of radio waves in the upper atmosphere is attributed to the presence of free electrons resulting from ionization of the earth's upper atmosphere, principally by radiation from the sun. The ionization passes through a daily and seasonal variation depending on sunlight and changes in the sun's radiation.



E_g – *Sine-wave input impressed on grid*
I_p – *Distorted output plate current wave*
I_c – *Grid current – when grid becomes positive occurring at right time intervals to set up second harmonic.*
I_h – *The harmonic component of the output current*

FIG. 413 — HOW DISTORTION CAUSES HARMONICS IN VACUUM TUBE OPERATION

Changing reflecting and refracting properties of the Kennelly-Heaviside layer, so named for the two men who independently and almost simultaneously proposed the existence of an ionized region in the upper atmosphere, are presumed to account for the rapid variation in the intensity of received signals that is called *fading*.



θ_1 ANGLE AT TRANSMITTER CORRESPONDING TO THE FIRST CRITICAL ANGLE
θ_2 ANGLE AT TRANSMITTER CORRESPONDING TO THE SECOND CRITICAL ANGLE

FIG. 414 — HOW RADIO WAVES TRAVEL FROM TRANSMITTER TO RECEIVER

The vertical and near-vertical rays penetrate the ionized layer and wander away. When one reaches the "limiting angle" the ray just does get bent enough to be kept from wandering away, but it continues to graze the layer and is after all worthless. Below this angle we have progressive reflection (or refraction) and the ray returns to earth. As the angle of departure from the transmitter is chosen flatter the energy strikes so far away as to miss the earth, possibly going out to the ionized layer again, and perhaps even being reflected down a second time if it has energy enough left.

Fig. 414 explains what is commonly referred to as the *skip distance*, that distance which sig-

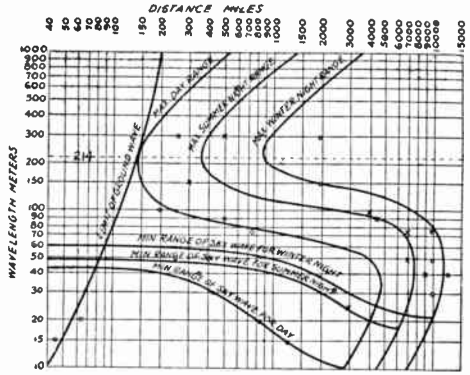


FIG. 415 — APPROXIMATE AVERAGE TRANSMISSION PERFORMANCE OF DIFFERENT WAVELENGTHS AT DIFFERENT DISTANCES

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

nals skip over. The signal decreases in intensity as we leave the transmitter due to spreading out and to energy absorption. It finally drops below a useful value, remaining out until we reach a great distance from the transmitter, after which it unexpectedly gets strong again, gradually dropping in intensity at still greater distances. The skip distance at night is much greater than in the day time. It gradually increases up to about midnight. The skip distance also is known to be greater in winter than in summer which seems reasonable because the ionization should be less then, due to shorter periods of sunlight. It can be seen readily from the charts that the skip distance is very definitely influenced by the transmitted frequency.

Fading is usually less violent over long distances because the waves can arrive by many routes, thus averaging conditions and giving a fair signal in spite of fading along some paths. Right at the edge of the skip distance interference effects may occur with very severe fading, while beyond this point the rays of high-angle radiation die out, giving a better chance for a steady signal. In general high-frequency communication results go to prove that the skip distance for any given time decreases with decreasing frequency. While skip-distance effects are important on our high frequencies they are not as noticeable on the broadcast band and less important still on low frequencies.

There is nothing absolute about any of the rules that different investigators have devised for determining whether a signal from a certain transmitter can be heard at a given point. However, some charts and rules are useful when studying the subject of transmission phenomena, even though they are approximate. Such a chart is shown in Fig. 415 with an explanation of what it means. It shows roughly what may be expected of different frequencies or the corresponding wavelengths in radio communication.

Amateur experience seems to indicate that the power of a transmitter is one of the less important considerations in high-frequency work. Extreme distances are covered day and night with less than ten watts in the antenna using 14,000- and 7000-kc. frequencies, and the signal strength of high and low power stations is much the same. The conditions in the upper atmosphere are undoubtedly the most important factor in determining the results.

Chapter Five

RECEIVER CONSTRUCTION

To GET the greatest fun and benefit from amateur radio work you will want to get into the game with a complete station. Perhaps some readers of this *Handbook* wish to "experiment" and to build equipment for testing purposes only. Some individuals get their chief pleasure in making measurements comparing the performance of apparatus by laboratory methods. Some are never happy unless they are continually examining different circuits, becoming familiar with their operation and tearing them down again. However, if you are like most amateurs, you probably will prefer to put together a complete but inexpensive station and get your enjoyment from its operation.

Building an amateur station usually is a gradual process. Most amateurs start out with a simple receiver, listening in on it until they become proficient in the art of tuning in high-frequency signals, and at the same time learning the code in preparation for obtaining a transmitting license. The first receiver need not be an elaborate one; in fact it is better to pick out a simple set for the initial attempt. It will be relatively easy to get such a set working and, even though it is built with the full knowledge that it will not be the permanent receiver of the finished station, the investment in the equipment for it will not be wasted. Most of the parts used in simple receivers can be used equally well in more intricate sets later on. In this chapter several types of receivers are described. All of them are thoroughly practical outfits, capable of giving excellent service if carefully built and correctly operated.

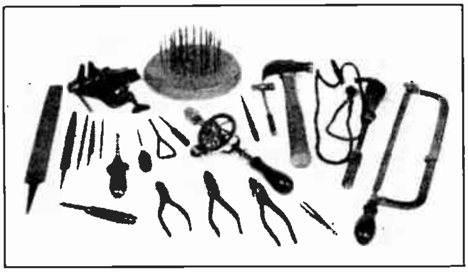


FIG. 51 — TOOLS FOR CONSTRUCTION

All are convenient but not entirely necessary. A set of small taps and dies, a circle cutter to cut holes for meters and tube sockets, a bit brace and a set of socket wrenches will be useful in addition, if regular construction work is planned.

Tools

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

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

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

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

A table of drill sizes giving the proper numbered drill to use for passing a screw through a panel or for tapping to take a certain size of machine screw is included in the Appendix. Only the sizes most used in radio constructional work are given. Wood screws also come in various sizes and lengths. Usually the numbers correspond to the drill-size numbers, the diameter given being that of the screw just below the head. Wood screws are stocked by most hardware stores in lengths to the nearest quarter inch of what you want.

Soldering and Wiring

In wiring different pieces of apparatus a neatly soldered job will repay the builder in good appearance and reliable operation. Good connections may be made without solder, but a well-soldered job has low contact resistances. A soldered outfit works quietly and uniformly over long periods of time. Soldering is decidedly worthwhile when properly done.

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

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

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

Bus wiring is neat and effective. The wires are laid out in straight lines running straight back, horizontally and vertically. The corners are made square. Hold bus wires firmly with pliers while a little solder "runs" into the joint.

In receiver wiring, battery leads may be bunched to good advantage. Radio-frequency circuits should have the leads well spaced. Wires should cross at right angles when crossing is necessary. Connections between coils and condensers in radio-frequency circuits should be as short as possible. However, coils and condensers must not be jammed together too much as this increases the effective resistance and lowers the sensitivity. Leads a couple of inches long are permissible and will allow mounting the condenser out of the field of the coil.

Designing the Receiver

Fortunately the short-wave receiver need not be a complicated affair like the broadcast receiver. The majority of amateurs use *autodyne* receivers, in which the signals are detected by an oscillating tube as explained in Chapter Four. Such a receiver may have two, three or four tubes, but even a single tube can serve to receive amateur signals over long distances. The first requirement in this type of receiver is a detector tube connected to a tuned circuit and provided with a tickler coil so that it may oscillate. A regeneration control must be provided so that the detector can be maintained in a condition of weak oscillation for the reception of telegraph signals or held at the point just below oscillation for 'phone reception. Most amateurs prefer louder signals than a single tube can give, and therefore additional tubes are used to provide amplification. Radio-frequency amplification is used between the antenna and the detector to make the receiver sensitive to weak signals, and audio-frequency amplification follows the detector to make all signals louder. More than one stage of radio-frequency amplification is rarely necessary at amateur frequencies, and a single stage of audio is usually sufficient for good headset reception, although two audio stages are often used.

Another type of receiver which is becoming increasingly popular among amateurs is the *superheterodyne.* Because the superheterodyne can be made much more selective — in other words, can separate more readily stations whose frequencies or wavelengths are close together — for the reception of modulated signals than the regenerative receiver, it has been adopted by a large number of amateur radio-phone operators. For c.w. telegraph reception, however, the ordinary superheterodyne receiver has not sufficiently greater selectivity than the autodyne receiver to make its use worth while unless it is of the "single-signal" type mentioned later in this chapter. Because of the greater number of tubes and other apparatus required and the complications of building a superheterodyne receiver, most telegraphing amateurs use regenerative receivers equipped with a stage of tuned radio-frequency amplification. The three-tube receiver described in this chapter will fully meet the receiving requirements of the average amateur.

Tuning Arrangements and Band Spreading

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

Tuning condensers used in high-frequency receivers are much smaller than those employed for the broadcast band and lower frequencies. A 350- or 250-μμfd. condenser will, at high frequencies, cover so much territory that tuning becomes extremely difficult, because the amateur bands occupy only a few divisions on the usual 100-scale dial. Many amateurs remove plates from standard-sized condensers to reduce the maximum capacity, or else use midget condensers, which can be obtained in a variety of capacities. If the receiver is to cover all frequencies between 20,000 and 3000 kc., common practice is to use a tuning condenser rated at 150 μμfd. with three plug-in coils, but even this arrangement crowds the amateur bands in a very small proportion of the dial scale. Most amateurs prefer to spread the bands over a large part of the dial.

The amateur bands are not entirely in harmonic relation, and therefore a condenser which spreads one band satisfactorily will not give the same spread on others. In order to make each band cover a large number of dial divisions, the ratio of maximum to minimum capacity must be different for each band. One method is to use plug-in midget tuning condensers which are changed each time the coils are changed. The standard midget condensers will not always work satisfactorily, and plates must therefore be removed until each band is spread as much as desired. Since this method is somewhat cumbersome mechanically, its use is not very practical if the receiver has a tuned r.f. stage.

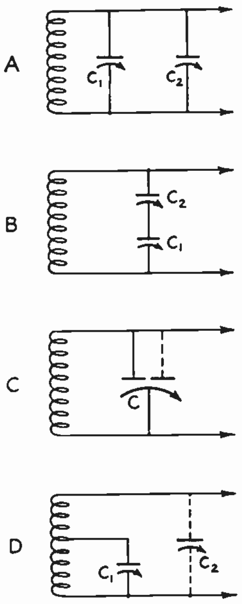


FIG. 52 — THE ESSENTIALS OF FOUR POPULAR BAND-SPREAD SYSTEMS

Several widely-used band-spreading schemes are shown in Fig. 52. At A is the parallel-condenser method. C_1 is the tuning condenser, usually with a maximum capacity of about 25 μμfd. C_2 is a "band-setting" condenser; its maximum capacity should be at least 100 μμfd. and may be larger. The setting of C_2 will determine the minimum capacity of the circuit, and the maximum capacity will be the maximum capacity of C_1 plus the setting of C_2. A different maximum-to-minimum capacity ratio can be chosen to give good band-spreading on each band. Fig. 53 shows a condenser made for this system of band-spreading.

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

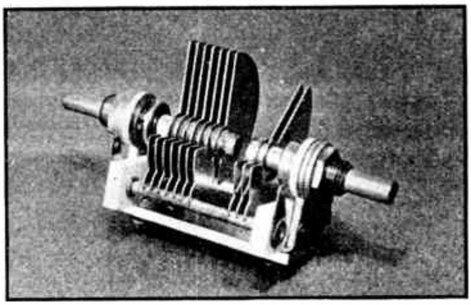


FIG. 53 — A TYPICAL BAND-SPREAD CONDENSER

At C is another arrangement which makes use of a "split-stator" tuning condenser — one with two separate stationary-plate sections and a single rotor. One of the stator sections is made small enough to give good band spreading on the 14- and 7-megacycle bands, and the second stator section, when connected in parallel with the small stator, will give good spread on 3500- and 1750-kc. The dotted connection for the two lower-frequency bands shown in C can be made by using a jumper in the low-frequency coil forms, the change being automatically made when the coils are plugged in. This method is used in the two-tube a.c. receiver described later in this chapter.

The tapped-coil system at D is used in one commercial amateur-band receiver and has also been adopted by a number of amateurs in home-built sets. Condenser C_1 may be fairly large — 100 μμfd. or so — but will give good spread on any band if the right size of coil is chosen and the tap to which the stator plates of the condenser are connected is made at the right place. This system is a little more tricky to adjust than the first three. Condenser C_2 is not strictly necessary but will be found helpful in getting the spread just right, and its use will help eliminate some of the cut-and-try in winding the coils. It should have a maximum capacity of about 25 μμfd.

Regeneration Control

The regeneration control is the next most important item in the receiver. Almost any arrangement of the tickler coil and feed-back control can be depended upon to give similarly loud signals, but some of them have the advantage of being more convenient and of permitting adjustment of regeneration without detuning the signal. It is also a great advantage if the regeneration control is absolutely quiet in action; if it permits a gradual adjustment up to and past the point of oscillation; and if it permits the tube to oscillate gently all across the frequency band on which the receiver is working without the necessity of touching anything but the tuning control.

Fig. 54 shows two ways in which regeneration may be controlled with a screen-grid detector. At A the regeneration control is a variable condenser having a maximum capacity of 100 or 150 μμfd. It acts as a variable by-pass between the low-potential end of the tickler coil and the cathode of the tube. If the by-pass capacity is too small the tube will not oscillate, while increasing the capacity will cause oscillations to start at a certain critical value of capacity. This method of regeneration control is very smooth in operation, causes relatively little detuning of the received signal and, since the voltage on the screen-grid of the tube is fixed, permits the detector to be worked at its most sensitive point. The sensitivity of a screen-grid detector depends a great deal upon maintaining the screen-grid voltage in the vicinity of 30 volts.

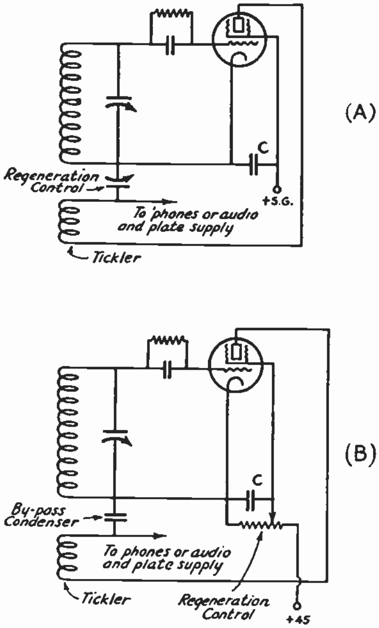


FIG. 54 — CONDENSER AND RESISTOR CONTROL OF REGENERATION

At B regeneration is controlled by varying the mutual conductance of the detector tube through varying its screen-grid voltage. The regeneration control is usually a voltage-divider — or so-called "potentiometer" — with a total resistance of 50,000 ohms or more. This circuit causes more detuning of the signal than A, and the resistor is likely to cause some noise unless by-passed by a large capacity (about 1 μfd.) at *C*. In A, condenser *C* may be .5 μfd. or larger. With circuit B it is necessary to adjust the number of turns on the tickler coil to make the tube just start oscillating with about 30 volts on the screen-grid if maximum sensitivity is desired.

Both the methods shown in Fig. 54 may be applied to three-electrode detectors, although these tubes have been largely superseded as detectors by the more sensitive screen-grid tubes. To use method B the regeneration-control resistor should be placed in series with the plate of the tube and it need not be used as a voltage-divider but simply as a series variable resistor. It can also, as a matter of fact, be used as a series resistor when controlling a screen-grid tube.

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

Radio-Frequency Amplifiers

A regenerative detector followed by a stage or two of audio-frequency amplification and used for c.w. telegraphic work will bring in amateur signals from all over the world on the higher frequencies. For such work, the sensitivity of this type of receiver usually proves to be ample. At times, however, a radio-frequency amplifier ahead of the detector is very desirable. The increase in sensitivity (and perhaps selectivity) provided by it can be put to good use in the reception of amateur radiotelephone signals or in copying telegraph signals from great distances. A further advantage of such an amplifier is that it isolates the detector from the antenna, reducing the radiation from the detector in an oscillating condition and making it impossible for the antenna, swaying in a wind, to cause the received signal to waver. A radio-frequency amplifier is also of considerable service in the elimination of "dead-spots" in the detector — points on the tuning dial at which the antenna, coming into resonance, might otherwise stop the detector from oscillating.

The three-element tube is almost useless as a radio-frequency amplifier in the short-wave receiver. The modern screen-grid tube, however, is most effective providing the circuit in which it is used is a suitable one. A common arrangement for the radio-frequency amplifier is one in which the grid circuit for the first tube comprises a resistor or choke connected directly between the antenna and ground. This so-called "untuned" radio-frequency amplifier isolates the detector from the antenna and gives some amplification, but it does not improve the selectivity of the receiver. Rather does it make the receiver susceptible to interference from any near-by powerful amateur or broadcast transmitters. Careful proportioning of the choke in the grid circuit makes it possible to avoid interference from broadcast stations, but not from other amateurs. If local interference is not likely to be troublesome an untuned r.f. stage will be found helpful. It is not hard to install because no shielding will be necessary.

Fig. 55 shows two methods of connecting an untuned r.f. amplifier to a regenerative receiver. That at A uses transformer coupling between the r.f. stage and detector, while at B impedance coupling is shown. Transformer coupling is preferable because the number of turns on the two coils can be proportioned to give the greatest amplification (usually the primary, *P*, should have about ⅔ as many turns as the secondary, *S*), and because the plate voltage for the r.f. tube is kept away from the detector circuit. It requires coil forms with enough pins to take care of primary, secondary and tickler, however. With impedance coupling, as at B, the detector coil must be isolated from ground by means of the by-pass condenser *C*. The grid leak must be connected between grid and filament instead of across the grid condenser, since the latter blocks the positive plate voltage from getting to the grid of the detector. Because of leakage across the grid condenser this circuit may be noisy unless a good mica condenser with extremely high insulation resistance is used.

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

Shielding

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

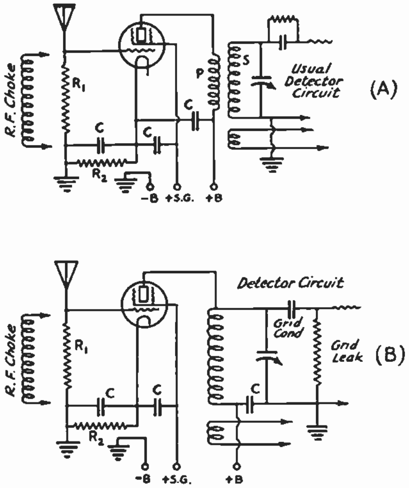


FIG. 55 — UNTUNED R. F. AMPLIFIER DIAGRAMS

A, transformer coupling, B, impedance coupling to detector. A resistor, R_1, having a resistance of 10,000 to 20,000 ohms is connected between the grid of the screen-grid amplifier tube and ground. An r.f. choke, consisting of perhaps 100 turns of small wire wound on a form about the size of a pencil, can be substituted for the resistor if interference is experienced from local broadcast stations. Resistor R_2 gives the tube the correct operating bias, as explained in a later section of the text. If the tube filament is directly heated a battery of the proper voltage should be substituted for the resistor, and the ground connection should be brought to the filament of the tube.

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

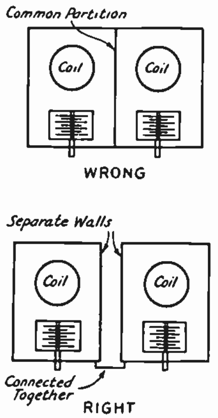


FIG. 56 — SHIELDING ALWAYS SHOULD BE COMPLETE ABOUT EACH PIECE OR GROUP OF APPARATUS SHIELDED

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

To be effective a shield must be grounded. Although an actual ground connection always will be best, it is sometimes sufficient to connect the shielding to a point in the receiver at zero r.f. potential, such as the negative side of the plate supply. Another point is that shields must be complete for each amplifier stage or group of apparatus shielded. Do not attempt to use a single sheet of metal to form a common wall for two shields as shown in Fig. 56; such a wall will actually couple the two shielded groups or pieces of apparatus together instead of shielding them from each other.

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

Although, as we pointed out in the previous section, shielding is not necessary if no tuned r.f. amplifiers are used, it is often helpful. A metal cabinet about a simple receiver will prevent direct pick-up of signals by the coils and wiring of the set, and it will also keep out "induction hums" from unshielded house wiring.

Amplifier Biasing

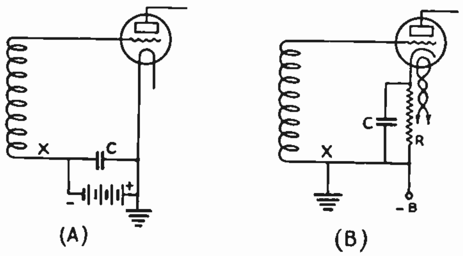
Practically all amplifiers, both audio and radio frequency, must be operated with a fixed negative voltage between the grid and cathode of the amplifier tube. This fixed or *bias* voltage may be obtained from a battery or from a suitable voltage drop through a resistor in the circuit. Fig. 57 shows these two methods in an elementary fashion.

In general, the battery-bias method should be used with tubes having directly-heated cathodes (*filament-type* tubes). In such cases one side of the filament is connected to ground so that in order to connect the bias battery in series with the lower end of the transformer secondary or whatever may be in the grid circuit of the amplifier tube it is necessary to insulate point X in Fig. 57-A from ground. Condenser C is used to provide a low-impedance path to the filament should the bias battery develop appreciable internal resistance. It should be about .01 μfd. in r.f. circuits and 1 to 2 μfd. in audio circuits.

The second method, known as *cathode biasing*, is shown at B. This method does away with the extra bias battery, but usually can be applied only to tubes with indirectly-heated cathodes (*heater-type* tubes). With this method point X is grounded and the cathode is isolated from ground and negative "B" through the biasing resistor R. By-pass condenser C will have the same values as in A. When plate current flows through the tube there will be a voltage drop through R which makes the cathode more positive than the grid — in other words, puts negative bias on the grid. The right value for R can be calculated by Ohm's Law, knowing the bias voltage required and the total space current through the tube. The space current is the sum of the plate current and all currents that may be taken by auxiliary grids in the tube. For example, a four-element tube requires a bias of 10 volts with 150 volts on the plate and screen-grid; at this plate voltage the plate current will be 15 ma. and the screen-grid current 5. The bias resistance required will be:

$$R=\frac{10\text{ volts}}{.02\text{ amp.}}=500\text{ ohms.}$$

Cathode-resistor biasing can be used with tubes having directly-heated filaments provided a separate source of filament-heating is used with each stage so biased. This is often done in a.c.-operated receivers having an audio power output



(A) (B)

FIG. 57 — BATTERY AND CATHODE-RESISTOR BIASING

stage, the power tubes being heated by a separate filament winding on the power transformer.

Audio-Frequency Amplifiers

The problem of sensitivity is taken care of by the regenerative detector and r.f. amplifiers, but in order to obtain "comfortable" signal strength audio amplification is required.

For reception of amateur code signals, it is unnecessary and even undesirable to have the distortionless amplification which is the aim of designers of broadcast receivers. Expensive audio transformers with excellent frequency characteristics are therefore not required. In fact, a transformer which has a decided "hump" at some portion of its frequency curve is preferable, particularly if the hump is in the neighborhood of 1000 cycles. Such a transformer will provide "audio-frequency selectivity," since it amplifies one frequency a great deal more than others. This is decidedly helpful in receiving signals in the more crowded amateur bands, because two signals are rarely on exactly the same frequency, and the beat notes between the oscillating receiver and the received signals are usually sufficiently far apart in the audio scale to allow selection of the desired signal at the audio transformer "peak" frequency, with the result that there is greater amplification of the desired signal than of the unwanted ones.

A different method of obtaining audio-frequency selectivity is incorporated in one circuit now fairly generally used. A large coil is tuned by means of small fixed condensers to 1000 cycles, and the combination forms a coupling impedance which acts as a rejector circuit. Beat notes at about 1000 cycles cannot pass through this tuned circuit and are, therefore, passed on to the grid of the next tube, while those of higher or lower frequency are by-passed to a large extent.

Audio-frequency selectivity can be carried much farther by the use of band-pass or low-pass filters in the audio amplifier circuits. These filters, however, are not easy to build and to adjust, and consequently find favor chiefly in the ranks of advanced amateurs who find their use justified in important communication work when messages must be received through interference at all costs.

For 'phone reception the same principles should be applied as for ordinary high-quality amplification. Plate voltage and "C" bias on the amplifier tubes are important, and should be those recommended in the instruction sheets accompanying the tubes or may be taken from the table. Since, in amateur radiotelephony, we are concerned only with the transmission and reception of speech, it is unnecessary that the equipment be capable of handling frequencies higher than about 3000 cycles per second. Frequencies above this, indeed, serve merely to cause interference and they might well be eliminated.

The receivers described in detail in this chapter are intended to be used with headphones, although they can operate a loud-speaker at low or moderate volume. For satisfactory loud-speaker operation, however, a power audio stage should be used. A number of diagrams for this purpose are given in Fig. 58. These amplifiers had best be a.c.-operated, using power supplies of the type described in Chapter Ten. Other tubes than those shown can be used provided the voltages are changed to the recommendations in the tube table.

Receiving Tubes

The large number of types of receiving tubes available often causes considerable confusion to

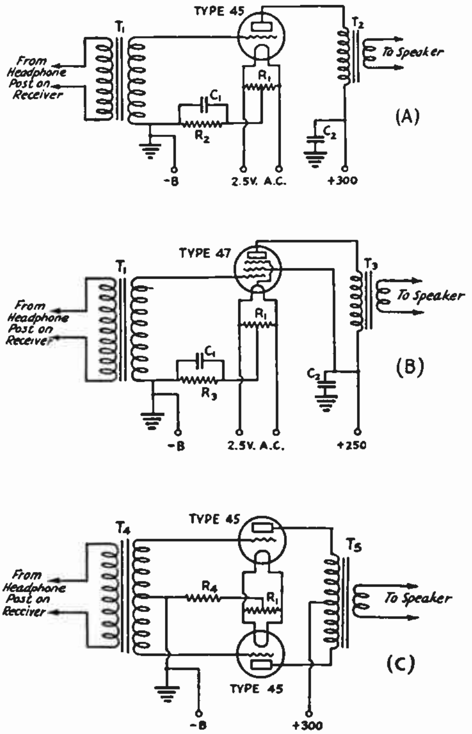


FIG. 58 — AUDIO POWER AMPLIFIERS FOR LOUD-SPEAKER OPERATION

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

the beginning amateur because it seems difficult to choose the proper ones for the contemplated receiver. Modern receiving tubes are grouped into three classes, depending upon the type of service for which they are intended. One group is for dry-cell operation and is characterized by tubes with 2-volt directly heated filaments which take very small currents. The second group has filaments designed for use with a 6-volt storage battery. Most of the tubes in this group have indirectly-heated filaments. The third, or "a.c." group, has filaments which take rather heavy currents at 2.5 volts a.c. In this group the tubes used as r.f. amplifiers and detectors have indirectly-heated filaments while the power audio amplifiers have directly-heated filaments.

In each group will be found general-purpose three-element tubes which are useful as detectors, audio amplifiers and oscillators; screen-grid amplifiers (usually two types of these, one with the "variable-mu" feature, the other without); and various kinds of power amplifiers — triodes, pentodes and special tubes for Class B amplifiers (see Chapter Eight).

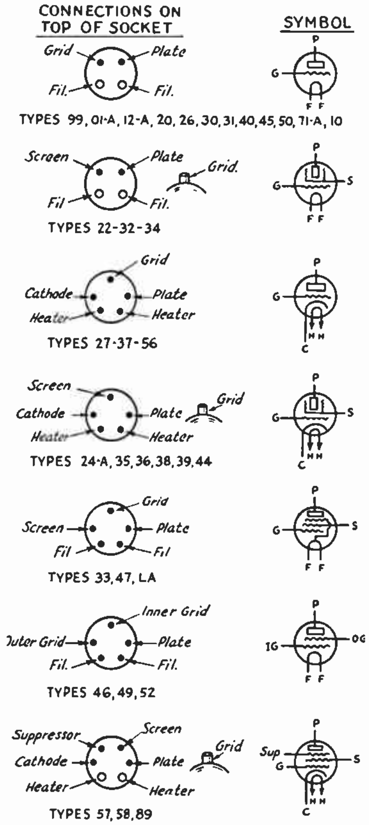


FIG. 59 — SOCKET CONNECTIONS AND SYMBOLS FOR RECEIVING TUBES

The solid circles represent holes for small-diameter pins; larger circles, not filled in, are for the heavy pins.

In addition to these groups, there are also several older types such as the 99 and 01-A which have been superseded by the newer and better tubes and are now only used for special purposes.

From the above it is obvious that the first question to be decided is that of filament supply. If a.c. is available it is undoubtedly best to use the a.c. tubes, not only because no batteries will be required but because, type for type, the a.c. tubes are better than the others. On the other hand, an all-d.c. set will have no "hum troubles."

The table should make it easy to pick out the type of tube needed.

Fig. 59 shows the socket connections for all the tubes listed in the table. The symbol for each type of tube also is shown.

Practical Receivers

The receiver descriptions which follow are intended to illustrate the points just discussed. The various arrangements need not be followed slavishly by the constructor, providing principles of good design are not violated. For instance, any of the various band-spreading schemes already detailed may be substituted for the one in the particular set in which you are interested. If you prefer to use coils wound on old tube bases in a set in which the prescribed coils were wound on manufactured forms by all means do so, but at the same time remember that some modification of the coil sizes given will be necessary if the forms differ in diameter very much from the tube bases. Audio systems may be interchanged, likewise. A little common sense applied to most of the problems you may encounter will solve nearly all difficulties.

A Two-Tube D.C. Receiver

The two-tube receiver illustrated in Figs. 510 and 511 is simple to build, yet it is thoroughly practical and can be depended on to give readable signals, under good conditions, over even the longest distances.

To make construction easy it has been necessary to sacrifice some of those features which we have already stated as being desirable, such as spreading the amateur bands over most of the tuning dial, r.f. amplification, etc. The set is a sort of "preparatory" outfit, to be used until it serves its purpose of helping its owner learn the code, learn something about short-wave receivers, and become acquainted with amateur radio. When this has been accomplished the parts may be used over again in the construction of a receiver more suited to general amateur needs.

Although the receiver is somewhat elementary in design, it is strictly modern, using a screen-grid detector and a pentode audio amplifier. The 2-volt d.c. tubes are used, the detector being a 32 and the amplifier a 33. The circuit diagram and a list of the parts required is shown in Fig. 512. The wooden baseboard of the set is 9½ inches wide by 7 inches deep and is three-fourths of an inch thick. For the sake of appearance it should be sandpapered and lacquered. The panel is a piece of 1/16-inch sheet aluminum measuring 6½ by 9 inches. It is not absolutely necessary to have a metal panel, but it is helpful in pre-

RECEIVING TUBES

Type No.	Description	Fil. Volts.	Fil. Amps.	Plate Voltage	Screen Voltage	Neg. Grid Voltage	Plate Current Ma.	Screen Current Ma.	Watts Output
56	Amp., Det., Osc.	2.5*	1.0	250		13.5	5.0		
57	R.F. Amp., Det.	2.5*	1.0	250	100	3.0	2.0	1.0	
58	Variable-μ R.F. Amp., Det.	2.5*	1.0	250	100	3.0	8.2	3.0	
27	Amp., Det., Osc.	2.5*	1.75	250		21.0	5.2		
24-A	R.F. Amp., Det.	2.5*	1.75	250	90	3.0	4.0	1.3	
35	Variable-μ R.F. Amp., Det.	2.5*	1.75	250	90	3.0	6.5	2.5	
45	Power Amp.	2.5*	1.5	250		50.0	34.0		1.6
46	Power Amp. (Class A ratings)[1]	2.5*	1.75	250		33.0	22.0		1.25
47	Pentode Power Amp.	2.5*	1.75	250	250	16.5	31.0	6.0	2.5
37	Amp., Det., Osc.	6.3	0.3	180		13.5	4.7		
36	R.F. Amp., Det.	6.3	0.3	180	90	3.0	3.1	1.7	
39	Variable-μ R.F. Amp., Det.	6.3	0.3	180	90	3.0	4.5	1.2	
38	Pentode Power Amp.	6.3	0.3	135	135	13.5	9.0	2.5	0.5
LA	“ “ “	6.3	0.3	165	165	11.0	17.0	3.5	1.2
52	Power Amp. (Class A ratings)[1]	6.3	0.3	120		0	42.0		1.0
89	Triple-Grid Power Amp.[1] (Triode) Pentode	6.3	0.4	160 180	 180	20.0 18.0	17.0 20.0	 3.0	0.3 1.5
30	Amp., Det., Osc.	2.0	0.06	180		13.5	3.1		
32	R.F. Amp., Det.	2.0	0.06	180	67.5	3.0	1.7	0.4	
34	Variable-μ R.F. Amp., Det.	2.0	0.06	180	67.5	3.0	2.8	1.0	
31	Power Amp.	2.0	0.13	180		30.0	12.3		0.375
33	Pentode Power Amp.	2.0	0.26	135	135	13.5	14.5	3.0	0.7
49	Power Amp. (Class A ratings)[1]	2.0	0.12	135	135	20.0	5.7		0.17
26	Amp.	1.5*	1.05	180		14.5	6.2		
99	Amp., Det., Osc.	3.3	0.063	90		4.5	2.5		
20	Power Amp.	3.3	0.132	135		22.5	6.5		0.110
22	R.F. Amp., Det.	3.3	0.132	135	67.5	1.5	3.3	1.1	
01-A	Amp., Det., Osc.	5.0	0.25	135		9.0	3.0		
40	Amp.	5.0	0.25	180		3.0	0.2		
12-A	Power Amp.	5.0	0.25	180		13.5	7.6		0.26
71-A	“ “	5.0	0.25	180		40.5	20.0		0.7
10	“ “	7.5*	1.25	425		39.0	18.0		1.6
50	“ “	7.5*	1.25	450		84.0	55.0		4.6

* Alternating current may be used on these filaments.
[1] This tube also intended for Class B service.

venting "body capacity" or the tuning effect of movements of the operator's hand in the vicinity of the tuning condensers and coils. On the panel are mounted the tuning condenser, C_1, the filament rheostat, R_1, and the regeneration control condenser, C_2. The dial is a National Type B. The high vernier ratio of this dial is useful in setting the tuning condenser precisely on the received signal.

The remaining parts are placed on the top of the baseboard in such a fashion that fairly short connections, particularly in the radio-frequency circuit, can be made. The coil forms plug into a 5-prong socket immediately behind C_1, the connections to the socket being made as shown in Fig. 513. The 5-prong socket at the rear center of the baseboard is for the battery connections;

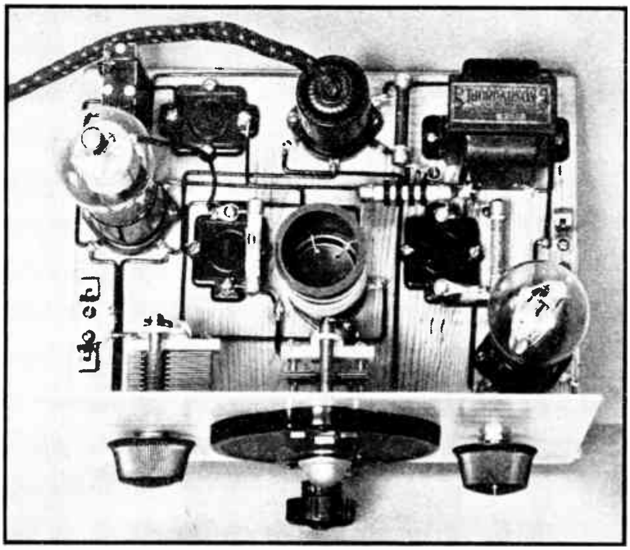


FIG. 510 — GENERAL VIEW OF THE TWO-TUBE D.C. RECEIVER

The dial and tuning condenser, C_1, are centered on the panel. At the left is the regeneration control condenser, C_2, and at the right the filament rheostat, R_1. Directly behind C_1 is the coil socket with a coil in position. At the left side of the baseboard are the Fahnestock clips for antenna and ground connections; just back of them is the detector tube. Between the detector and the coil socket is the grid condenser, C_3, and leak, R_2. The audio amplifier tube is on the baseboard behind R_1, with a pair of clips just back of it for the 'phones. The fixed condenser near the audio tube is C_6; near it is the audio grid leak, R_3, and the radio-frequency choke, RFC. The audio transformer used as a coupling device is at the rear right-hand corner.

a 5-wire battery cable with the wires soldered into the pins of an old 5-prong tube base plugs into this socket. The location of the other parts is explained under Figs. 510 and 511.

Covered bus bar is used for all connections. To make neat wiring all connections should be run parallel to the sides of the baseboard and bends made at right-angles. All joints should be carefully soldered, of course, except those connections which can be made by bending the bared end of the bus bar around a machine screw which can be screwed down tightly.

Because of the high plate impedance of the screen-grid detector it is necessary to use a special coupling between the detector plate circuit and the amplifier grid circuit. This is done by using impedance coupling. The impedance, L_4, in the plate circuit is an audio transformer with the primary and secondary connected in series, and is coupled through condenser C_6 to the grid of the audio tube. R_3 is the audio grid leak. R_4 is shunted around L_4 to take out "fringe howl," an audio howl which sometimes will occur when the detector is just going into oscillation. With some transformers R_4 will not be needed. A coupler such as the one used in the two-tube a.c.-d.c. receiver described in the next section may be substituted for the audio transformer-condenser-grid leak arrangement shown here.

The wire in the battery cable which carries the plus "A" lead is connected externally to the negative "B" and positive "C" batteries. Make sure that the plus "A" lead connects to the grounded side of the filaments. Reversing these connections will increase the tendency toward fringe howl, and is likely also to make the action of C_2 in controlling regeneration less smooth.

The receiver will work well with either 90 or 135 volts on the plates. The grid bias on the amplifier should be fairly high to keep the plate current drain

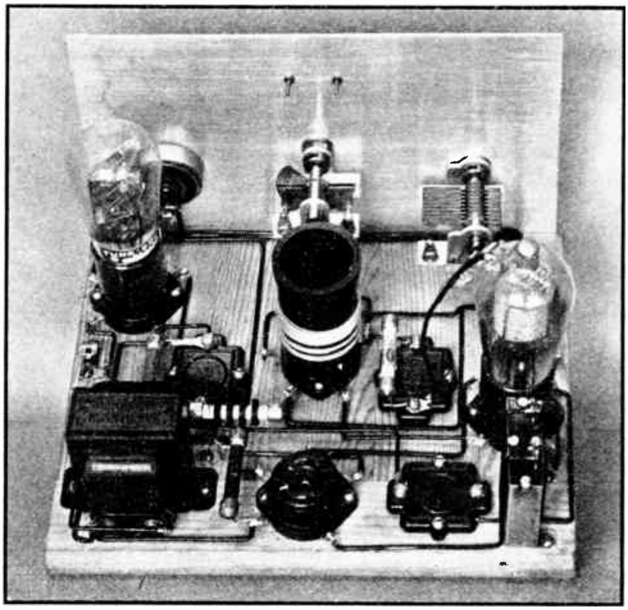


FIG. 511 — ANOTHER VIEW FROM A DIFFERENT ANGLE

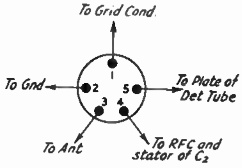
In front of the detector tube is the screen-grid by-pass condenser, C_4. To the left of C_4 is by-pass condenser C_5, fastened down to the baseboard. The 5-prong socket for the battery cable is next in line. Between it and the audio transformer is resistor R_4.

low. A "C" battery with taps will be useful; use as much bias as is consistent with good signal strength.

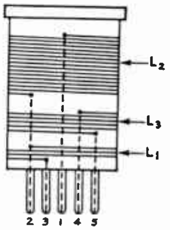
The coils should be wound as shown in Fig. 513. Be certain that the connections on both coil forms and coil socket are exactly as shown and that all the windings are wound in the same direction. If this is not done the detector tube may not oscillate. The coil specifications for the different bands are given under Fig. 512. Although this receiver is not designed for band spreading, the small tuning condenser will be found to spread the lower-frequency bands fairly well over the dial so that tuning in amateur signals will not be difficult.

In the initial testing of the receiver after the construction has been completed the first step should be to connect the "A" battery to test out the filament wiring.

Assuming that all wiring has been checked and found satisfactory, and after making sure that the filament rheostat is in the "off" position, the tubes should be inserted in the sockets and the "A" battery connected to the proper terminals on the battery cable. This battery should consist of a pair of No. 6 dry cells connected in series or an Eveready Air-Cell. The rheostat knob should then be turned until about a quarter of the resistance is in circuit — almost to the "full-on" position.



COIL SOCKET CONNECTIONS



COIL FORM CONNECTIONS

FIG. 513 — COIL FORM AND SOCKET CONNECTIONS

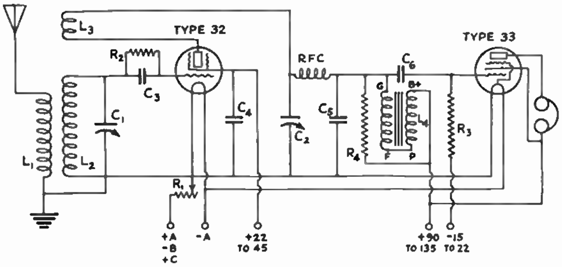


FIG. 512 — WIRING DIAGRAM OF THE TWO-TUBE D.C. RECEIVER

C_1 — 20-μμfd. midget variable condenser (Hammarlund MC-20-S).
C_2 — 140-μμfd. midget variable condenser (Hammarlund MC-140-M).
C_3 — 100-μμfd. fixed condenser (Pilot).
C_4 — 1-μfd. non-inductive condenser (Flechtheim).
C_5 — 100-μμfd. fixed condenser (Pilot).
C_6 — .005-μfd. fixed condenser (Pilot).
R_1 — 20-ohm rheostat (Yaxley).
R_2 — 5-megohm resistor (I.R.C.).
R_3 — 1-megohm resistor (I.R.C.).
R_4 — .25-megohm resistor (I.R.C.).
RFC — Receiver-type r.f. choke (National).

Coil Data

Band	L_1	L_2	L_3
1750 kc.	10	70	14 turns
3500 kc.	5	40	8 "
7000 kc.	5	17	4 "
14,000 kc.	3	6	4 "

All coils close wound with No. 28 d.c.c. wire except the 1750-kc. coil, which is wound with No. 32 s.c.c. Approximately 1/8 inch between coils on form. Forms are 5-prong (National) having a diameter of 1½ inches.

Additional parts required are one 4-prong and three 5-prong Pilot sockets, 5-wire battery cable, National Type 8 dial, wooden baseboard and aluminum panel.

Next connect the 'phones, "B" and "C" batteries. Then, with a coil inserted, turn the regeneration control knob so that the capacity of C_2 is gradually increased, and if the set has been made correctly a click will be heard when the knob is approximately at the half-way position. This click — it is hardly that, but more like a soft thud — indicates that the detector has started to oscillate, which means that the receiver is ready to be connected to the antenna and ground and pick up signals. If the click is not heard try touching a finger to the *stationary* plates of the tuning condenser with the regeneration control set in a number of positions. If, when the condenser plates are touched, a decided click is heard the tube is oscillating — if the values given here have been deviated from slightly the detector may oscillate at all settings of the regeneration control.

On the other hand, if no pronounced click is audible the detector is not oscillating and the wiring should be checked over once more. Changing the detector tube may make some improvement, especially if it is not new. Other causes of refusal to oscillate might be the reversal of winding direction on one of the coils (all coils must be wound in the same direction and the connections *must* be made as shown in Fig. 513); one of the coils on the amplifying transformer might be open-circuited; "B" battery may be old and voltage too low; one or two more turns may be required on L_3; or there may be no plate current getting to the amplifying tube. The test for the latter condition may be made quite simply by pulling out one of the 'phone tips from the Fahnestock clip; if a loud click is heard the amplifier plate circuit is OK. Look out for "rosin joints" — a soldered connection which *looks* good but actually does not make contact or has very high resistance. Be sure to clean off all the rosin which may have run on the coil-form pins when the ends of the coils were being soldered in place. To check for any of the other possibilities the piece of apparatus under suspicion should be taken out and tested. This may be done with a dry cell and a pair of 'phones, which should be put in series with the condenser or transformer winding being tested. There should be no pronounced click in the 'phones when testing a condenser, but there should be a readily noticeable click through transformer windings. These tests usually will indicate where the trouble lies.

The detector is most sensitive to signals when the regeneration control is set at the point where oscillations just start. In searching for signals, therefore, the tuning dial and regeneration control should be worked simultaneously so the tube is always just barely oscillating. It may take a little practice to get the knack of tuning down to a fine art, especially on the coils which cover the higher frequencies, but there is nothing difficult about it.

A Two-Tube D.C.-A.C. Receiver

The receiver just described is an excellent type for the beginner to attempt. The other receivers about to be described are more effective and more attractive in appearance, but they are more difficult to construct.

The second two-tube receiver is designed to use tubes with indirectly heated cathodes. It may be all-d.c. operated by using tubes of the 6.3-volt series with a 6-volt storage battery for filament supply, or the necessity for having a filament battery can be avoided by the use of 2.5-volt a.c. tubes with a suitable filament transformer. Because these tubes are more effective than the 2-volt types the receiver will give better results than the set first described. Then, the provision of a split-stator tuning condenser allows the amateur frequency bands to be well spread on the dial. In this way the receiver is made particularly suitable for use in actual amateur two-way communication. The circuit is very similar to that of the first receiver, the chief differences resulting from the use of tubes of a different type, and capacitive instead of inductive coupling between the antenna and detector circuit.

The panel is a piece of $\frac{1}{8}$-inch sheet aluminum, 7 inches high and 12 inches wide. On it are mounted the drum dial which controls the tuning condenser, the regeneration control resistor, and the "B" cut-off switch, as shown in Fig. 514. The remaining apparatus is mounted on the shelf or "sub-panel," which is also sheet aluminum, 12 inches wide and 6 inches deep. The sub-panel mounting brackets are one inch high.

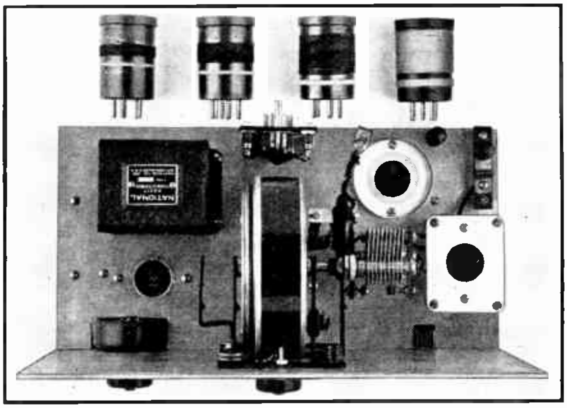


FIG. 515 — THE TOP OF THE SUB-PANEL

The audio coupler, audio amplifier tube socket and regeneration-control resistor are to the left of the drum dial. Connections are brought out to the cable socket to the rear of the dial. Tip-jacks for the 'phones are mounted on this socket. This photo also shows the method of mounting the tuning condenser, grid condenser and leak, and shows the coil socket and antenna condenser mountings from another angle. The ground binding post is mounted on the sub-panel between the detector tube socket and the antenna condenser.

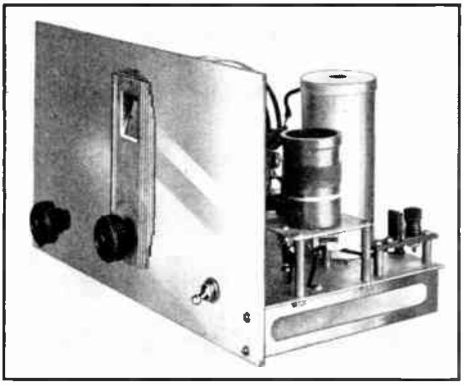


FIG. 514 — THE FRONT PANEL AND PART OF THE "CHASSIS" OF THE TWO-TUBE D.C.-A.C. RECEIVER

This photograph shows the detail of the coil and antenna condenser mountings. The detector tube shield is also visible.

Three five-prong sockets are required, one for the plug-in coils and two for the tubes; the variety used in this particular set are sub-panel sockets of the type widely used by broadcast-receiver manufacturers. It is not necessary to use the same style, of course, although they lend themselves nicely to sub-panel wiring and are inconspicuous.

The tuning condenser is a National Type SE-100 with several plates removed for band-spreading. The drum dial is a National Type HS, which is the projector dial with special mounting brackets for the Type SE condenser. To the right of the condenser, as shown in the top view of the receiver, Fig. 515, is the mounting for the coil socket, and just behind the latter is the mounting for the antenna coupling condenser and the antenna binding post. The reason for these two special mountings is obvious when it is

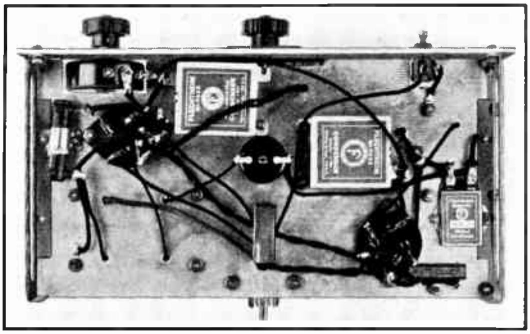


FIG. 516 — UNDER THE SUB-PANEL

The center-tapped resistor for the heater leads is mounted directly underneath the ground binding post. The small condenser to the left is the plate by-pass condenser; the one below the detector tube socket is the screen-grid by-pass condenser. The r.f. choke is in the center. The cathode resistor for the '27 is at the extreme right, held in place by a home-made bracket. The by-pass condenser across the resistor is mounted between the r.f. choke and the front panel. The metal piece behind the r.f. choke is a bracket which rests on the table and serves as a mechanical support for the sub-panel.

remembered that the sub-panel is metal. The mounting for the coil socket is made from a piece of 1/16th-inch aluminum 2 inches by 2½ inches, supported at each corner by brass sleeves 1⅜″ long bolted to the sub-panel.

The antenna coupling condenser is mounted on a 2-inch strip of bakelite which is supported above the sub-panel by two spacers sufficiently long to give ample clearance for the screws holding the condenser and antenna binding post. The condenser itself consists of two strips of thin brass about a half inch wide, bent to face each other about ⅛ inch apart as shown in the photograph.

To spread the various bands satisfactorily the capacity ratio of the tuning condenser is changed for each band so that stations will not be unduly crowded.

The type of tuning condenser used is a particularly easy one to alter for band spreading, since the stationary plates can be removed without difficulty. The nuts holding the stationary plate assembly to the insulating strip on the front of the condenser should be removed; then the two screws holding the rear strip to the frame should be taken out and the stationary plates can be lifted out. The condenser as revamped for this receiver has two stationary sections insulated from each other. One consists of one plate and the other of two, each section being mounted on one of the insulating strips. Three-quarter inch 6-32 machine screws are used to hold the two stator sections in place. Fig. 519 shows clearly how these changes are made.

The connections between the condenser and the coil socket are made as shown in Fig. 518. The single plate alone may be used, or the two sections may be connected in parallel. With the single-plate stator only, the 7000- and 14,000-kc. bands will be amply spread on the dial scale, while with the two sections in parallel the 1750- and 3500-kc. bands will cover a goodly portion of the dial. The change from one condenser section alone to two in parallel is made automatically by connecting a jumper between the coil-form prongs which connect to the two stator sections of the tuning condenser when the coil is placed in the socket.

Other details of the arrangement of the parts and of the wiring can be followed in an examination of the illustrations. It will be noted that a Yaxley cable socket is used in place of binding posts for external leads and that all wiring is made with flexible "hook-up" wire, the leads running directly from one point to another.

In this receiver the coils are wound on manufactured five-prong coil formers. Specifications for the windings are given, but it may be necessary to make slight changes in them in order to obtain the best possible performance. Since the antenna will have some effect on the tuning of the detector circuit, it may be found that the bands will not be centered on

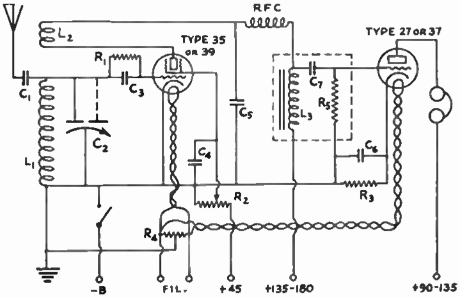


FIG. 517 — THE CIRCUIT OF THE TWO-TUBE A.C. SET

The filament supply should be 2.5 volts a.c. if 35 and 27 tubes are used, 6-volt storage battery with 39 and 37 tubes.

C_1 — Antenna coupling condenser; see text for details.
C_2 — Split stator condenser; see text.
C_3 — 100 μμfd.
C_4 — .5 μfd.
C_5 — 200 μμfd.
C_6 — 1.0 μfd.
R_1 — 10 megohms.
R_2 — 100,000-ohm variable resistor.
R_3 — 2000 ohms.
R_4 — 20-ohm center-tapped resistor (not required if d.c. tubes are used).
RFC — Receiver-type r.f. choke.
L_3, C_7, R_5 — National Screen-Grid Detector Coupler, Type S-101. If a home-made coupling is assembled, C_7 should be about .006 μfd. and R_5, 2-4 megohms. See text for details of L_3.

Coil Data

Band	L_1	L_2
1750	70 turns No. 32 s.c.c.	10 turns No. 32 s.c.c.
3500	37 " " 22 d.s.c.	6 " " 30 "
7000	19 " " " "	4 " " " "
14,000	8 " " " "	4 " " " "

All coils are close-wound except the 14,000-kc. grid coil. The spacing between turns on this coil is adjusted until the band is covered. Spacing is approximately half the diameter of the wire.

the tuning dial unless a few turns are added to or subtracted from the numbers specified for the grid coils. It is particularly important that the tickler windings be adjusted so that the detector oscillates with approximately 22 volts on the screen-grid. To accomplish this it is helpful to connect the screen-grid lead temporarily to a 22½-volt tapping, then adjusting the ticklers until the detector just oscillates at the "high" setting of the regeneration control, R_2. With the screen lead back on the 45-volt tapping there will be plenty of range for the regeneration control.

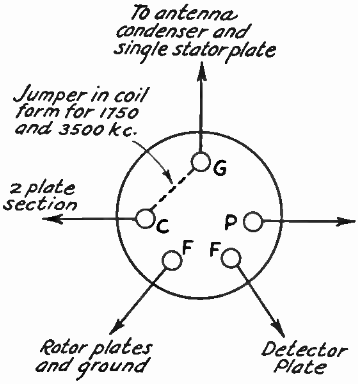


FIG. 518 — COIL FORM AND SOCKET CONNECTIONS FOR THE TWO-TUBE A.C. RECEIVER

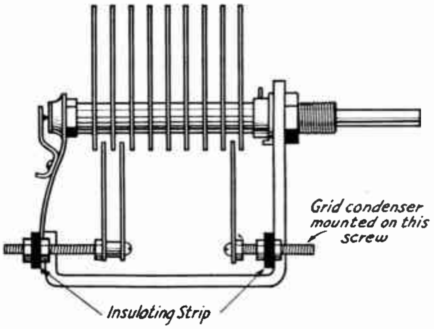


FIG. 519 — HOW THE TUNING CONDENSER IS REMODELLED

Instead of using an audio transformer with the primary and secondary connected in series as a coupling impedance in the detector plate circuit as was done in the first receiver, a special coupler made for the purpose is used in this set. The audio transformer stunt may be used instead, of course.

There should be no hum in the receiver with 35 and 27 tubes and an a.c. filament supply. If filament hum is encountered make certain that the center-tap resistor, R_4, is connected properly and that the receiver is connected to a good ground. A cold water pipe is best. If this does not cure it, try other tubes. An otherwise good tube may have a bad hum, especially when used as a regenerative detector. There will be no hum, of course, with d.c. tubes and a storage battery filament supply.

Either batteries or "B" substitutes may be used for the plate and screen-grid voltages. Many "B" substitutes, while entirely adequate for broadcast receivers or audio amplifiers, are unsatisfactory on short-wave regenerative receivers because their output voltage is not constant, making the received signals sound unsteady, or because of tunable hums. Chapter Ten goes into this subject in more detail. If batteries are used the switch in the minus "B" lead should be opened when the receiver is not in operation, to cut off the current which otherwise would be drained through R_2. This receiver will work well with 135 volts of "B" batteries, and since the total current is only about 5 or 6 milliamperes the batteries will last a long time.

A Three-Tube A.C. Receiver

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

The three-tube receiver now to be described has a tuned r.f. stage with controllable sensitivity. The circuit arrangement differs a little from those previously described, but the operating principles are the same. The band-spreading system will be recognized as the first of those outlined early in this chapter. It is used in this set because it is one of the eastest systems to get working when the tuning of two stages is to be ganged, and because the relatively large capacity in the tuned circuits makes the detector oscillate more stably and thus prevents the signals from wavering should the "B" supply voltage change slightly.

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

It is important, in building up the chassis, to make certain that good contact is made between all metal parts. Loose panels in the shield boxes

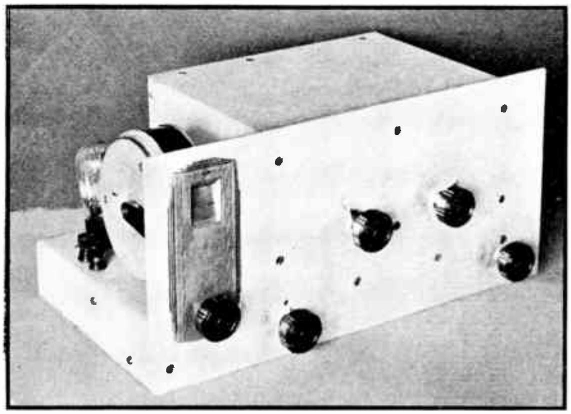


FIG. 520 — THE THREE-TUBE TUNED R.F. RECEIVER

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

will result not only in poor shielding but will undoubtedly be the source of many noises.

The tuning condensers are Hammarlund midgets, mounted as shown in Fig. 521. To gang the two condensers the spring contacts which wipe on the shaft should be removed so that a flexible coupling can be slipped over the shaft. The connection to the rotor plates of the condenser so altered should be made through the front bearing when this is done, because the rear bearing will be noisy. The condensers and dial are connected together by means of pieces of quarter-inch shafting and small flexible condenser couplings.

The detector circuit is designed to permit the use of 5-prong coil forms. Only three terminals are needed for the oscillating circuit, the other two being available for the coupling coil from the r.f. stage.

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

The wiring diagram, Fig. 523, is arranged for operation from an a.c. power pack which will deliver 2.5 volts a.c. for the filaments and 200 volts d.c. for the plates. Voltages for the screen grids are obtained by means of voltage dividers and series resistors. If batteries are to be used on the plates, resistors R_5 and R_6 may be omitted and a separate lead brought out from R_{10} to the 45-volt tap on the "B" battery.

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

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

Should the set not work right at the first trial, check over the wiring and apply the tests outlined at the end of the description of the two-tube d.c. receiver or the section on "Hunting for Trouble" later in this chapter. These tests also apply to the two tube a.c.-d.c. receiver previously described.

The Superheterodyne

Amateurs who desire the utmost in sensitivity and selectivity will do well to build a superheterodyne receiver. For ordinary c.w. reception the additional advantages of this type of receiver are generally outweighed by its greater cost and increased difficulty of construction, but for high-frequency 'phone reception its performance is unequalled. No other receiver of the types com-

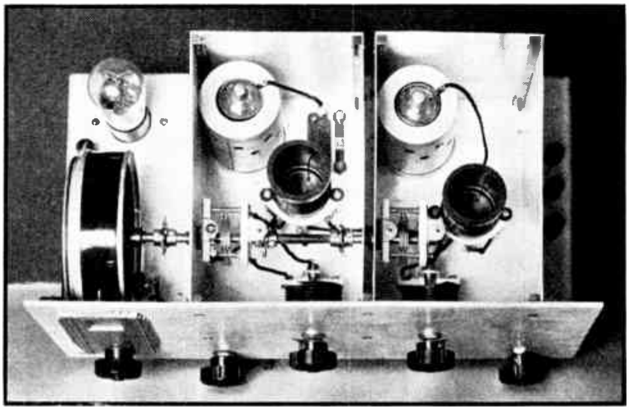


FIG. 521 — LOOKING INTO THE SHIELD BOXES

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

monly employed for high frequencies can compare with it in selectivity on 'phone signals, and the disadvantages of reception by means of a regenerative detector are eliminated.

The Superhet Converter

If one has a modern broadcast receiver it is possible to obtain the advantages of superheterodyne performance for 'phone reception without the necessity for expensive or complicated receiver construction. The broadcast receiver supplies the intermediate frequency amplifier, second detector and audio amplifier; the only units which the constructor need furnish are the first detector and oscillator. The photographs show one form of converter for this purpose which has proved entirely satisfactory.

While it is possible to construct the converter so that its plate and filament supplies can be obtained from the broadcast receiver by inserting a plug in the first r.f. tube socket, this method is not recommended if maximum performance is desired. The plate and filament power should be provided either by separate supplies or else taken directly from the receiver power-pack. In the model shown a filament transformer is mounted on the chassis.

The circuit diagram of the converter is given in Fig. 526. The construction is an example of "unit" shielding; the dotted lines about certain of the components in Fig. 526 indicate the shields visible in the photographs.

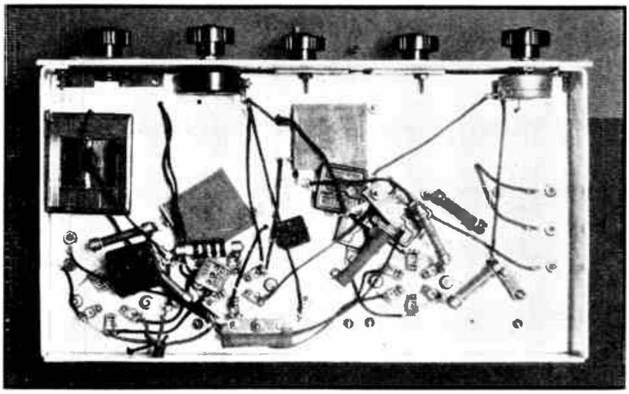


FIG. 522 — UNDER THE BASE OF THE THREE-TUBE RECEIVER

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

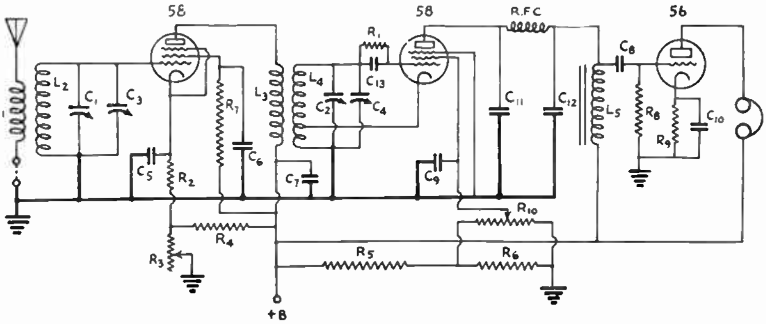


FIG. 523 — WIRING DIAGRAM OF THE THREE-TUBE RECEIVER

All the tube filaments and the dial light are wired in parallel, although omitted from the diagram for the sake of simplicity. The r.f. tube is a 58, detector a 58, and the audio amplifier a 56. The 6-volt d.c. tubes may be used if 5-prong sockets are substituted for the 6-prong sockets in the r.f. and detector stages, in which case the r.f. amplifier should be a Type 39, the detector same, and the audio amplifier a 37; the suppressor grid connections shown above will be omitted. Heavy lines indicate grounds which should be made to a single point on the chassis.

C_{1-2} — 35-μμfd. midget condensers (Hammarlund Mc-35-S). See text.
C_{3-4} — 100-μμfd. midget condensers (Hammarlund MC-100-S).
C_{5-8} — .01-μfd. mica condensers (Aerovox).
C_{9-10} — 1-μfd. non-inductive paper condensers (Morrill).
C_{11-12} — 100-μμfd. fixed mica condensers (Aerovox).
C_{13} — 250-μμfd. mica condenser (Aerovox).

R_1 — 5-megohm resistor (I.R.C.).
R_2 — 250 ohms, 2 watt (I.R.C.).
R_3 — 10,000-ohm wire-wound potentiometer, tapered (Yaxley).
R_4 — 50,000 ohms, 2 watt (I.R.C.).
R_5 — 14,000 ohms, wire-wound, 5 watt (I.R.C.).
R_6 — 5000 ohms, wire-wound, 5 watt (I.R.C.).
R_7 — 100,000 ohms, 1 watt (I.R.C.).
R_8 — 1 megohm (I.R.C.).
R_9 — 2000 ohms, 1 watt (I.R.C.).
R_{10} — 50,000-ohm potentiometer (Frost).

Coil Data

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

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

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

The panel is 8 by 12 inches, of ⅛-inch sheet aluminum. The "chassis" or base is made in the same way as the base for the 3-tube receiver just described, and measures 8 by 12 inches by 1½ inches high. The coils for the different tuning ranges plug in from the front of the panel into sockets mounted in National Type B30 shield cans. The tuning condensers, mounted on the arms of a National Type HS dial, are covered by National Type J30 shield cans. These cans are bolted to square aluminum plates which are held in place by the condenser mounting nuts.

The resistors and condensers shown below the chassis line in Fig. 526 are all mounted underneath the base. These should be placed in positions convenient to the leads to which they are attached.

The condensers marked C_2 are 35-$\mu\mu$fd. mica trimmer condensers which fit into the tops of the National coil forms as shown in Fig. 527. They are used to compensate for small variations in inductance and to regulate the minimum circuit capacity so the oscillator and first detector circuits will "track" together to make the tuning single control. The condensers marked C_1 are the tuning condensers, mounted on the arms of the National Type HS dial so they both turn together. Condenser C_3 consists of a 70-$\mu\mu$fd. mica trimmer condensers and a 300-$\mu\mu$fd. fixed condenser connected in parallel. Two condensers are used because no single condenser of the right range (the capacity required is about 350 $\mu\mu$fd.) is available. The 70-$\mu\mu$fd. condenser is adjusted through a hole in the end of the oscillator condenser shield can, by means of a screw-driver.

To operate the converter with a broadcast receiver, disconnect the antenna from the latter and place it on the converter antenna post; connect the converter ground post to the ground on the broadcast set, and place the clip from L_5 on the grid cap of the first r.f. stage of the broadcast receiver. Set the latter at 550 kc.; trimmer condenser C_5 across L_5 and the similar condenser across L_4 should be set at about half capacity. The trimmer condensers across L_1 and L_3 also should be at about half capacity. C_3 should be set at 350-$\mu\mu$fd as nearly as can be judged. Turn the converter dial until a signal is heard and readjust C_3 for maximum signal strength. Make similar adjustments to the trimmers across L_4 and L_5. Now tune in a signal with the dial set for nearly minimum capacity in the tuning condensers and adjust the C_2 trimmers. When this has been done the two circuits should track across the whole coil range. To make the other sets of coils track, C_3 and C_5 need not be touched; the only adjustments necessary will be to the coil trimmers, C_2.

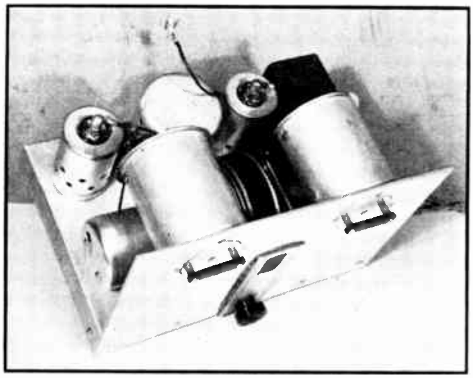


FIG. 524 — THE SUPERHET CONVERTER

Coils plug in from the front of the panel into sockets mounted inside standard shield cans. Below the coil shield on the left is the shield which covers the first-detector tuning condenser. A similar shield is for the oscillator tuning condenser on the other side of the tuning dial.

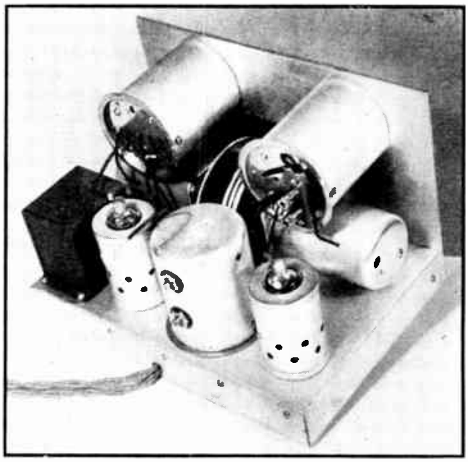


FIG. 525 — A REAR VIEW OF THE CONVERTER

Showing the backs of the coil shields and the apparatus mounted on the base. The shielded tube at the right is the detector; next to it is the shield in which the intermediate frequency transformer is placed. The shafts of the i.f. tuning condensers project from the rear side of this shield through insulating mountings. To the left of the i.f. transformer is the oscillator tube. The filament transformer is at the extreme left. The antenna and ground posts are mounted on a bakelite strip fastened to the detector coil shield. The grid clip to go on the first r.f. stage of the broadcast receiver projects from the i.f. transformer shield.

After a little exploring it will be possible to identify the various 'phone and broadcasting bands and log the dial settings so they can be returned to at any time. The converter is not entirely satisfactory for the reception of unmodulated c.w. signals because no beat note will be heard unless a separate oscillator to cover a small frequency range near 550 kc. is coupled to the receiver.

The Single-Signal Receiver

The selectivity obtainable from autodyne receivers with tuned radio-frequency amplifiers is limited by the impracticability of using more than one or two tuned amplifiers at high frequencies and by the fact that the resonance curves become increasingly broad as the frequency is raised. In addition to this, the oscillating detector always gives two beat notes on a received signal, depending upon whether its frequency is slightly higher or slightly lower than that of the signal. To get the order of selectivity which will separate signals whose frequencies are within a kilocycle or so of each other it is necessary, at the present state of the art, to use a very stable superheterodyne with a highly-selective intermediate-frequency amplifier. On such a receiver the selectivity in kilocycles will be essentially the same regardless of the frequency of the signal.

The "Single-Signal" type receiver, developed by James J. Lamb, Technical Editor of *QST*, attains this degree of performance. Extremely high selectivity is secured by the use of a quartz-crystal filter which resonates at the frequency of the intermediate-frequency amplifier. The beat note for c.w. reception is secured by the use of a separate semi-fixed oscillator which introduces the heterodyne at the second detector. The double beat characteristic of autodyne detectors is eliminated. Fig. 531 is the photograph of a custom-built Single-Signal type receiver.

Because of space requirements it is impossible to give a full description of a Single-Signal receiver in this *Handbook*. The interested reader is therefore referred to the August and September, 1932, issues of *QST*, in which complete constructional details of the receiver will be found. This set is unquestionably the finest c.w. receiver so far developed, and has in addition numerous advantages for 'phone reception.

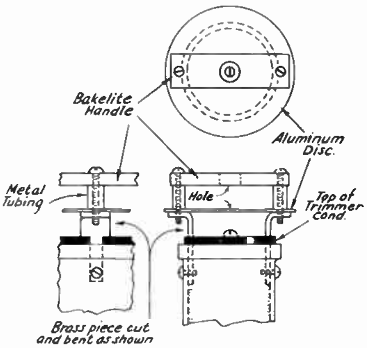


FIG. 527 — HOW THE HANDLES AND TRIMMER CONDENSERS ARE MOUNTED ON THE COIL FORMS

The aluminum disc forms part of the shielding around the coil. It is connected to the ground pin on the coil form. The brass pieces are drilled and tapped to take the machine screws. Regular National coil forms are used.

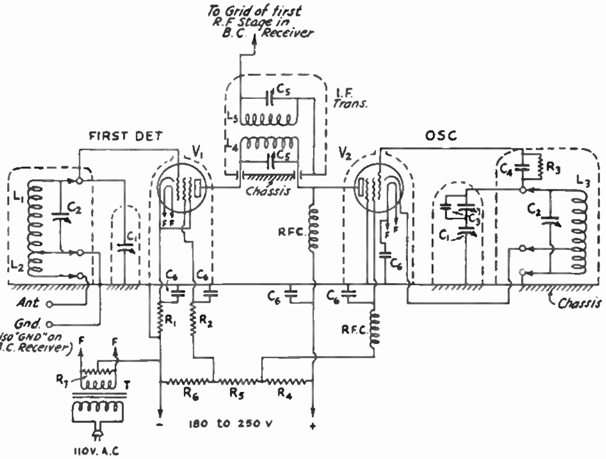


FIG. 526 — THE CONVERTER WIRING DIAGRAM

In this diagram, V_1 is a Type 57 tube and V_2 either a 57 or 58. Type 24-A and 35 tubes may be substituted by omitting the suppressor-grid connections shown. For d.c. operation Type 36 tubes should be used, again omitting the suppressor-grid connections.

L_1, L_2, L_3 — See table for details.
L_4-L_5 — Primary and secondary of 550-kc. intermediate transformer (National).
C_1 — 100-μμfd. midget variable condensers (National).
C_2 — 35-μμfd. mica trimmers for coil mounting (National).
C_3 — 70-μμfd. compression-type mica trimmer condenser (Hammarlund MICS-70) in parallel with 300-μμfd. fixed condenser.
C_4 — 250-μμfd. mica fixed condenser.
C_5 — 70-μμfd. midget variable condensers.
C_6 — .01-μfd. mica fixed condensers.
R_1 — 5000 ohms, 1-watt.
R_2 — 50,000 ohms, ½ watt.
R_3 — 50,000 ohms, ½ watt.
R_4 — 10,000 ohms, 2 watt.
R_5 — 7000 ohms, 1 watt.
R_6 — 3000 ohms, 1 watt.
R_7 — 20 ohms, center-tapped.
RFC — High-frequency r.f. choke coils (National Type 100).
T — 2.5-volt filament transformer.

The parts shown below the chassis line are mounted underneath the base.

Hunting for Trouble

A pair of 'phones, a dry cell, and a d.c. voltmeter are the most useful instruments for locating faults in the set. If the tube does not light, it should be tested for an open filament. Then the filament or heater circuit wiring should be traced carefully. The rheostat should be examined for an open wire, the socket for a sprung prong. With the "B" supply disconnected, trace the filament wiring from the "A" battery or heater transformer to the socket, using either the click in the 'phones or the voltmeter across the line. With a.c. filament supply an a.c. voltmeter should be used since the d.c. voltmeter will give no indication. A couple of pins on the ends of the voltmeter leads will make it possible to pierce the insulation for testing purposes.

If a clicking sound is heard in the 'phones when they are connected to the set as in regular operation, it probably means that the grid leak is open or of too high value. A lower-resistance leak will remedy this condition. A pencil mark between grid and filament (or grid and cathode) terminals on the bottom of the tube (or a line of India ink) will serve in an emergency.

If the filament lights but there is no sound in the 'phones, trace the plate circuit wiring carefully, paying attention to the 'phone jack or terminals to see that the 'phones are not shorted there. If there is a by-pass condenser across the 'phones, this should be checked with 'phones or voltmeter and battery to see that it is not shorted inside or by some solder across the terminals. The grid and plate terminals of the socket may be bent.

An open secondary coil or grid circuit lead may cause a clicking similar to that when there is no grid leak. The winding may be tested with the voltmeter or 'phones for an open circuit. If no signals come through and there is no "tuning," probably the variable condenser is not solidly connected across the secondary coil. Decreased signal strength may indicate that the antenna coil is open or that the antenna or ground is off. A shorted grid condenser may give the same effect. If no "clicking" is heard with the grid leak removed from the set there may be a shorted grid condenser, a soldering paste "leak" within the socket or across the grid condenser, or a poor tube (open grid). Try a new tube, test the grid condenser with the 'phones or voltmeter or clean up any leaky paths that are found between grid and filament.

Possibly it will be found that the receiver howls just as the detector starts to oscillate and that reception at this point is impossible. This "fringe-howl," as it is termed, can be cured by reducing the value of the resistance connected across the secondary of the audio coupler or transformer. A resistance not lower than .1 megohm should cure the trouble completely, but it should be kept in mind that the lower this resistance the greater will be the reduction in amplification caused by it.

In the operation of a receiver with battery supplies it should be remembered that batteries must always be in good condition. The batteries and the tubes should be given first consideration if the receiver becomes noisy or sluggish in operation. If all joints in the wiring have been carefully soldered, noises in the receiver will be caused by poor batteries and by poor contacts between the tube pins and the sockets. If the noise occurs only when the condenser is turned it is probably the result of dust between the plates or of poor contact between the rotor assembly and the lead to it. In some cases a noise of this type is caused by the shaft or the dial, if it is metal, rubbing against the panel or some other metal object. Yet another source of noise is the antenna system or outdoor wiring near the antenna. Any two wires in poor contact in or near the antenna can cause serious noises when they are blown about by the wind.

CONVERTER COIL TABLE

Frequency Range	First Detector Coils				Oscillator Coils			
	Turns L_1	Wire	Length	Turns L_2	Turns L_3	Wire	Length	Tap[2]
1400–2800 kc.	61	28 d.c.c.	1 5/16″	6	43	28 d.c.c.	15/16″	10
2800–5750 kc.	28	20 d.c.c.	1 3/16″	3	25	20 d.c.c.	1 1/16″	7
5000–9900 kc.	18	20 d.c.c.	1 7/16″	2	33[3]	20 d.c.c.	1 5/16″	10
9700–19,500 kc.	8	20 d.c.c.	1″	2	18[3]	20 d.c.c.	1 7/16″	4

The detector coils for the first two ranges and the oscillator coils for the first three ranges all are close wound. On the others the turns should be spaced out evenly to make the coil length as indicated.

[1] All close-wound at bottom of coil form with No. 30 d.s.c. wire.

[2] Turns from ground end of coil.

[3] Second-harmonic of oscillator used on these frequency ranges.

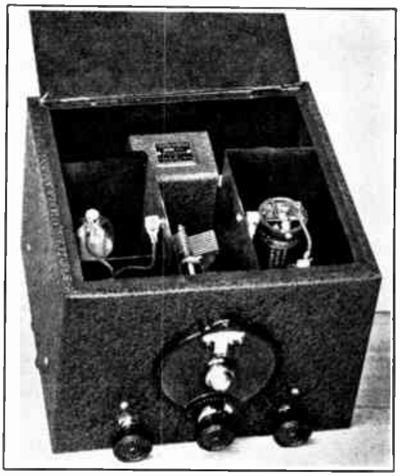


FIG. 528 — THE NATIONAL SW3 RECEIVER

Quiet operation in the short-wave receiver is of extreme importance. It is well to aim at sensitivity and open-scale tuning, but the value of these characteristics is nullified very greatly if there is not freedom from extraneous noise.

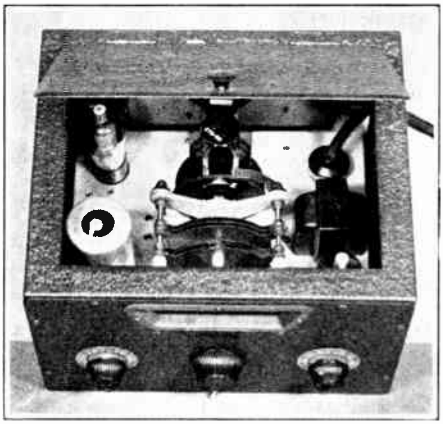


FIG. 529 — THE R.E.L. 279 SHORT-WAVE RECEIVER

Manufactured Receivers

In the years now past it was always necessary for the amateur to build his own receiver if he aimed to possess a piece of equipment really suited for the work in hand; there was no alternative. Recently, however, several radio manufacturers have interested themselves in the development of receivers designed especially for amateur work. These products are not to be confused with the ordinary short-wave broadcast receiver, being designed to provide band-spreading and other features that have been pointed out as desirable.

Two representative examples of the manufactured type of receiver are illustrated. The National SW3 is a three-tube set provided either for a.c. or d.c. operation. The condensers of the tuned screen-grid r.f. amplifier and the screen-grid detector are ganged on the one shaft and a trimmer condenser, fixed for each band, allows effective single-control operation. Band spreading is accomplished by tapping the tuning condensers across a portion of the secondary windings.

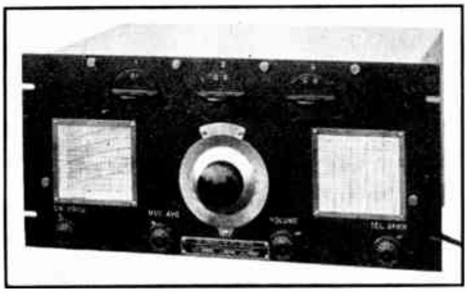


FIG. 530 — THE NATIONAL AGS SUPERHETERODYNE

The amateur receiver produced by Radio Engineering Laboratories, Inc., also has three tubes — a screen-grid untuned r.f. amplifier, a screen-grid detector, and a pentode output tube. Wide dial coverage for each band is made possible by the provision of an adjustable capacity shunting the main tuning condenser. A notched rotor allows accurate setting of this capacity to give the desired band spread. A full-vision tuning scale is featured.

The Hammarlund Comet Pro receiver is a superheterodyne covering a frequency range of 20,000 to 1500 kc. Small tuning condensers controlled by the main tuning dial are paralleled with larger band-setting condensers to give good band spreading about any frequency selected. A power pack is included in the chassis. The set uses eight tubes, including first detector, oscillator, two i.f. stages, second detector, heterodyne oscillator for c.w., one audio stage, and the rectifier.

FIG. 531 — A TYPICAL SINGLE-SIGNAL TYPE SUPERHETERODYNE CUSTOM BUILT BY HENDRICKS & HARVEY

A second superheterodyne receiver is the National Type AGS illustrated. Features of this receiver are a stage of pre-selection before the first detector, automatic volume control for 'phone reception, and pentode audio output. Nine tubes are used in a circuit comprising a stage of tuned r.f. amplification at the signal frequency, first detector, oscillator, two i.f. stages, power second detector, beat oscillator, automatic volume control tube, and audio output. The power pack for this receiver is a separate unit.

The Receiving Antenna

A good antenna is desirable for the short-wave receiver, though it will be found surprising how simple and crude the antenna can be without greatly hampering the operation of the receiver.

Many amateurs use a receiving antenna consisting of some fine cotton-covered wire run along one side and end of the room on the picture molding. An antenna of this type is completely effective with a sensitive receiver such as the four-tube outfit described in this chapter. With the simpler receivers, however, an outdoor antenna is recommended. If the receiver is used in conjunction with a transmitter, the transmitting antenna can be employed by fitting an antenna switch to connect the receiver to some point on the leads from the transmitter to the antenna or feeder wires. If it is desired to work the station "break-in," a separate receiving antenna is necessary. With such an arrangement both the receiver and transmitter are in operating condition at the same time and all that is necessary to transmit is to press the transmitter key. To receive, nothing more is necessary than to release the transmitting key.

A satisfactory outdoor antenna may be made with a length of 14 to 16 gauge enameled copper wire strung horizontally between insulators at a height of between 10 and 50 feet above ground. The length of the wire in the antenna is not a very important consideration but the longer the antenna, up to a certain point, the louder the signals. Some amateurs find a very long low antenna, even 800 feet, of distinct advantage in obtaining a better ratio between the strength of the signals and the strength of static and other extraneous noises. When separate antennas are used for receiving and transmitting they should be kept as far apart as possible and preferably at right angles to each other. This is necessary to reduce the amount of energy absorbed from the transmitter by the receiving antenna.

And now, when the receiver has been built, adjusted, and placed in satisfactory working condition it will be permissible to sit back and take a long breath. For the receiver is one of the essential parts of an amateur station. If it has been correctly built and if the location of the station is satisfactory it will receive as far as any transmitter can send. If it has open tuning scales; if it has lots of sensitivity and amplification; and if it is smooth and quiet in operation, it will be a very great comfort and a source of splendid pleasure.

Chapter Six

MONITORS AND FREQUENCY METERS

ONE might suppose that, having finished the receiver, the next piece of equipment to be built would be the transmitter. But before the job of adjusting a transmitter to maximum effectiveness can be tackled, the amateur must have some means of checking its performance — particularly, how it is going to *sound* to other amateurs — and of making certain that the frequency of the signals is inside the band in which the transmitter is supposed to be working. Without the facilities to determine definitely whether the frequency of his transmitter is within the limits of the band the amateur has no right in the world to send even a single dot.

It is fortunate that when the station has been equipped with a monitor — which is nothing but a simple shielded oscillator — it is also provided with what is without doubt the cheapest and most effective apparatus for setting the transmitter frequency within the band. More elaborate instruments, which we call frequency meters, can be constructed for precise frequency measurement, but an inexpensive monitor, intelligently used, will insure against committing the unforgivable sin of amateur radio — working "off-frequency."

Building a Monitor

A monitor is a miniature receiver, usually having only a single tube, enclosed with its batteries in some sort of metal box which acts as a shield. It need not be a costly or elaborate affair. The example shown in Figs. 61 and 62 illustrates the simplicity of a typical monitor. The constructional work probably would not occupy more than an hour or two.

The requirements of a satisfactory monitor are not difficult to satisfy. It should oscillate steadily over the bands on which the station is to be active; the tuning should not be excessively critical, although the degree of band-spreading ordinarily considered desirable for receivers is not essential; the r.f. pick-up from the 'phone cord should be sufficiently nullified and the shielding complete enough to permit the monitor to be set near the transmitter and still give a good beat note when tuned to the fundamental frequency of the transmitter (this is usually impossible with the receiver because the pick-up from power supply leads is so great); and it should be constructed solidly enough so that it can be moved around the station without the necessity for retuning when listening to a fixed signal.

Almost any sort of metal box large enough to contain the necessary components can be used as a shield for the monitor. The one shown in the photographs is a tin lunch-box of a type which can be picked up at almost any hardware store. Tin cracker boxes will serve equally well. The tube is a 30, which will work satisfactorily with a single No. 6 dry cell for filament supply. All the parts except the 'phone jack and tuning condenser are mounted on a small piece of wood fitted into the bottom of the lunch-box at one end, leaving room for a small-size plate battery at the other end. The dry cell for filament supply is held in place in the hinged cover of the box by the strap which originally was intended to hold a thermos bottle. The wiring diagram is shown in Fig. 63. The coils, wound on tube bases, are described under the diagram. Make certain that the coils are "poled" correctly so the monitor will be sure to oscillate. If both coils on the form are wound in the same direction with the grid coil at the upper end, the top terminal should go to the grid of the tube, the lower end of the grid coil to the filament, the upper end of the plate coil to by-pass condenser C_2, and the lower end of the plate coil to the plate of the tube.

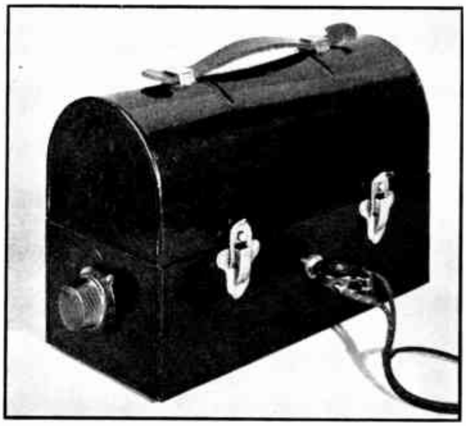


FIG. 61.—A "LUNCH-BOX" MONITOR FOR CHECKING THE QUALITY OF THE TRANSMITTER SIGNALS AND AIDING IN SETTING THE FREQUENCY

Although the monitor is inexpensive and exceedingly simple it is a valuable piece of station equipment.

The data under the diagram should be used chiefly as a guide, because it may be found that slight changes in the number of turns on the plate coils will be required to maintain smooth oscillation over the entire tuning range, since the monitor has no regeneration control.

Installation and Adjustment

A monitor has two functions to perform, the first being that of providing a means of listening to the transmitter signal under conditions similar to those at distant receiving stations; that is, with the signal weak enough so that its tone and general characteristics can be distinguished readily. The second function is that of acting as a small transmitter radiating a weak signal which can be picked up in the regular receiver for the purpose of aiding in setting the transmitter frequency by the method described in a subsequent section.

In order to make full use of the monitor it must be placed carefully with respect to the receiver and transmitter so that the signal in it from the transmitter is not too loud and so that the signal produced by it in the receiver also is of reasonable strength. If the receiver is located several feet from the transmitter a satisfactory location for the monitor will be found alongside the receiver. If the receiver is across the room from the transmitter it will be necessary to move the monitor to a spot convenient to the transmitter whenever adjustments are to be made. Of course, the monitor can be placed alongside the receiver for frequency setting and monitoring of the transmitter during transmissions. It may be found that the pick-up with the lid of the shield closed is not enough to give a pleasantly loud signal. In such a case the lid can be opened until the required signal strength is obtained and left in that position for monitoring.

It is a very worthwhile plan to fit the receiver with a small double-pole double-throw switch so that the 'phones can be thrown from the receiver to the monitor. In this way it is possible to monitor all transmissions simply by flipping over the switch when a change is made from the transmitter to the receiver. Ordinarily the transmitter makes a tremendous and very uncomfortable thump in the receiver 'phones during operation. If it is possible to throw the 'phones over to the monitor this thump is then replaced by a moderate signal which will be almost a replica of the signal that the other fellow has to copy. This makes for much snappier and more readable sending and provides a continuous check on the signal. Should anything go wrong with the transmitter or antenna to cause the frequency to change, the trouble is immediately apparent.

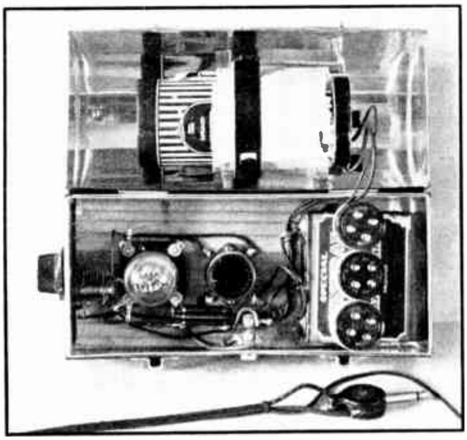


FIG. 62. — INSIDE THE "LUNCH-BOX" MONITOR

The dry-cell for filament supply is fastened in the lid of the lunch box. A small "B" battery occupies the right-hand portion of the bottom. The various parts are mounted on the sides of the box itself or on a small piece of wood screwed to the bottom. A filament-control 'phone jack is used so that the filament is automatically turned on or off when the 'phone plug is inserted or removed. The coils for the various bands, wound on old tube bases, also are shown.

Checking the Transmitter Frequency

In checking the frequency of the transmitter the monitor is used both as a miniature receiver and transmitter, as will be explained. But before any frequency checking can be done there must be a starting point, which in this case is a rough calibration of the receiver itself. After the receiver has been in use for a little time the locations of the amateur bands are pretty definitely known, because large numbers of amateur stations can be heard working on the more important bands at almost any hour. First get the receiver working on the band in which the transmitter is to be set and note the limits between which amateur stations are heard. Often high-power commercial stations will be heard working just outside these limits, and the frequencies of these stations can be looked up in lists such as the one in the *Radio Amateur Call Book*. Similar lists are also occasionally published in *QST*. These commercial stations generally are accurately set on their assigned frequencies and furnish a means for making

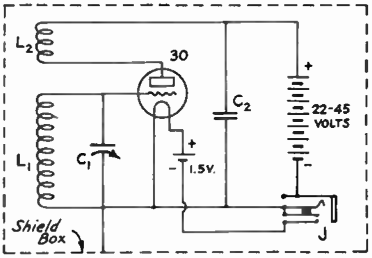


FIG. 63. — WIRING DIAGRAM OF THE MONITOR

C_1 — 50-μμfd. midget variable condenser.
C_2 — .002-μfd. fixed condenser.
J — Filament-control 'phone jack.
L_1, L_2 — Coils wound on old tube bases of No. 30 s.s.c. wire as follows:

	L_1	L_2
1750 kc.	65	12 turns
3500 kc.	35	8 "
7000 kc.	15	6 "
14,000 kc.	5	4 "

Both wound in same direction, grid coil at top of form.

an approximate calibration of the receiver. Amateurs call them, appropriately enough, "marker stations."

No specific examples will be given here because the frequency assignments are changed from time to time, and the latest call book should be consulted for accurate information. Suppose, however, that a station is heard whose frequency, as shown by the list, is 6980 kc. This is only 20 kc. outside the 7000-kc. band, and therefore serves as an approximate marker for the 7000-kc. end. On the high-frequency end of the band we might find a station listed at 7350 kc. which will help in locating the 7300-kc. limit. Obviously the transmitter cannot be tuned to all frequencies between these two markers because both are somewhat removed from the actual limits of the band, and it would easily be possible for the transmitter to be set to some frequency not assigned to amateurs. Due allowance must therefore be made for the fact that marker stations are never actual markers of the band limits, but are outside the bands by an appreciable amount.

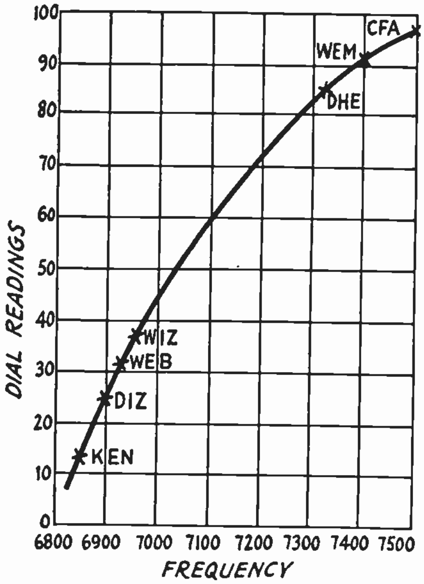


FIG. 64. — SAMPLE CALIBRATION CURVE

made from calibration points supplied by commercial "marker" stations. Such a curve may be made for the receiver or monitor, and will aid in determining the limits of the amateur bands. It is impossible to measure frequency exactly with this type of calibration, so the transmitter should be set well inside the indicated limits to be certain that all transmissions will be inside the band. Each of the above blocks represents a half-inch square on ordinary cross-section paper. The intermediate lines are not shown because of the difficulty of reproduction in printing.

The receiver may be calibrated roughly by picking up a number of such marker stations at various frequencies near the amateur bands and plotting the tuning-dial readings for each frequency, in the fashion shown in Fig. 64. The general shape of the curve can be determined from the plotted points and drawn in. In the illustration shown the actual limits of the band would be at 44 and 83 on the tuning dial, although the nearest marker stations are outside these limits. A curve plotted in this way is not entirely accurate, but is good enough to show approximately where the band lies.

After the band limits have been determined to a fair degree of certainty, a suitable working spot should be picked within the band and the receiver left running at that setting. The monitor now should be put into operation. If an extra pair of 'phones is not available a spare plug with its contacts shorted by a piece of wire may be plugged into the monitor so that its filament circuit will be closed, thus lighting the tube. Next tune the monitor slowly across the band, stopping when the signal from it is heard in the receiver. The monitor will now be set exactly on the frequency to which the transmitter is to be tuned. If no signal is heard, check the monitor to make sure it is oscillating (the same tests should be applied as were described for oscillating detectors in Chapter Five), move it closer to the receiver, or open the lid so that the shielding will not be so great. Make certain that the right coil is in the monitor.

With the monitor setting determined, transfer the headset from the receiver to the monitor, start up the transmitter, set its tuning controls at approximately the point where the band should be, and tune carefully until a signal from the transmitter is heard in the monitor. Set the transmitter frequency to "zero beat" — the silent space between the two beat notes — and the transmitter frequency will be exactly on the spot picked out. Since the calibration obtained as described above is only approximate, no attempt should be made to work close to the edges of the band, but the transmitter frequency should be set so that it is safely inside.

This method does not provide the means for setting the transmitter on any definite frequency unless there is a known station there to mark it, but it does enable the transmitter to be tuned to, say, the center of the band, to a spot a quarter of the way from the top, or to any roughly estimated point. It is not often that the amateur finds it essential to tune his transmitter to within a kilocycle or so of a given frequency but if such is the case there are means involving greater difficulties which can be used. They will be detailed later. The prime requisite usually is to have the transmitter within the limits of the band and perhaps in some particular section of it. For this work the simple monitor is all that is necessary.

If the monitor has been carefully constructed from good parts and a readable dial is used, it may be calibrated directly from the marker stations. Set the monitor oscillating, tune in a marker signal on the receiver, tune the monitor to zero beat with the marker signal and note the dial reading. A series of these readings may be plotted as shown in Fig. 64. A calibration of this sort will hold for quite a long period of time provided the monitor is well built and the battery voltages do not change. A few minutes should be devoted at intervals to checking the calibration curve and making such changes in it as may be necessary.

Absorption Frequency Meters

Setting the transmitter frequency as described above is subject to a possible error which, particularly with high-power transmitters, may lead to off-frequency operation unless the approximate transmitter-control settings for the band are known. All vacuum-tube oscillators, in addition to generating oscillations at the frequency to which the coil and condenser tune, also set up *harmonics*, or oscillations at other frequencies which are integral multiples of the frequency set by the coil and condenser (the *fundamental* frequency). For example, a 1750-kc. oscillator will have harmonics at twice 1750 kc., or 3500 kc., at three times 1750 kc., or 5250 kc., at four times 1750 kc., or 7000 kc., and so on. If this oscillator is a monitor, it will pick up signals from a powerful transmitter set to any of this series of frequencies, although the signal will be weaker the farther it is in frequency from the fundamental.

This sometimes leads to trouble, because the total tuning range will be large in a transmitter circuit using a large variable condenser and a small inductance as nearly all self-controlled oscillators do. As an illustration, suppose a self-controlled High-C oscillator such as one of those described in Chapter Seven is to be tuned to a frequency in the upper half of the 3500-kc. band; say, 3800 kc. The second harmonic is 7600 kc.; it is possible for the monitor to pick up signals on either of those frequencies. Unless the operator is thoroughly familiar with the tuning of his transmitter it would easily be possible for him to set the transmitter on 7600 kc.—which is not included in any amateur band — under the impression that he was putting it on 3800 kc.

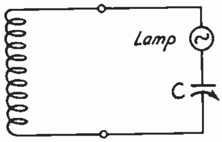


FIG. 65. — ABSORPTION FREQUENCY METER CIRCUIT

An absorption meter can be made in a few minutes from an old variable condenser, C, having a maximum capacity of about 350 μμfd., and a series of coils, L, to cover a large range of frequencies. The meter should be arranged so that the coils are readily interchangeable, although the construction need not be elaborate. The lamp acts as a resonance indicator when the absorption meter is used with a transmitter; its use is not essential, although it is a convenience. The absorption meter is not adapted to accurate measurement of frequency but is helpful in approximately locating an unknown frequency, as described in the text.

An error of this sort can be discovered very readily by the use of an absorption frequency meter. This consists simply of a coil and condenser, often with a small flashlight lamp in series although the lamp is not strictly necessary. See Fig. 65. Such a meter can be made from spare parts to be found in every amateur station and is well worth the few minutes' time involved in building it. Although it is not adapted to accurate frequency measuring nor to setting the transmitter frequency inside the band once the approximate settings of the transmitter controls are known, it can be useful in a variety of ways.

A series of coils should be provided for the absorption meter so that it will cover a continuous frequency range from about 1500 kc. up to the highest frequency likely to be needed — perhaps 20,000 kc. A rather large condenser should be used; a variable with 350 μμfd. maximum capacity is about right. Coils to cover the range with a condenser of this size may be made as shown in the table below. The frequency ranges are approximate only. The specifications are for coils wound on a two-inch form with No. 20 d.c.c. wire, no spacing between turns.

Range	*Turns*
1500–5000 kc.	*25*
3000–10,000 kc.	*10*
6000–20,000 kc.	*5*

It is not necessary to have calibration curves for these coils nor even to have permanent calibration points. The use of the meter can best be explained by continuing the example already cited. To make sure that the transmitter is actually on 3800 kc. and not 7600 kc., the coil which covers the range from 3000 to 10,000 kc. should be connected to the condenser and coupled loosely to the tuning coil in the detector circuit of the receiver. Set the receiver to 3800 kc. with the detector oscillating gently and turn the dial on the absorption meter condenser. At some point toward the high-capacity end of the condenser the meter will absorb enough energy from the detector to cause it to stop oscillating. Move the meter a little farther away until this occurs at one very definite point on the meter dial. The meter will then be set approximately to 3800 kc.

Now turn on the transmitter and couple the meter, without changing its dial setting, to the transmitter tank coil. If the meter is equipped with a lamp indicator, the lamp will glow if the transmitter is tuned to 3800 kc. Always use the loosest possible coupling in making this kind of test; that is, keep far enough away from the tank coil to prevent the lamp from doing anything more than show a faint glow at a definite point on the meter dial. A "broad" indication, or one in which the lamp lights over a considerable range of meter tuning, is not nearly so good. Should the meter be without a lamp indicator, the same effect can be obtained by watching the plate milliammeter on the transmitter. It will show a slight increase as the absorption meter is tuned through resonance with the transmitter.

Continuing the example, if no indication of resonance appears when the meter is coupled to the transmitter, the chances are that the transmitter is tuned to a harmonic of the monitor instead of to its fundamental frequency. This can be checked by decreasing the capacity of the condenser in the meter, upon which the indication should appear toward the low-capacity end of the scale. If the receiver can tune to 7600 kc. the order of the frequency to which the transmitter is tuned can be checked quite easily by following the method described in the paragraph second above, this time varying the detector tuning and holding the absorption meter condenser setting constant.

An absorption meter is also useful when, as sometimes happens, a doubling stage in a crystal-controlled transmitter is accidentally tuned to the third harmonic instead of the second. A few minutes spent in checking often will prevent off-frequency operation.

More Precise Methods

So far we have outlined the simple procedure necessary to determine definitely whether the transmitter frequency is within the limits of the band and roughly in what part of the band it is located. Many amateurs will be interested in knowing how a transmitter can be tuned to within a few kilocycles of a given frequency. For this work some calibrated standard will be necessary against which to compare the frequency of the transmitter. Such a standard is the heterodyne frequency meter.

The heterodyne frequency meter somewhat resembles the monitor in that it is a small oscillator, completely shielded, but the refinement and care in construction is carried to a high degree so that the frequency meter can be accurately calibrated and will retain its calibration over long periods of time. The oscillator used in the frequency meter must be very stable; that is, the frequency of oscillation at a given dial setting must be practically the same under any conditions. No plug-in coils are used in the frequency-meter; one solidly built and firmly mounted coil is permanently installed in it, and the oscillator covers one band only. A low-frequency band is used for this purpose, and when the meter is to be used on the higher-frequency bands its harmonics instead of the fundamental oscillation are used. The single coil can be mounted in a much more solid fashion than could plug-in coils, and since it is not subject to continual handling such as plug-in coils receive, the turns will not be loosened or pulled out of place.

The frequency meter must possess a dial which can be read precisely to fractions of divisions. To obtain accuracy it is necessary to read the scale to at least one part in 500, and ordinary dials such as are used for receivers are inadequate. The National 4″ Type N and 6″ Type N and NW dials are provided with vernier scales for reading to a tenth of a scale division (one part in 1000), and are well suited to this work. The General Radio 704 and 706 series dials also are excellent. There are a few other good dials on the market, but care must be used in selecting one which has fine lines for division marks, and which has an indicator very close to the dial scale so that the readings will not be different when the dial is viewed from different angles.

FIG. 66. — A PANEL VIEW OF THE ELECTRON-COUPLED FREQUENCY METER

When carefully calibrated, this instrument can be depended upon for measurements accurate enough for all amateur work. Its features are a highly stable oscillator circuit, high-precision dial, extremely solid mechanical construction, and the ability to deliver harmonics in all amateur bands.

The frequency meter also can be used as a monitor if desired with the resulting simplification in checking transmitter frequency. For maximum accuracy, however, the frequency meter should be left permanently in a fixed place on the operating table, since handling the meter may jar it enough to destroy its calibration unless it is very solidly constructed. A monitor, on the other hand, is a much handier instrument if it can be carried around when tests or adjustments are being made on the transmitter.

The Electron-Coupled Frequency Meter

One of the most stable oscillator circuits, electrically, that has been devised, is the electron-coupled oscillator circuit. This circuit uses a four-element screen-grid tube and by properly proportioning the plate and screen voltages the oscillation frequency will be practically independent of moderate changes in supply voltages. Variations in plate and filament supply voltages constitute probably the greatest source of frequency change attributable to electrical causes in vacuum tube oscillators. Furthermore, by using the grounded screen grid as the anode in the oscillatory circuit the other elements in the tube are electrostatically shielded from the plate, just as they are in an ordinary receiving screen-grid amplifier, and it becomes possible to take output from the plate circuit with practically no reaction on the frequency of the oscillator. This is a feature of great value, because it means that the frequency meter can be coupled to the receiver with no danger of changing its calibration. A third feature of the electron-coupled oscillator which makes it ideally suited to use in frequency meters is that strong harmonics are generated in its plate circuit so that the meter is useful over an extremely wide range of frequencies.

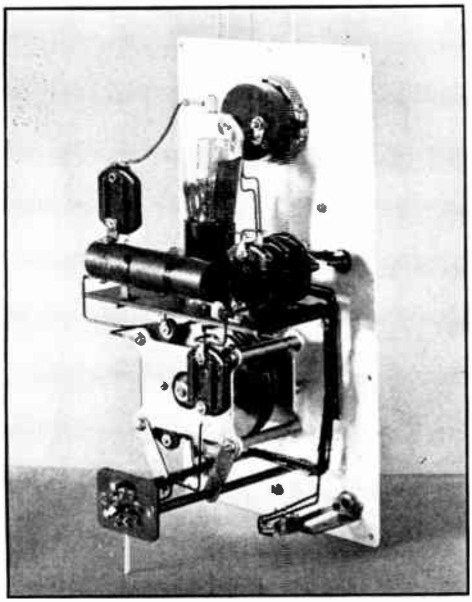


FIG. 67. — CONSTRUCTION OF THE ELECTRON-COUPLED FREQUENCY METER

This layout keeps all r.f. leads short and direct. All the components are supported by the panel so that the frequency meter can be removed as a unit from its case. The construction is explained in more detail in the text.

Front and rear view of a typical electron-coupled frequency meter are shown in Figs. 66 and 67. This meter is assembled on an aluminum panel measuring 7 by 13 by ⅛ inches. The wiring diagram is shown in Fig. 68. A small bakelite shelf held to the panel by metal angles supports the tube, a 24-A, the oscillator inductance, and three of the mica by-pass condensers. The grid condenser, C_2, and grid leak are mounted vertically on one end of the bakelite tube on which the inductance is wound so that the lead to the grid of the tube will be fairly short. Just below the shelf is the tuning condenser, a General Radio Type 556. This condenser is designed especially for amateur-band frequency meters. The fourth by-pass condenser can be seen just behind the tuning condenser. All the supply leads are cabled and brought out to a Yaxley cable socket which fits into a hole in the rear of the cabinet. Two brass rods hold this socket the proper distance from the panel. To prevent the rods from moving and thus causing possible frequency changes, additional supports consisting of brass strips fastened to the tuning condenser are provided. A 'phone jack to allow the frequency meter to be used as a monitor is mounted on one of the lower corners of the panel and an on-off switch at the other. The output binding post is mounted on the panel just to the left of the vernier scale on the dial, which is a 6″ National Type N. Both the 'phone jack and the output post are insulated from the panel. The cabinet is of wood, lined with thin sheet copper with all joints soldered. A milliammeter for checking the current taken by the tube is also incorporated in this meter, although it can be omitted without detriment to the operation. The plate of the tube is coupled to the output post through a condenser of extremely small capacity, the details of which are shown in Fig. 69.

Mechanical considerations are most important in the construction of a frequency meter. No matter how good the instrument may be electrically, its accuracy never will be good if it is flimsily built. Mount everything solidly; make connections with stiff wire and place all leads so they cannot be moved in the course of ordinary handling. Thoughtful care in the construction of the frequency meter makes the difference between the precise instrument and just an ordinary oscillator.

The frequency meter described can be used

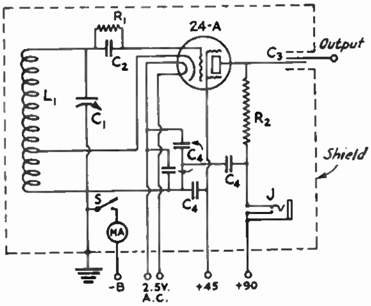


FIG. 68. — CIRCUIT OF THE ELECTRON-COUPLED FREQUENCY METER

This circuit is for use with indirectly heated tubes such as the 24-A and 36.

C_1 — Band-spread condenser, minimum capacity 53 μμfd., maximum capacity, 81 μμfd., approximately. (General Radio Type 556)
C_2 — 250-μμfd. mica condenser.
C_3 — Output coupling condenser shown in Fig. 69.
C_4 — .01-μfd. mica by-pass condenser.
R_1 — 100,000-ohm grid leak.
R_2 — 50,000-ohm 1-watt resistor, pigtail type, non-inductive.
J — Closed-circuit 'phone jack.
S — On-off switch, s.p.s.t.
L_1 — Approximately 90 turns of No. 30 d.s.c. wire close-wound on a 1-inch bakelite tube, tapped at the 30th turn from the grounded end. A few more or less turns may be needed to spread the 1750-kc. band over the dial scale to the best advantage.

either with batteries or a B eliminator for plate supply, the former being preferable. The filament can of course be supplied from the usual 2.5-volt transformer; in fact, the same transformer that supplies the receiving tube filaments can be used. For all-d.c. operation, some changes in the circuit diagram may be necessary. If the filament supply is a 6-volt storage battery, a 36 can be substituted for the 24-A with no change in the circuit diagram or constants except that the by-pass condensers between each side of the filament and ground can be omitted. The 36 also can be used with a.c. filament supply if the condensers are retained. The use of a tube with a directly-heated filament such as the 32 or 22 will require an additional winding on the oscillator inductance, because the filament is not at ground potential and connecting the filament battery directly to the filament would be likely to cause instability and perhaps prevent the tube from oscillating at all. A circuit for these tubes is shown in Fig. 610.

While the specifications for the oscillator inductance under Fig. 68 will be found to work out closely, it may be necessary to add or substract a few turns to get the band-spread just right. The frequency meter covers the range from 1715 to 2000 kc. with a little to spare at each end of the dial. For the higher-frequency bands harmonics of the oscillator are used. Thus the second harmonic will cover the 3500–4000 kc. band, the fourth the 7000–7300 kc. band over part of the scale, and so on to the highest frequencies used by amateurs. Strong harmonics can be taken from the frequency meter even on the 56,000-kc. band, which is the highest-frequency band amateurs have used for practical communication.

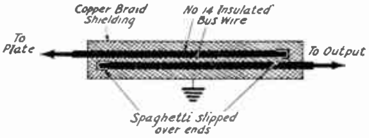


FIG. 69. — HOW THE OUTPUT COUPLING CONDENSER IS MADE

Two pieces of covered bus wire about three inches long placed side by side in a piece of metal braid form the condenser. Any small condenser having a capacity of 10 to 20 $\mu\mu$fd. may be used.

The cathode tap on the coil usually will be set at about ⅓ the length of the coil from the grounded end. The location of the tap is not critical, but if too many turns are used between cathode and ground it sometimes happens that a species of multiple oscillation will be set up, corresponding to the howl a regenerative detector will give if too much regeneration is used. This results in the production of an extended series of beats on either side of the desired one and can easily be cured by reducing the number of turns between cathode and ground. When the coil has been completed and the tap correctly placed the winding should be coated with lacquer or collodion to hold the wires firmly in place.

The signal from the frequency meter can be fed into the receiver quite easily by connecting a wire from the output post on the meter to the antenna post on the receiver. This will give strong signals on all harmonics; in fact the signals may be stronger than is deemed desirable. If this should be the case the wire from the output post can be disconnected from the receiver but left in the vicinity of the receiving lead-in. Satisfactorily loud signals from the frequency meter ordinarily can be obtained even with such loose coupling.

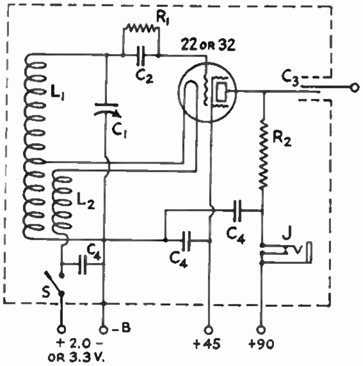


FIG. 610. — ELECTRON-COUPLED FREQUENCY METER CIRCUIT FOR USE WITH DIRECTLY-HEATED TUBES SUCH AS THE 22 AND 32

The circuit is essentially the same as that of Fig. 68 except that both sides of the filament must be fed through coils to prevent grounding the filament. L_1 has the same specifications as in Fig. 68. L_2 has the same number of turns as the tapped portion of L_1. It may be wound over the corresponding part of L_1 or directly on the coil form between the turns of the tapped portion of L_1. The other components have the same values as in Fig. 68. In this circuit the filament switch as well as the output binding post and 'phone jack must be insulated from the shield.

When the frequency meter is first turned on some little time is required for the tube to reach its final operating temperature and during this period the frequency of oscillation will drift slightly. Although the drift will not amount to more than two or three kilocycles on the 3500-kc. band and proportionate amounts on the other bands, it is desirable to allow the frequency meter to "warm up" for about a half hour before calibrating or before making measurements when the utmost accuracy is desired. This is with indirectly-heated tubes. The directly-heated tubes, because of the smaller filament power required, warm up much more quickly. The on-off switch in Fig. 68 is a useful adjunct to the meter because the "B" supply can be cut off independently of the filament supply, permitting the operator to keep the frequency meter up to temperature without wasting "B" current when no measurements are being made.

With careful construction, a good readable dial, and an accurate calibration made as described in the next section, measurements made with the electron-coupled frequency meter can be depended upon to be accurate to within 1 part in 1000, or one-tenth of 1%, an accuracy more than sufficient for amateur work. Just how close this accuracy is can be realized more readily when it is appreciated that if the receiver is set with the aid of the frequency meter to pick up a signal of known frequency, the signal when heard will be within beat-note audibility on the 7000-kc. and lower-frequency bands. In terms of setting the receiver dial, this will be within a fraction of a dial division with ordinary band-spread. The greater the accuracy of the frequency meter the more closely the transmitter can be set to the edges of the bands without danger of overstepping the mark.

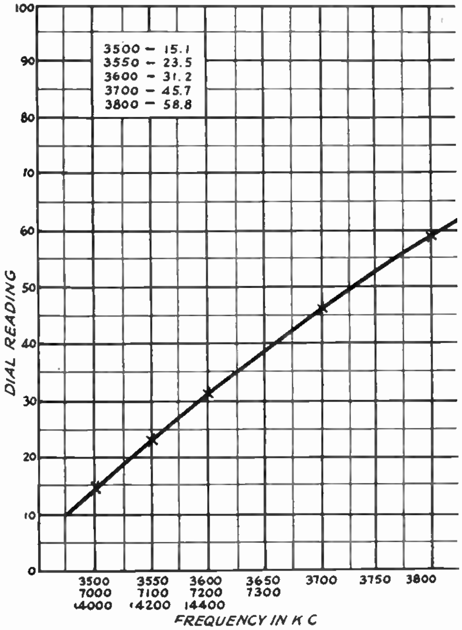


FIG. 611. — TYPICAL CALIBRATION CURVE FOR THE FREQUENCY METER

Each of the small blocks represents a half-inch block on ordinary cross-section paper. The chart must be large enough so that tenths of divisions can be read accurately on the dial reading scale, and the frequency scale must be spread out sufficiently to allow easy reading to within a few kilocycles.

Calibrating the Frequency Meter

When the frequency meter is finished it must be calibrated before it can be put into service. After its tuning range has been checked to be certain that it covers the 1750-kc. band with a little overlap at each end, an approximate calibration may be made using marker stations. These markers may be near *any* of the amateur bands, not necessarily only in the vicinity of 1715 and 2000 kc. For example, stations in the vicinity of 4000 kc. can be used as markers, the actual frequency of the station being divided by 2 to get the calibration point since the second harmonic of the frequency meter is being used. Again, marker stations near 7000 kc. can furnish points for the low-frequency end of the scale, the calibration frequency being the marker station frequency divided by 4 because the checking will be done on the fourth harmonic of the frequency meter. A large number of points can be secured in this way for the purpose of making up a preliminary calibration.

The general procedure is to tune in the marker station on the receiver with the detector oscillating, then back off the regeneration control until the detector stops oscillating but is still giving a great deal of regenerative amplification, just as if a 'phone station were being tuned in. The dial on the frequency meter should now be turned until the signal from the meter is heard to beat with the marker station signal. This amounts to using the frequency meter as a separate heterodyne. Adjust the frequency meter to give zero beat with the marker signal and note the dial reading. The calibration point will be the marker station frequency divided by whatever harmonic of the frequency meter is being used. A number of these points will give a complete enough calibration to make possible the drawing of an approximate calibration curve on regular graph paper.

After this approximate curve has been constructed the current issue of *QST* should be consulted for information as to the next transmission of standard frequencies for calibration purposes. These transmissions are given once or twice each week by the stations comprising the A.R.R.L. Standard Frequency System. A word about the A.R.R.L. Standard Frequency System is in order here because the service is unique in the radio world. The Standard Frequency System consists of three stations especially licensed to transmit calibration signals for amateur use and located in different geographical sections of the United States. Each of the stations is equipped with a frequency standard which is accurate to better than one part in 10,000 or .01%. These individual standards have been calibrated directly against the national frequency standard located in the laboratory of the Bureau of Standards at Washington, and the calibration signals transmitted for amateurs are therefore based on the national frequency standard. Every amateur is urged to make the fullest possible use of the transmissions. In general the transmissions consist of signals which mark accurately the limits of the 3500-, 7000- and 14,000-kc. bands with intermediate points at 100 kc. intervals.

The date and exact form of each transmission is indicated in each issue of *QST*. They generally take the form of an eight-minute period for each frequency, the first part of which is devoted to a QST — general call to all A.R.R.L. stations —

then a series of long dashes followed by an announcement of the exact frequency, and a final short period in which the frequency of the transmission to follow in a few minutes is announced.

The same procedure should be followed in calibrating from Standard Frequency Transmissions as in calibrating from marker stations. The purpose of the marker station calibration is simply to serve as a guide in locating the Standard Frequency signals when the frequency meter is ready for its first calibration.

After the dial readings for various frequencies have been secured, they should be plotted carefully on a curve sheet. The curve should not be "cramped" — that is, the scale should not be so small that accurate readings of frequency cannot be made from the curve. Fig. 611 shows a satisfactory way of making up such a curve. The paper used is standard cross-section paper (20 lines to the inch), and each of the blocks shown in the drawing represents a half-inch block on the paper. It may be necessary to use two sheets to draw the entire curve, one for the low-frequency half of the band and the other for the high-frequency half. The illustration shows calibrations only for the three bands on which Standard Frequency Transmissions are sent. For the 1750-kc. band the 3500-kc. readings would be divided by two. The dial settings are the same for all frequencies harmonically related.

Safety First!

Always play safe when setting the transmitter frequency. Make allowance for all possible errors in frequency measurement and then set the transmitter well inside the limits of the band. Take every opportunity to check the monitor or frequency meter to make sure that nothing has happened to the calibration. *Know* whether you are in the band or not — that part is easy if no attempt is made to crowd the edges. Although accurate determination of frequency is becoming increasingly important, the amateur who follows the simple directions given earlier in this chapter can at least be certain that he is operating in his legally assigned territory, even though no elaborate methods are used for actual measurement of frequency.

Chapter Seven

PLANNING AND BUILDING TRANSMITTERS

THE transmitter is truly the most important piece of equipment in the amateur station. It is the station's mouthpiece through which the operator conveys his thoughts to other amateurs the world over. Distant amateurs must therefore judge the station by the quality of the transmitter's output and by the way it is operated. The amateur is judged by the signal he owns. A steady signal with a clean "pure d.c." note is the finest testimonial an amateur station can have. It is well worth attaining, not only because it indicates possession of a good transmitter intelligently operated but also because it shows that the station's operator is not "hogging" more than his share of the amateur bands — as he would with a rough, wobbly, creeping signal. Moreover, the steady pure d.c. signal is acknowledged to be far superior to all other types for communicating under adverse conditions. Although it may not be the loudest signal heard at the receiving end, the "PDC" signal, with its penetrating flute-like whistle, will be easiest to copy through interference of all kinds. Particularly is this so when a modern ultra-selective receiver is used or one in which a selective "peaked" audio-frequency amplifier is fitted. All the transmitters described in this chapter are designed to deliver steady, clean-cut d.c. signals when built, tuned and operated according to the instructions.

Types of Transmitters

Though there is a great variety of transmitters suitable for the amateur, all of them employ the vacuum tube as a generator of the high-frequency alternating current necessary for the production of radio signals. For this reason, it is quite impossible to have a good understanding of the operation of transmitters without first understanding the way in which vacuum tubes function. It is suggested that the beginner should make a careful study of the second and third chapters before attempting the construction or operation of any of the apparatus described in this chapter.

Present-day amateur transmitters are of two general types: those which employ "self-controlled" oscillators and those in which a crystal-controlled oscillator is used. The first of these types is called "self-controlled" because the frequency of the oscillations generated in the transmitter depend on the constants of the circuit (chiefly the size of the coil and condenser used in the plate circuit of the oscillator). The crystal-controlled transmitter, on the other hand, makes use of a special type of crystal (usually quartz) in the oscillator. In this case, the crystal "sets the pace" and is the chief factor in determining the frequency on which the transmitter operates.

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

Of all transmitters, the crystal-controlled type of set is by far the most satisfactory. In its usual form it is somewhat more complicated than the self-controlled self-excited transmitter but the advantages to be gained in its operation and in the signal it produces far outweigh the added cost. The crystal-controlled transmitter is fast becoming universal throughout the world. There is, of course, still a place for the low-powered self-excited self-controlled transmitter. Its simplicity and its low cost make it attractive to the beginner in amateur radio. Further, it must be admitted that such a transmitter, when built and operated very carefully, is capable of a good performance.

Before we proceed to the actual construction of transmitters of various types, let us outline the requirements in oscillators — both self-controlled and crystal-controlled — and in the amplifiers which may be associated with them.

Self-Controlled Oscillator Circuits

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

The choice of a circuit is not of great importance, for if the circuit is arranged to suit the particular tube or tubes used, and is adjusted properly, similar results can be obtained with any of them. In every oscillator provision is made to tune the condenser-coil circuits to the required frequency and to vary the amount of energy fed into the grid circuit from the plate circuit (the grid excitation). Other means are provided to adjust the grid bias, to match the impedance of the tube, and to adjust the load to that value which will allow the most efficient transfer of energy from the plate circuit. Some method of making all of these adjustments is to be found in every satisfactory circuit. In fact a circuit is nothing more than a combination of the necessities for making such adjustments, the object in making them being to get the largest output without exceeding the input rating of the tube and always maintaining a steady clean-cut signal.

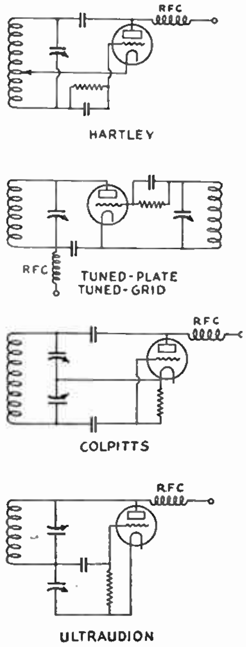


FIG. 71 — FOUR COMMONLY-USED OSCILLATOR CIRCUITS

The Hartley and tuned-plate tuned-grid are the most popular among amateurs for frequencies up to 30,000 kc. On the ultra-high frequencies the Colpitts and ultraudion are popular with experimenters.

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

In the Hartley oscillator the tank circuit, which is a feature of all the circuits, has its ends connected to the grid and plate of the tube. The filament circuit of the tube is also connected to the coil at a point nearer the grid end of the coil than the plate end. In this way the coil is really divided into two sections, one in the grid circuit and a larger one in the plate circuit. Oscillations are maintained because of the inductive coupling between these two sections.

In the tuned-grid tuned-plate circuit there are two tank circuits, one connected between the grid and the filament of the tube and the other between the plate and filament. In the high-frequency oscillator these two circuits are not coupled inductively and the capacity of the tube itself is utilized to provide the coupling between the grid and plate circuits which is necessary to cause oscillation.

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

A fourth circuit is the ultraudion. It belongs to the Colpitts family of circuits, and like the Colpitts, is used by only a comparatively small number of amateurs. The Hartley and tuned-plate tuned-grid circuits are most popular, probably because the adjustments which regulate feedback and frequency of oscillation are more independent in those two circuits, thus making them somewhat easier to handle.

A great many variations of these fundamental circuits have been evolved and it is not surprising that the newcomer is often confused by them. It is well to remember that however complex or unusual the circuit may appear, it can without doubt be "boiled down" to one of the fundamental arrangements. And, what is more important, when it has been adjusted carefully it will provide almost an identical performance to that of any other circuit.

Frequency Stability and Efficiency

The factors affecting frequency stability and efficiency in the self-controlled oscillator are generally interdependent, although the conditions for best frequency stability are not always those giving the highest efficiency with any oscillator circuit. Frequency stability is ever the first consideration and factors affecting it are therefore of utmost importance.

The ideal signal for c.w. telegraph work is one which consists of a single frequency only. This type of signal occupies a minimum of space in the radio-frequency spectrum, thus minimizing interference with other stations, and, since its energy is concentrated on one frequency only, has greater carrying power. An oscillator incapable of maintaining a high degree of frequency stability, whether it feeds the antenna directly or through amplifiers, is characterized by a broad creeping signal, mushy or rough note. It indicates that its owner is inconsiderate of the rights of others in the operation of his station, because any amateur can construct a transmitter of good frequency stability and learn to operate it properly.

The causes of frequency instability can be roughly divided into two groups, those which are "mechanical" in nature and those which are "dynamic." Mechanical instability results from variations in the circuit constants due to mechanical vibration and thermal effects. Mechanical vibration will cause rapid fluctuations in frequency by varying the spacing between condenser plates, the separation between coil turns or the distance between the tube elements. These are avoided largely by rigid construction and by reducing the vibration. Frequency fluctuation ("creeping") due to thermal effects results from variation in spacing of the tube elements (variation in inter-element capacity) with changes in temperature. Creeping can be minimized by keeping the power dissipated in the tube at or below its normal rating, by choosing tubes having internal construction particularly intended to reduce frequency-creeping, and by using circuits which have large capacities in parallel with the tube's input and output capacities. Such circuits are popularly known as "High-C" circuits. The use of a large shunting capacity in the plate circuit is particularly effective.

"Dynamic" instability is caused by anything which affects the tube's characteristics, especially its plate impedance, during operation. Any variation in plate impedance must cause a change in frequency. The principal cause of dynamic frequency instability — sometimes called "frequency flutter" — is the variation in plate voltage which results when a poorly-filtered plate supply is used. It is most pronounced when the tube has insufficient grid bias and is over- or under-excited. It is therefore essential that the plate supply be the best "pure d.c." obtainable and that the grid bias — or grid leak— be sufficiently high in value. Moreover, too much care cannot be exercised in adjusting the grid excitation. Dynamic instability can be reduced by careful circuit design and here again the use of a High-C plate tank is very effective. Such a tank circuit is capable of reducing the amplitude of frequency fluctuations with variations in plate impedance.

The characteristics of the load circuit (which include the plate tank circuit, the antenna circuit or the input circuit of a succeeding tube amplifier) and the losses in the grid circuit affect the oscillator's plate efficiency. The plate efficiency is the ratio of radio-frequency power output to plate power input, although power consumed in the filament should be considered also in determining the true over-all efficiency. The losses in the grid circuit are largely the power dissipated by the grid leak and the losses due to radio-frequency displacement currents between the grid and filament. The latter may be considerable at high frequencies with tubes having large grid-filament capacity.

There is no simple method of accurately determining the plate efficiency of a high-frequency oscillator. If the tube is operated at normal plate dissipation, usually indicated by dull red coloring of the plate, the power output will be approximately the difference between total plate input (d.c. plate voltage multiplied by the plate current in amperes) and the rated plate dissipation in watts. For a more exact determination, the power dissipated in the grid leak should be subtracted also. The power dissipated in the grid leak is the resistance of the leak in ohms multiplied by the square of the d.c. grid current in amperes.

The Crystal-Controlled Oscillator

In marked contrast to the self-controlled oscillators which we have just described is the family of crystal-controlled oscillators. In these circuits the frequency of oscillation is influenced hardly at all by the constants of the circuit or the load associated with it. The reason for this is that the frequency-controlling element is a small slab of crystal (usually quartz) which, because of its electro-mechanical properties, will oscillate at a frequency determined almost entirely by its dimensions. When it is properly connected in the controlling oscillator circuit, the line voltage can vary, the antenna can swing, and the tubes may heat without seriously affecting the output frequency of the transmitter. A ripple in the plate-supply voltage will cause amplitude modulation of the output of such an oscillator but can cause practically no frequency flutter. For this reason, the note produced by a transmitter driven from a properly adjusted crystal-controlled oscillator is always of a piercing musical character. Such a note is unmistakable evidence of a good amateur station.

Before considering the circuits of crystal-controlled oscillators let us examine the crystals themselves.

Crystal Cuts and Grinding

Good active quartz plates are no longer the scarce and expensive articles they were a few years ago and the better understanding of crystals and their operation now available has erased the formerly prevalent idea that crystal control was something for only experienced amateurs to play with. Even the inexperienced can now be assured of success with crystal-controlled transmitters. In some ways the use of crystal control actually simplifies transmitter construction and adjustment.

Although some amateurs, experienced in crystallography and possessing the necessary equipment, cut active slabs from chunks of "raw" quartz, it is more economical to purchase a ground crystal or unfinished "blank," particularly if only one or two crystals are wanted. Finished crystals are now so reasonably priced that it is hardly worth while even to buy an unfinished blank and finish the grinding. The experience to be gained from the grinding process is valuable, however, and many amateurs do buy partially ground blanks and finish the plates themselves.

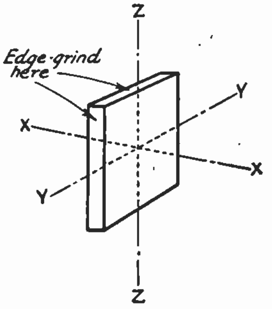


FIG. 72 — RELATION OF THE AXES OF AN X-CUT QUARTZ PLATE

A quartz crystal has three major axes, designated X, Y and Z. The Z axis is the optic axis. The Y axis is the mechanical axis. The X axis is the electric axis and is the one used as a reference in designating the cut of the plates used in oscillators. A plate cut with its major surfaces perpendicular to an *X* axis is known as an X-cut plate. This cut is also referred to as the "perpendicular" and "Curie" cut. Plates cut with their major surfaces parallel to an X axis are known as "Y," "parallel," and "30-degree" cuts. The most accepted terms for these two cuts are X-cut and parallel or 30-degree cut.

Each of these cuts has characteristics of its own and these characteristics determine its suitability for different services. For a given frequency, an X-cut plate is thicker than a 30-degree-cut plate. The X-cut plate has but one major frequency of oscillation which is a function of its thickness but a 30-degree cut plate sometimes has two, generally a kilocycle or so apart. The 30-degree cut plate is usually the more ready oscillator although properly ground and mounted plates of either cut oscillate quite persistently in well-designed power circuits. The X-cut plate is more generally used in power oscillators, although many amateurs have a preference for the 30-degree cut.

When a finished crystal or unground blank is purchased, a statement of the cut should be obtained from the seller. This is particularly important when a blank is purchased because the grinding cannot be done so easily if the ratio of thickness to frequency is not known. For X-cut plates $f \times t = 112.6$ and for 30-degree-cut plates $f \times t = 77.0$, where f is the frequency in kilocycles and t is the thickness in inches. From these relations the thickness for a desired frequency of a crystal of known cut can be determined quite accurately by measurement with a good micrometer such as the Starrett No. 218-C, ½ inch. This tool also can be used to make sure that the crystal is the same thickness at all points and that bumps or hollows are not being ground in. The best crystals are about 1" square, perfectly flat, and the two major surfaces are parallel.

Since the thickness of an oscillating crystal is inversely proportional to its frequency, the plates become very thin and fragile at frequencies above those in the amateur 3500-kc. band. For this reason the most satisfactory amateur crystals are those ground for the 1750-kc. and 3500-kc. bands. If the transmitter is to be operated on the 3500-kc. and higher frequency bands only, a crystal having a suitable frequency in the 3500-kc. band will be best. The higher frequencies are obtained from such a crystal by means of the harmonic generators or frequency doublers to be described further on. Some carefully-ground 7000-kc. crystals are now being used in amateur transmitters but they require very careful handling. There are even instances of successful operation of 14,000-kc. crystals but they are exceptional.

Grinding is usually done by rotating the crystal in irregular spirals on a piece of plate glass smeared with a mixture of No. 102 carborundum and water or kerosene. It is better to have the crystal stuck to a perfectly flat piece of thin brass or a glass microscope slide than to bear down on the surface of the crystal with the fingers. Even pressure over the whole area of the crystal is essential for flat grinding. The crystal will stick to the flat brass plate or slide if the top of the crystal is moistened with kerosene. The crystal should be frequently tested for oscillation in a test circuit such as that shown in the diagram. If the crystal should stop oscillating during the grinding process the edges should be ground as indicated in the illustration of an X-cut plate. The frequency also can be checked by listening to the signal in a receiver and measuring the frequency as described in Chapter Six. When the frequency is within a few kilocycles of the desired value it is well to use a finer grade of carborundum powder for finishing. The FF and FFF grades are suitable for the final grinding.

The Crystal Oscillator Circuit

A typical and widely-used crystal-controlled oscillator circuit is that shown in Fig. 73. It is similar to the tuned-grid tuned-plate except that the crystal replaces the grid tank circuit. Its action is identical with that of the t.g.t.p. circuit. When the plate tank circuit is tuned to a frequency slightly higher than the natural frequency of the crystal, the feed-back through the tube excites the grid circuit and the crystal, due to its piezo-electric properties, oscillates at its natural frequency — *and at that frequency only*. A very good power oscillator arrangement is that shown in the accompanying illustration. The tank circuit for a 3500-kc. oscillator may consist of 18 turns of No. 14 wire or small copper tubing on a 3-inch diameter and a 250-$\mu\mu$fd. receiving-type variable condenser. The plate connection to the oscillator tube may be made at about the center of the inductance to limit the grid excitation and to secure maximum power output from the oscillator, although usual amateur practice is to place the plate tap directly at the end of the inductance.

Bringing the plate tap down on the tank inductance is particularly advantageous when the plate voltage on the crystal oscillator tube is much over 250. The tube may draw more plate current and work at reduced efficiency but the power output will be greater and the oscillator will operate more stably. Since the feed-back which maintains oscillations is through the grid-plate capacity of the tube, its value will be set by the amount of inductance between the plate connection and the filament of the tube. The larger the feed-back the greater will be the radio-frequency current through the crystal circuit. Excessive r.f. crystal current will cause the crystal to heat, as a result of the increased amplitude of mechanical vibration with greater excitation. This will cause the frequency to creep, and, if carried too far, may cause the crystal to crack.

Frequency creep is caused by the temperature-frequency coëfficient of the crystal.

The temperature coëfficient of X-cut plates is negative, that is, the frequency goes down with rising temperature. The temperature coëfficient for 30-degree cut plates is positive, the frequency increasing with rising temperature. To completely overcome creeping with change in temperature, crystals are operated at constant temperature. This is accomplished by mounting the crystal in a compartment equipped with electric heating units controlled by a thermostat. This arrangement is the best for maintaining the frequency constant but is not essential in amateur transmitters.

Nearly all three-electrode tubes with low or medium values of plate impedance will be satisfactory as crystal oscillators. The Type 10 and Type 45 probably are the most popular, since they will handle voltages of the order of 250 nicely and will deliver a reasonable amount of power at that voltage. Smaller tubes will do with lower plate voltages. Low plate voltages are in fact preferable since frequency creep and the danger of cracking the crystal are reduced. In no case should the plate voltage be greater than 400 volts with triode tubes. Recent investigations have shown that the Type 47 pentode is an excellent crystal oscillator tube, giving about the same power output as the triodes at the same plate voltage but with much less radio-frequency current in the crystal circuit. Plate voltages up to 500 may be used with the pentode with no more danger to the crystal than with 250 volts on the triodes. Such voltages are not recommended, however, since they are almost double the rated plate voltage of the 47. Most satisfactory operation is secured with the pentode when the screen voltage is maintained at 90 to 120 volts for plate voltages of 180 and higher. The screen grid should be effectively grounded through a large by-pass condenser, 0.05 μfd. or more. In other respects the circuit is the same as that shown.

Grid bias for the oscillator is supplied through a choke shunting the crystal and is usually obtained from a dry "B" battery. The bias for a Type 10 or Type 47 tube is usually 22.5 volts. Bias for low-impedance tubes will be greater. The Type 45 will operate satisfactorily with negative bias of 67.5 or 90 volts. Grid-leak bias may be used also, the value of the grid-leak resistance being between 10,000 and 50,000 ohms.

Grit or an oily film on the surface of a crystal will affect its operation and will sometimes prevent oscillation. The crystal should be cleaned whenever erratic behavior or stoppage of oscillation gives evidence of a dirty condition. Carbon tetrachloride (Carbona) or grain alcohol are the best cleaning fluids. Handling of the crystal is especially likely to give it an oily surface, and the crystal should always be cleaned after it has been touched by the hands.

Crystal Mountings

To make use of the piezo-electric oscillation of a quartz crystal, it must be mounted between two metal electrodes. There are two types of mountings, one in which there is an air-gap of about one-thousandth inch between the top plate and the crystal and the other in which both plates are in contact with the crystal. The latter type is simpler to construct and is generally used by amateurs. It is essential that the surfaces of the metal plates in contact with the crystal be perfectly flat. Satisfactory mountings can be purchased from most dealers in crystals or can be made up by the amateur.

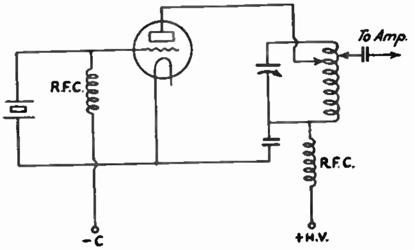


FIG. 73 — THE POWER CRYSTAL OSCILLATOR CIRCUIT

The plate tap on the tank inductance permits control of the grid excitation.

The simplest way for the amateur to rig his own mounting is to make up two flat brass plates, the crystal being placed on one of them and the other being arranged to rest on the crystal with no more pressure than that provided by the weight of the brass. A crystal mounting of this type is illustrated. The plates preferably should be turned flat in a lathe and then ground to a fine finish. Successful plates can be made, however, by cutting them with a hack-saw from ⅛-thick brass plate, then grinding them in much the same way as the crystal would be ground. A suitable size for the top plate is about 1″ square. The bottom plate may be made large enough to accommodate the whole mounting, as shown.

Though it is possible to operate the crystal between such plates merely by arranging the plates and the crystal in the form of a sandwich on a piece of insulating material or on the table top, it is a very much better plan to make up some form of holder out of which the crystal or plates cannot be jarred. The arrangement illustrated in Fig. 74 is one suitable type. Connection to the upper plate can be made by means of a very light leaf of spring brass but a small spiral of very fine copper wire usually is more satisfactory. This wire can be soldered to the plate if care is taken to use an absolute minimum of heat in the soldering process to avoid warping the plate.

From Oscillator to Antenna

We have devoted considerable space to the general consideration of oscillators of various types because the oscillator is the most important single unit of any transmitter. It must be remembered, however, that an oscillator is far from being a complete and practical transmitter. In the simplest form of transmitter (the self-excited transmitter) the chief addition necessary is a means of feeding the antenna system with radio-frequency energy developed by the oscillator. The arrangement most widely used is a coil connected in the antenna feeder or in the antenna itself and inductively coupled with the plate tank coil of the oscillator. To allow adjustment for the maximum possible power transfer between the oscillator and antenna, the coupling between the two coils is made variable. With some such antenna coupling device, with an appropriate power supply and with some keying arrangement, our self-controlled or crystal-controlled oscillator becomes a complete self-excited continuous-wave transmitter.

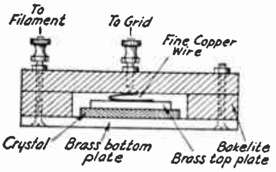


FIG. 74 — SIMPLE FORM OF CRYSTAL HOLDER

The flat brass bottom plate may be round or square, whichever is more convenient. The center part of the inner piece of bakelite is cut out to allow the crystal to rest upon the bottom plate. The top piece is solid and completely encloses the crystal and top plate. Three-sixteenths or quarter-inch bakelite should be used for the inner piece. The brass plates should be 1/16th- or ⅛th-inch stock.

As it happens, a transmitter of this type would not be altogether satisfactory for the serious amateur. The self-controlled version would be simple and inexpensive but it would be subject to all the ills of frequency instability which we have already mentioned. The crystal-controlled version would have excellent frequency stability but its power output would be very limited. Then, it would only be suited for operation on the lower frequency amateur bands unless special and relatively expensive tourmaline crystals were used in place of quartz — the latter being unsatisfactory when used in an oscillator operating on the higher frequency bands. Further, the crystal-controlled self-excited transmitter would require a special crystal for each frequency band on which operation was desired.

Most of these disadvantages are overcome by the use of an oscillator-amplifier type of transmitter. In this case, the output of the oscillator feeds the grid circuit of an amplifier tube. The plate circuit of this amplifier may be coupled to the antenna or may be arranged to provide excitation for further amplifiers preceeding the antenna. The purpose of these amplifier tubes is not only to increase the power output of the transmitter but, in the crystal transmitter, to provide some means of obtaining operation on the higher frequency bands when a relatively low frequency crystal is used in the oscillator.

Amplifiers operated in this fashion are called "frequency multipliers." The plate tank, in a frequency multiplier, is tuned to a frequency which is a harmonic of the exciting frequency. If the output is tuned to twice the exciting frequency, the amplifier is known as a "doubler." The doubling action obtained is caused partly by excitation from the second harmonic output of the oscillator (or preceding amplifier) and partly by distortion in the amplifier itself. Although it is possible to triple frequency with frequency multipliers, doubling is most generally applicable to amateur transmitters because the amateur frequency bands are in even harmonic relation. In typical amateur crystal-controlled transmitters, to be described later, we find several "doublers" operated one after the other in order to obtain good power output on the higher frequency bands.

When an amplifier's output is tuned to the excitation frequency, the amplifier is known as a "straight" amplifier. This is the form of amplifier most commonly used in the self-controlled oscillator-amplifier transmitter and in the final stage of the more powerful crystal-controlled transmitters. Since both the grid and plate circuits are tuned to the same frequency in this form of amplifier, the arrangement becomes a type of tuned-grid tuned-plate circuit which would allow the amplifier to oscillate of its own accord unless special precautions were taken. The most common method of preventing oscillation is by neutralizing the circuit. Circuits of various forms of neutralized amplifiers are given in Fig. 75. If a screen-grid tube is used in the "straight" amplifier or if the amplifier is a "frequency multiplier," troubles from self-oscillation are not likely to occur. Screen-grid tubes, as a matter of fact, were developed for the very purpose of obviating the necessity for neutralizing. In them a second grid is placed between the control grid and the plate and is of such design that these two elements are electrostatically shielded from each other, thus reducing the capacity between control grid and plate to a negligible figure. This reduces the natural feed-back through the tube to such an extent that the tube cannot oscillate as a tuned-plate tuned-grid oscillator; consequently it cannot oscillate when connected in ordinary amplifier circuits if the input and output circuits are properly isolated from each other to prevent direct electromagnetic or electrostatic coupling between them. Unfortunately, the medium-size screen-grid tubes suitable for intermediate amplifiers in amateur transmitters are still relatively expensive.

Neutralizing continues to be one of the very important necessities in most amateurs transmitting equipment. For this reason, we will proceed to give detailed consideration of the circuits used for neutralizing and the manner in which they function.

Neutralizing

As we have already explained, a three-electrode tube used as a radio-frequency amplifier will itself oscillate because of the radio-frequency feed-back through the grid-plate capacity of the tube unless that beed-fack is nullified. The process of neutralization really amounts to taking some of the radio-frequency voltage from the output or input circuit of the amplifier and introducing it into the other circuit in such a way that it effectively "bucks" the voltage operating through the grid-plate capacity of the tube, thus rendering it impossible for the tube to supply its own excitation. There are several ways of doing this, the more common ones being shown in the drawings. Parts of the circuit which are not essential to the neutralizing scheme considered are not included in the diagrams; they will be quite conventional in nature. Circuit B will be recognized as that shown in the 100-watt amplifier illustrated in Figs. 726 and 727.

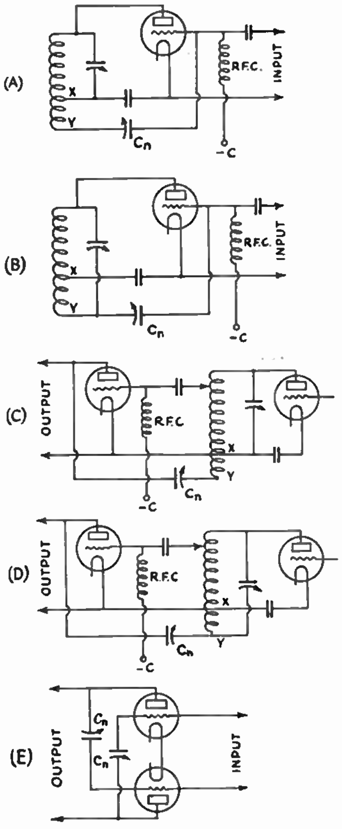


FIG. 75—A GROUP OF AMPLIFIERS SHOWING FIVE METHODS OF NEUTRALIZING

The first four are for use with single-tube amplifiers or for tubes in parallel. The fifth is widely used with push-pull amplifiers.

In Circuits A and B the operation is the same; the choice between one or the other is simply a matter of preference or mechanical considerations. A point on the tank inductance (usually a third or half the way up toward the plate end) is made to assume the same r.f. potential as the filament by connecting it to the filament through a by-pass condenser. The voltage at the lower end of the coil is therefore opposite in phase to that at the plate end, and this voltage is fed back to the grid through a small condenser, C_n, to balance the voltage which appears across grid and plate. Exact balance is obtained by properly proportioning the number of turns between X and Y and by adjusting the capacity of C_n. If parallel plate supply feed is used the by-pass condenser between the point X and the filament is unnecessary, since there will be no d.c. voltage between the two points and a direct connection can be made.

Circuits C and D also are equivalent. In these circuits the neutralizing or bucking voltage is obtained from the tank circuit of the preceding tube and is fed to the plate of the amplifier through the neutralizing condenser. The tank tuning condenser may be connected across part of the coil or all of it, whichever seems most desirable. It will be noted that these circuits bear a strong resemblance to the Hartley oscillator, with the neutralizing condenser taking the place of the grid condenser. They will in fact perform as such unless the capacity of neutralizing condenser is adjusted to the value which just balances the effect of the grid-plate capacity of the tube.

Circuit E is one often used with push-pull amplifiers, and is known as "cross-neutralization." The neutralizing condensers are connected between the grid of one tube and the plate of the other, and, when their capacities are equal to the grid-plate capacities of the tubes, perform the same function as those in the other circuits. This method of neutralizing is independent of the inductance values in the input and output circuits so long as the center-taps on the coils are set correctly, which is a convenience when the transmitter is shifted frequently from one band to another. With the other circuits, changing the coil which supplies the balancing voltage is almost certain to upset the neutralizing with the result that the neutralizing condenser must be readjusted when changing bands. The by-pass condenser which "grounds" the tap on the inductance to the filament must have low reactance at the frequency on which the amplifier is operated; otherwise it is impossible to completely neutralize the tube. A .002-μfd. or larger condenser will suffice for most amateur transmitters.

The procedure necessary to make actual adjustments for neutralizing will be treated later in this chapter.

Now that we have considered the fundamental principles with which we must be concerned in planning any modern amateur transmitter, we may proceed to the more practical considerations and to the actual construction of the apparatus.

Transmitting Tubes

The type of tube or tubes to be used should be given consideration before a start is made with the construction of any of the apparatus for the transmitter. The design of almost every item in the transmitter will be influenced by the tube with which it is to be operated. The rating of the transformers, the current-carrying capacity of the filter, the rating of the fixed condensers, the type of variable condensers and the design of the inductances, all will depend upon the power and voltage rating of the tube.

Fortunately there is a splendid array of transmitting tubes from which to choose. What is more, the tubes available are of high quality with satisfactory characteristics. If they are handled carefully and operated correctly they will give wonderful service.

The amateur usually uses the lowest-power transmitting tube, the Type 10 — or even a

TRANSMITTING TUBES

Type	Use[1]	Normal Output (Watts)	Plate Volts[2] (E_b)	S.-G. Volts (E_d)	Plate Ma. (I_p)	Negative Grid Bias Volts[3] (E_c)	Fil. Volts (E_f)	Fil. Amps. (I_f)	Typical Characteristic Values		
									Amp. Factor (μ)	Plate Impedance Ohms (r_p)	Mutual Conductance Micromhos (g_m)
45*	A B C	1.6 5.0 5.0	275 300 300		36.0 50.0 50.0	56.0 90.0 180.0	2.5 (a.c.)	1.50	3.5	1670	2100
46	A B[4] C	1.25 10.0 12.0	250 400 400		22.0 63.0 60.0	33.0 0 50.0	2.5 (a.c.)	1.75	5.6	2380	2350
47	A B C	2.5 5.0 5.0	250 250 250	250 100 100	32.0 50.0 50.0	16.5 22.5 45.0	2.5 (a.c.)	1.75	90.0	35,000	2500
50	A, M	4.6	450		55.0	84.0	7.5 (a.c.)	1.25	3.8	1800	2100
10*	A B C	1.6 12.0 10.0	425 350 350		18.0 43.0 60.0	39.0 39.0 100.0	7.5 (a.c.)	1.25	8.0	5000	1600
841	V		425		7.5	8.0	7.5 (a.c.)	1.25	30.0	21,500	1400
842	A, M C	3.0 7.5	425 350		28.0 60.0	100.0 250.0	7.5 (a.c.)	1.25	3.0	500	1200
65*	B C	7.5 7.5	500 500	125 125	30.0 60.0	40.0 90.0	7.5 (a.c.)	2.0	150.0	200,000	750
03-A	B C	160.0 100.0	1000 1000		130.0 175.0	35.0 100.0	10.0 (a.c.)	3.25	25.0	6000	4200
11	A B C M	10.0 160.0 100.0	1000 1000 1000 1000		65.0 130.0 175.0 25.0	52.0 75.0 200.0 68.0	10.0 (a.c.)	3.25	12.0	3400	3530
845	A, M	23.0	1000		75.0	147.0	10.0 (a.c.)	3.25	5.0	1800	3000
850	B C	30.0 100.0	1250 1000	175 175	150.0 175.0	8.0 150.0	10.0 (a.c.)	3.25			
852*	B C	120.0 100.0	2000 2000		60.0 100.0	150.0 250.0	10.0 (a.c.)	3.25	12.0	10.000	1200
860*	B C	120.0 100.0	2000 2000	300 300	60.0 100.0	50.0 200.0	10.0 (a.c.)	3.25	200.0	180,000	1100
04-A	B C	340.0 350.0	2000 2000		143.0 275.0	70.0 175.0	11.0 (a.c.)	3.85	25.0	6300	4000
849	A, M B C	100.0 660.0 450.0	3000 2000 2000		100.0 260.0 350.0	132.0 95.0 200.0	11.0 (a.c.)	5.0	19.0	3200	6000
861*	B C	600.0 540.0	3000 3000	500 500	167.0 350.0	60.0 200.0	11.0 (a.c.)	10.0	300.0	143,000	2100

* Particularly suited to use as an oscillator or radio-frequency power amplifier at frequencies above 3000 kc. (wave-lengths below 100 meters).

[1] *A* — Audio-frequency output amplifier. *B* — Radio-frequency power amplifier, particularly as a linear amplifier for modulated radio-frequency. Power ratings given are peak output. Carrier power will be one-fourth values shown for 100% modulation. Plate currents indicated are average, not peak. *C* — Oscillator or modulated radio-frequency power amplifier. *M* — Plate (Heising) audio-frequency modulator. *V* — Voltage amplifier. A more detailed explanation of the transmitting tube designations will be found in the chapter *Radiotelephony*.

[2] Plate voltage specified for receiving tubes is maximum. Plate voltage for *B* and *C* use is maximum for modulated operation. Unmodulated, values may be slightly higher.

[3] Bias measured from filament center-tap or cathode with a.c. filament supply.

[4] Audio-frequency rating.

receiving tube — for his first transmitter. This practice is a good one. The use of low power enables the transmitter to be built cheaply and yet provides full opportunity for the amateur to gain a knowledge of the operation and handling of a transmitter. Many of the most experienced amateurs actually prefer a low-power transmitter of this type, knowing that they can readily communicate over many thousands of miles under good conditions. The distance that can be covered by a transmitter is, in fact, not very much dependent upon the power of the transmitter. Even a receiving tube in the hands of an experienced amateur can send across the world when conditions are very good. The higher-powered transmitters can send no farther than this but they have the advantage of being able to put signals into far distant countries with greater reliability and readability.

Many amateurs use tubes having a higher power output rating than the 10-watt Type 10. Such tubes are listed in the table which is a part of this chapter. Screen-grid power tubes are included also. The explanation of the Class A, B and C designations is given in the following chapter on radiotelephony.

The type designations of transmitting tubes in this table, as well as of the rectifier tubes in Chapter ten and the modulator tubes of Chapter eight, are generally applicable to standard tubes of American manufacture. The designation consists of the last two figures of the manufactures' type number preceded by the word "Type." The only exceptions are for tubes which are made exclusively by one concern or where two entirely different types of tubes happen to have the last two figures of their type numbers in common, as with the UX-245 and UV-845.

Planning the Transmitter

The low-powered transmitter really can be considered as an oversize oscillating receiver. There are few essential differences in its arrangement and not much more difficulty involved in its construction. The chief thing to remember is that, whereas extremely minute currents flow in the tuning circuits of the receiver, very heavy currents flow in even the low-power transmitter. This means that the first constructional difference between the transmitter and receiver is in the size of conductors used for the tuning coils and the leads connecting them to the tuning condensers. Heavy wiring is required in most other parts of the transmitter but it is of greatest importance in the tuning circuits, where the currents obtained are many times greater than those in any other portions of the circuit.

Another essential difference between the receiver and transmitter is that the fields around the coils and condensers of the transmitter are very much more intense than in the receiver. Consequently greater spacing between the coils and other apparatus is desirable and the elimination of unnecessary heavy insulating material supports inside the coils is important.

Yet another prime difference is that the voltages in the transmitter are of a much higher order than in the receiver. Insulation throughout the transmitter must therefore be given particularly careful consideration.

There is a splendid field for the exercise of thought and originality in the arrangement of the apparatus of the transmitter. The shortness of leads and the placement of the coils and condensers with respect to the other apparatus are matters of such importance that the amateur will always be rewarded for time spent in consideration of the problem. In the pages that follow some examples of satisfactory layouts will be given. These will serve to give a general idea of how the transmitter can be arranged. However, they are not the acme of perfection. Neither are they applicable to all types of apparatus. The use of even a different variable condenser than that shown in any one of the examples — a condenser with its terminals in a different place — may make some entirely different lay-out preferable. The amateur should not allow this discussion to dishearten him, however, for it cannot be denied that excellent results are being obtained every day in amateur stations all over the world with the apparatus arranged in quite different fashions.

Most of the transmitters to be described are baseboard-mounted with all the apparatus exposed and readily accessible for adjustment or experiment. If desired, the apparatus can be mounted on a baseboard and a vertical panel in a manner somewhat similar to the receiver. Unless the apparatus is arranged with great care, however, this type of construction is likely to mean a sacrifice of convenience in making alterations and adjustments.

Building a Transmitter

The construction of a simple transmitter can be accomplished in the shortest time and with the least difficulty by mounting the apparatus on a baseboard in somewhat the manner shown in the illustrations. We will use this self-controlled self-excited transmitter as an example and describe it in detail. If the reader studies the circuit diagram, the photographs and the description carefully he will find that the transmitter is even simpler than it looks. If he understands just what it is all about he will find it easier to modify the arrangement to suit the particular apparatus at his disposal.

This transmitter is perhaps the simplest and most nearly fool-proof ever designed. It contains the very minimum of parts and is therefore extremely low in cost. The construction is in no way complex and the adjustment is easily accomplished by even the inexperienced operator. The circuit is a modification of the popular tuned-grid tuned-plate arrangement. Despite its simplicity, the set has excellent frequency stability and efficiency, comparing favorably with more complicated arrangements.

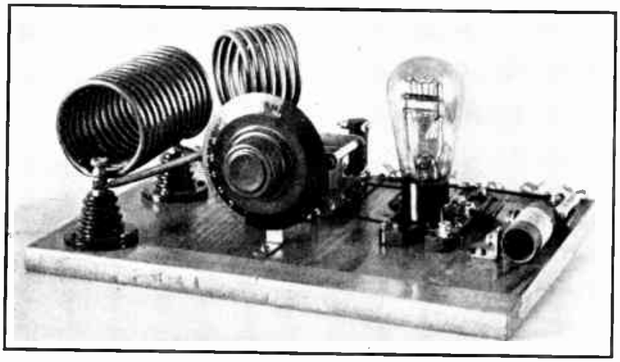


FIG. 76 — THE SINGLE-CONTROL LOW-POWER TRANSMITTER

The plate tank circuit is at the left. The grid coil, leak and grid condenser are to the right of the Type 10 tube. The antenna coil is shown swung away from the plate coil to give loose antenna coupling.

The frequency is determined by the tuning of the plate tank circuit and the excitation is dependent on the constants of the grid circuit. Since one excitation adjustment is satisfactory over a considerable range of plate-tank tuning, it is possible to use a fixed coil in the grid circuit for each amateur band. An antenna coupling coil is provided in the set but an external antenna tuning condenser (perhaps two of them) will usually be found necessary. The set is designed to use a Type 10 tube with a 500-volt d.c. plate supply and a 7.5-volt a.c. filament supply, a Type 45 tube with a 350-volt d.c. plate supply and a 2.5-volt a.c. filament supply, or a Type 01-A tube with a 135-volt d.c. plate supply and a 6-volt d.c. filament supply.

Construction of the Set

The schematic wiring diagram is given in Fig. 77, together with the constants, and the photographs show how the set looks when constructed. The layout chosen is one which allows short r.f. leads.

The grid coils L_2, are wound with No. 30 d.c.c. wire on 2½-inch length of 1-inch tubing, which may be of bakelite, paper, wood or any other of the common insulating materials. The coils should be given a coat of collodion or clear Duco varnish to maintain their characteristics. Two small brass angles, obtainable from any hardware store, serve both as connections and supports for these coils, the ends of the winding being brought out to small machine screws inserted at the ends of the coil forms.

The baseboard itself is a bread-board 12½ inches long by 10 inches wide. Two General Radio stand-off insulators are mounted at one end, as shown in the photographs, and serve as a support for the plate coil, L_1. These insulators should be placed 4½ inches apart between centers. This mounting is very solid mechanically, and allows easy changing of coils. If changes from one band to another are frequent, it might be advisable to use wing-nuts to fasten the coils down instead of the hexagonal nuts furnished with the insulators.

The plate coils themselves are ¼-inch soft copper tubing, wound around a pipe 2⅜ inches outside diameter. The ends of the coils are flattened in a vise and drilled to fit over the machine screws in the G. R. insulators. The 3500-kc. coil should have the turns so spaced that when finished it will just fit on the insulators without having the ends bent out, as is done on the coils for the higher-frequency bands. The spacing between turns on the 7000-kc. coil is about 3/16-inch, and on the 14,000-kc. coil about ⅞-inch. After the coils are finished they should be polished with fine steel wool, thoroughly cleaned with alcohol, and given a coat of clear Duco, greatly diluted with "thinner," to keep them bright.

The tuning condenser C_5, in this case a 21-plate

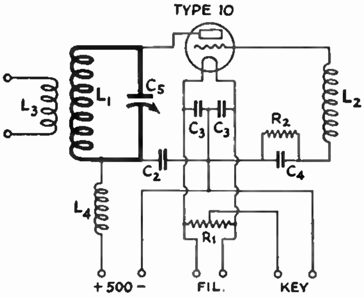


FIG. 77 — THE CIRCUIT OF THE TRANSMITTER

L_1, L_2 and L_3 — Plate, grid and antenna coils. The specifications are given under the illustration of the coils.

L_4 — A commercial "short-wave" receiving-type radio-frequency choke will do or one can be made by winding a two-inch length of half-inch tubing or wooden dowel with No. 38 d.s.c. or d.c.c. wire.

C_1 — 2000-μμfd. (.002 μfd.) mica fixed condenser, receiver type.

C_2 — 2000-μμfd. (.002 μfd.) mica fixed condenser, receiver type, if plate voltage does not exceed 500.

C_3 — 5000-μμfd. (.005 μfd.) mica fixed condenser, receiver type.

C_4 — 250-μμfd. (.00025 μfd.) mica fixed condenser, receiver type.

C_5 — 500-μμfd. (.0005 μfd.) variable condenser. Any good receiving condenser will be satisfactory.

R_1 — Center-tapped resistor, 75 to 100 ohms total resistance.

R_2 — Grid leak resistor, 10,000 ohms. Any small resistor rated at 5 watts or more will do.

Three General Radio or similar stand-off insulators will be necessary, as well as 8 Fahnestock clips, some miscellaneous small machine screws and nuts, and a few feet of bus wire.

Cardwell, is mounted on small brass angles of the same type used for mounting the grid coil. Connections between the condenser and the coil are made by pieces of copper tubing, since the leads in the tank circuit must be as heavy as the inductance itself. The connection to the insulator at the front of the baseboard should be from the rotary plates (the condenser frame), that to the rear insulator going to the stationary plates. This puts the "hot" end of the coil at the back of the set and reduces the effect of hand capacity.

The plate by-pass condenser, C_2, is mounted close to the tuning condenser on the baseboard. The radio-frequency choke, L_3, is just behind it. The filament by-pass condensers, C_3, are directly behind the tube socket. The purpose of these condensers is to provide an easy path for radio-frequency currents flowing to the filament of the tube which would otherwise have to go through the resistor R_1. When the filament of the tube is heated from alternating current these "center-tap" resistors are necessary to avoid having the alternating voltages on the filament reach the grid, for this would cause modulation or "ripple" on the transmitted signal. The voltage at the leads to the filament is constantly changing at the 60-cycle supply frequency but the voltage at the center point of the resistor R_1, is constant. Another method of accomplishing the same result is to use a center tap in the filament-supply winding of the transformer. The center-tap resistor arrangement is sometimes preferable, however, since it permits the use of a filament rheostat in the secondary of the filament transformer instead of the primary. Rheostats for the secondary winding are more readily available than the other type. In place of the resistors, Christmas-tree lamps or automobile headlight lamps can be used. They are equally effective.

The grid condenser, C_4, and lead, R_2, are to the right of the filament by-pass condensers. The condensers in this set, which are Sangamo, are mounted flat by means of machine screws running up through the baseboard. The filament center-tap resistor, R_1, is mounted directly on top of the filament by-pass condensers.

The antenna coil, made in similar fashion to the tank coils, is mounted on a G.R. insulator (immediately behind the tank condenser). Connection to the far end of this coil is made by means of a clip and a small piece of flexible wire. The coil may thus be swung away from the plate tank coil in order to vary the antenna coupling.

All connections are run to the rear of the board where they terminate in Fahnestock clips. From right to left in the photograph, the first pair of clips is for antenna or feeder connections, the second for "plus" and "minus" high voltage, the third for filament supply and the fourth pair for the key. The wiring of the whole set is quite simple, and in case it is to be duplicated no difficulty should be experienced in following the diagram and photographs.

The 350-volt power supply described in Chapter Ten is an excellent one to use with this transmitter when the transmitter tube is a Type 45. This power supply may also be used to supply plate voltage for a Type 10 oscillator, in which case a separate 7.5-volt filament transformer for the 10 will be required. Alternatively, a 550-volt supply for a Type 10 tube may be built up from the information given in Chapter Ten. Most 550-volt power transformers intended for radio use have 7.5-volt filament-heating windings for the oscillator or amplifier and rectifier tubes, in addition to the plate windings. If a Type 01-A receiving tube is used, the plate supply can be a 135-volt "B" substitute of 135 volts of "B" batteries. Filament supply can be from a 6-volt battery, through a 6-ohm rheostat.

Tuning the Transmitter

The tuning of any transmitter is a matter of the greatest possible importance. The performance of even the best transmitter can be spoiled by the slightest misadjustment, and on the other hand almost any transmitter can be made to perform well by an amateur experienced in the work. Even the most experienced amateur, however, cannot tune the transmitter effectively unless he

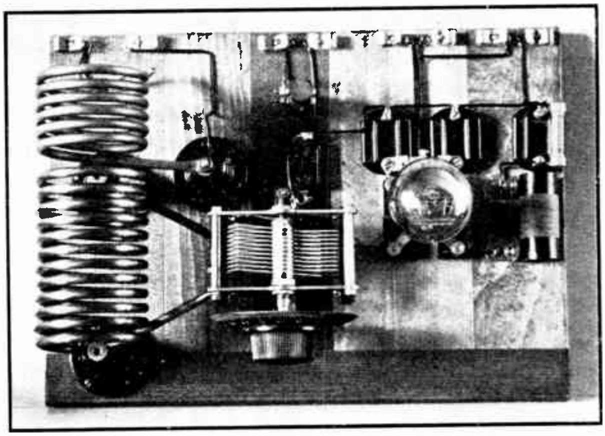


FIG. 78 — PLAN VIEW OF THE TRANSMITTER

The antenna coil, L_3, is to the rear of the plate inductance. The fixed condenser, C_2, and the radio-frequency choke are behind the tuning condenser, C_5. The two fixed condensers behind the socket are the filament by-pass condensers C_3. The filament center-tap resistor, R_1, is mounted on top of these condensers. The grid condenser, C_4, and grid-leak resistor, R_2, are to the right of the socket. The grid inductance, L_2, is in front of the grid condenser and leak. The connections to the Fahnestock terminals are explained in the text.

is able to listen to it as he adjusts the controls. The use of some sort of monitor to listen to the signal as the transmitter is tuned is essential. A detailed description of simple monitors will be found in Chapter Six. It should be studied and a monitor built before any attempt is made to tune the transmitter.

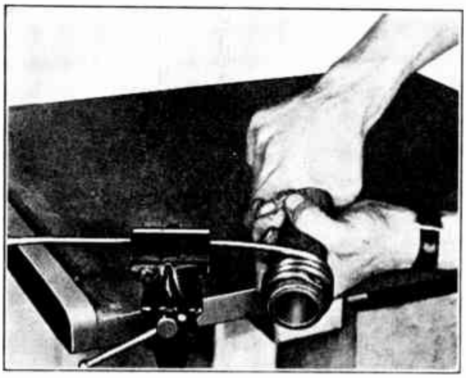


FIG. 79 — WINDING A COPPER-TUBING INDUCTANCE

One end of the tubing is held in the vise and the other is flattened out and bolted to the pipe used as a winding form. Pulling on the tubing and turning the pipe in the hands, the operator walks towards the vise. The turns should be wound as closely together as possible and spaced later.

In addition to the monitor, an extremely desirable aid to tuning is a "tuning lamp." This is nothing more than a flash-lamp bulb connected in series with a single turn of heavy wire about two or three inches in diameter. In use, the turn of wire is coupled to the tank coil of the oscillator or amplifier and induced currents cause the lamp to glow. With practice, it soon becomes possible not only to detect the presence of r.f. current in the tank coil with such a lamp but also to gain a very useful idea of the amount of "soup" in the tank.

Before the transmitter can be tuned, it is obviously necessary to have available a suitable power supply, antenna and keying circuit. It will therefore be assumed that the reader will have studied the chapters on those matters and built the necessary equipment before attempting the all-important tuning process. It will be assumed, also, that the oscillator coils and leads have been made rigid; that the transmitter itself has been mounted in such a way as to escape vibration from keying and that the antenna and feeder wires have been made tight enough to avoid any swinging in the wind. We are ready to start tuning only after all these matters have been given attention.

Even then, we cannot expect to do a good job of tuning the set unless we have one or more meters. Of greatest importance is a plate current meter in the positive high voltage lead to the transmitter. Without such a meter, we have no idea of the power input to the tube and so are in danger of wrecking the tube and possibly other equipment right at the start. For a single tube transmitter like this one, the plate meter might well be a d.c. milliammeter reading to 100 m.a. Meters reading to 250 and sometimes to 500 m.a. will be necessary for the higher powered sets. The other very desirable meter is a thermo-couple ammeter to be connected in the antenna or feeder circuit. When this meter is connected at a point of maximum current in the antenna (a current anti-node) its reading will give a good indication of *changes* of power in the antenna with changes in the transmitter adjustment. It is possible to dispense with the antenna meter and still tune the transmitter effectively if the operator is prepared to pay very careful attention to the plate meter and to make use of the tuning lamp.

Assuming that at least a plate meter is in the circuit, the first move is to switch on the filament supply, make certain that the tube lights and check the voltage at the tube terminals. Excessive filament voltage will soon ruin any tube. Then,

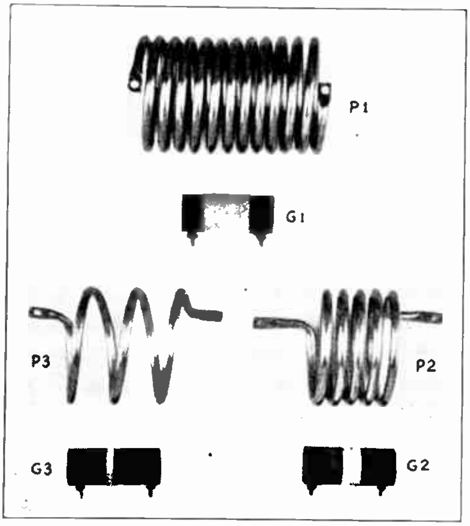


FIG. 710 — THE PLATE AND GRID COILS

A description of these coils is contained in the text, while the number of turns on each is given below.

Coil	Band	Turns
P-1	3500	12
P-2	7000	5
P-3	14,000	3
G-1	3500	60
G-2	7000	25
G-3	14,000	9

For the 1750-kc. band, a plate coil of 25 turns of No. 14 d.c.c. on a 3″ diameter form with spacing between turns equal to the diameter of the wire; a grid coil of 150 turns on the same size form as the other grid coils. The number of turns on the grid coils may require some modification. Turns should be added or removed until the set operates stably and efficiently over the required frequency band.

The antenna coil is of 6 turns exactly similar to those used in coil P-1. A clip on this coil enables the best number of turns to be selected.

the antenna leads should be disconnected, the key opened and the plate tank tuning condenser set to approximately the correct position. If the constructional specifications have been followed closely, this setting will be with the rotor plates about four-fifths meshed for the 3500-kc. band; about three-quarters meshed for the 7000-kc. band; and about half meshed for the 14,000-kc. band. The antenna system should have been constructed to specifications for a frequency in the middle of one of the bands, preferably for about 3575 kc. in the 3500-kc. band.

Tuning for operation on the 3500-kc. band (with the 12-turn plate coil), set the condenser with the rotor plates four-fifths in, turn on the power supply and close the key. If the tuning lamp is now held near the front end of the plate coil the bulb should glow, indicating that the set is oscillating. The loop should not be held too close to the coil, however, because the bulb is likely to burn out. The frequency should now be checked with the frequency meter following the method described in the preceding chapter. If the frequency is outside the band, the transmitter should be retuned to a frequency inside the band.

During this process the plate current milliammeter should be watched to make certain that the plate current falls to a minimum as the plate tank is tuned to the desired setting. Should this minimum point occur at a frequency lower than that desired, it is an indication that the grid coil has too many turns. If the minimum point occurs at too high a frequency, it shows that the grid turns should be increased. This trouble is not likely to happen, however, if the constructional specifications are followed carefully.

Coupling the Antenna

With the oscillator operating on the desired frequency, the feeder or antenna may be connected and the antenna coil swung at an angle of about 45 degrees to the plate coil. As the antenna or feeder condensers are tuned it will now be found that the plate current rises as the antenna comes into tune with the oscillator. Also it will be seen that while the tuning lamp bulb may glow brightly (when the loop is placed near the tank coil) with the antenna de-tuned, it will become dim as the antenna comes into tune and takes power from the tank. These effects of the rising plate current and the dimming tuning lamp are of the greatest assistance in tuning the antenna circuit when no antenna meter is available. With an antenna ammeter, of course, it is merely necessary to tune the antenna or feeder circuit for maximum meter reading in order to locate the point of resonance.

The next adjustment to be made is that of antenna coupling. It must be kept closely in mind that there is an optimum value of coupling which allows the greatest transfer of power from the tank circuit to the antenna. Closer coupling than this results in lowered efficiency and, in the case of the self-controlled self-excited transmitter, invariably destroys the quality of the transmitted signal. Excessive coupling usually can be detected by the existence of two settings of the feeder or antenna condensers at which the feeder or antenna current rises to a peak. In a transmitter of this type, the antenna coupling must always be less than the optimum value just mentioned. Experience has shown that it is a good plan first to get the optimum coupling for greatest output and then to reduce the coupling until the feeder or antenna current reads about 85 per cent. of the first value. Then, the antenna or feeder circuit should be detuned until the current drops a further 10 or 15 per cent. These adjustments should only be made while listening to the signal on the monitor since the most unexpected things may happen to the quality of the signal and its frequency. The signal quality is usually better with the antenna circuit detuned on one side of resonance than on the other.

It is futile to give definite instructions with respect to the proper plate current since this depends so much on the plate voltage and on the manner in which the transmitter is adjusted. When the oscillator is operated at high efficiency, the input can be carried above the 350 volts and 60 m.a. at which the Type '10 tube is rated. About the only practical procedure is to keep a careful watch for heating of the tube plate. Even a dull red plate is indication of excessive plate dissipation. The remedy is either decreased plate current or improved efficiency.

Using Two Tubes

If one wants more power output from the transmitter than one tube can give and yet does not wish to go to the expense of installing the next larger size of power tube, it is possible to use two tubes in parallel or push-pull to double the power output. Tubes connected in parallel have their plates, grids and filaments respectively connected together; the oscillatory circuits used with them are otherwise exactly the same as for one tube. The push-pull oscillator circuits correspond to the push-pull amplifier circuits so common in present-day broadcast receivers; that is, the tubes are in effect connected in series in both input and output circuits. Although theoretically the total power output is the same with either method of connection, in actual practice the push-pull arrangement is preferable for oscillator circuits at the high frequencies used by amateurs. When tubes are used in parallel it is quite likely that "parasitic oscillations" — undesired ultra-high-frequency oscillations which occur simultaneously with the oscillations at the operating frequency, and which cause loss of power and consequent reduction of efficiency and often adversely affect the frequency stability — will be set up unless small radio-frequency choke coils are inserted in

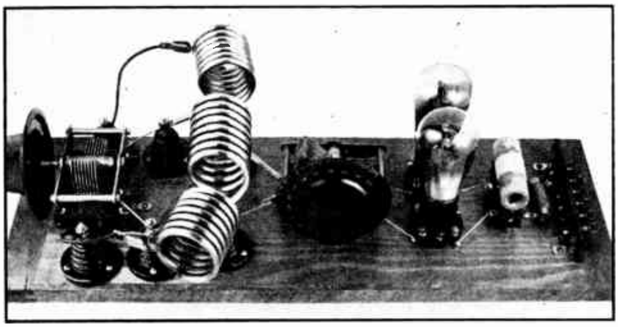


FIG. 711 — THE PUSH-PULL TRANSMITTER

The variable condenser at the extreme left is the antenna tuning condenser. The stand-off insulators immediately in front of and behind it serve as antenna or feeder connection posts and also connect to flexible leads which terminate in clips fastened to the antenna coupling coils, which are mounted on the adjacent pair of insulators. A third pair of stand-off insulators holds the plate coil. Next is the plate tuning condenser, then the tube sockets, grid coil and mounting, grid leak, and finally a connection strip.

the grid lead to each tube. A further disadvantage of parallel operation is the fact that the tube inter-electrode capacities are paralleled and thus are likely to have a greater effect on the frequency of oscillation than would the inter-electrode capacities of a single tube. Generally this means that the transmitter frequency will creep to a greater extent than it would with a single tube.

In the push-pull circuits these disadvantages are overcome to a large extent. The input and output capacities of the tubes are in series across the tuned circuits, thereby effectively halving the effect of shunting tube capacities. This increases efficiency by reducing the losses due to high inter-electrode capacity, and improves frequency stability.

All of the "standard" circuits are adaptable to conversion to push-pull but some are better qualified than others. The essential difference between the set-up of a push-pull circuit and a single-ended circuit is that in the push-pull circuit the plates of the tubes are connected to opposite ends of the output circuit and the grids are connected to opposite ends of the input circuit. A study of the various Hartley, Colpitts, ultraudion and tuned-grid tuned-plate arrangements immediately shows that their push-pull versions are of various degrees of complication in construction and adjustment. The push-pull tuned-grid tuned-plate circuit is possibly the simplest and most straightforward.

A Push-Pull Transmitter

Although two tubes are used, the design and layout of a push-pull transmitter is no more difficult or intricate than that of a single-tube set, as the accompanying photograph shows. This transmitter is intended to be used with either Type 45 or Type 10 tubes.

The circuit is essentially that of the previous transmitter adapted for push-pull operation. The grid coils are center-tapped, as required for the push-pull circuit. The center-tap on the plate coil is obtained by means of a clip attached to a flexible lead which comes up through the baseboard. The location of each part is clearly shown in the photograph; all are mounted on top of the baseboard except the r.f. choke, filament center-tap resistor, and the filament by-pass condensers, which are fastened to the under side of the board. A separate photo-

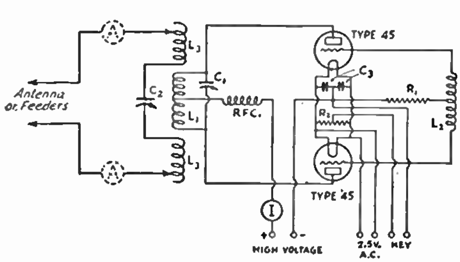


FIG. 712 — THE PUSH-PULL TRANSMITTER CIRCUIT

C_1 — 500-μμfd.
C_2 — 350 or 500-μμfd.
C_3 — 250-μμfd.
R_1 — 50,000 ohms for Type 45's; 10,000 ohms for Type 10's.
R_2 — 75-ohm center-tapped resistor.
L_1, L_2, L_3 — See photograph for details.
I — 0-200 d.c. milliammeter.
A — 0-1 thermo-couple ammeter.

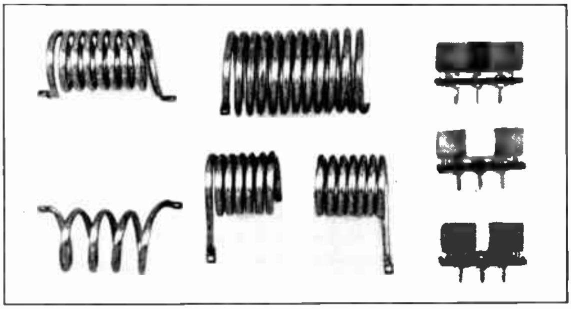


FIG. 713 — GRID AND PLATE COILS FOR THE PUSH-PULL TRANSMITTER

The two copper-tubing coils on the left are the 7000-kc. and 14,000-kc. plate coils. The large coil in the center is the 3500-kc. plate coil, and the two below it are the antenna coupling coils. The grid coils for the three bands have the following specifications: 3500 kc., 72 turns of No. 32 s.s.c.; 7000 kc., 40 turns of No. 28 d.c.c.; 14,000 kc., 16 turns of No. 28 d.c.c. All are wound on forms of one inch outside diameter, and all are tapped at the center turn. The plate and antenna coils are formed on iron pipe with an outside diameter of 1⅝ inches except the plate coil for 3500 kc., which is wound on 2⅜-inch pipe.

graph shows plate and grid coils for three bands as well as the antenna coupling coils.

This type of transmitter should be tuned in almost exactly the same manner as the single tube set. If any adjustments are found necessary in the grid coils, a similar number of turns should be added or removed on both sides of the center tap. The antenna coupling and tunning should be adjusted until maximum antenna current is secured and then "backed off" as described with the previous transmitter. The frequency should be checked again, as should also the quality of the note. The antenna coupling coils should be set at equal distances from the plate coil.

The 350-volt power supply illustrated in Chapter Ten is an excellent one to use with this transmitter when Type 45 tubes are used as oscillators. With Type 10's the power supply should be capable of an output of 120 milliamperes at 500 volts.

An Alternative Design

Both of the transmitters already mentioned were built around the "tuned-plate tuned-grid" circuit. There is no reason, of course, why excellent transmitters can not be built with other circuits. To illustrate the use of another circuit, we will describe briefly the transmitter shown in Figs. 714 and 715. This unit employs one of the "unity coupled" circuits which are now becoming so popular. The circuit really belongs to the Hartley circuit family but its new name is justified by the fact that the grid coil is *inside* the tubing which forms the plate coil. The circuit is valued because of its simplicity and the ease with which it can be built into a small transmitter. It is particularly suitable for the amateur who desires to build up several small transmitters, each operating on a different frequency band.

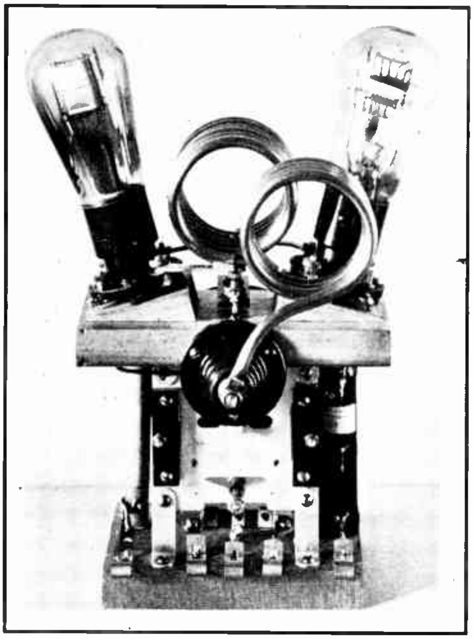


FIG. 714 — THE UNITY-COUPLED TRANSMITTER

The tube sockets are arranged so that the grid and plate terminals face each other. Very short leads from the grid and plate coils are then possible.

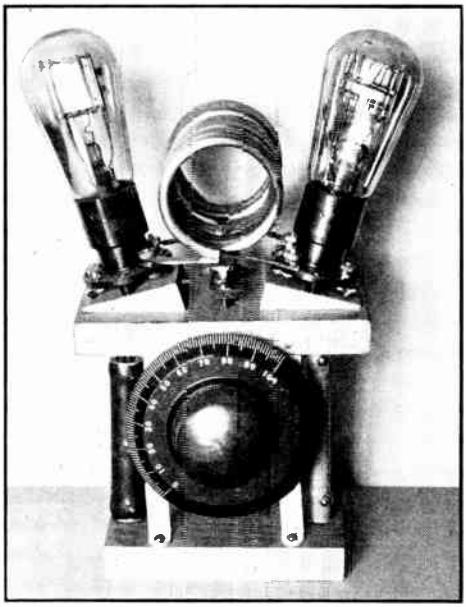


FIG. 715 — A REAR VIEW OF THE SAME TRANSMITTER

The grid-leak stands vertically at the left of the set, the radio frequency choke at the right. The tubes are tilted to allow plenty of room for the large coils necessary for the lower frequency bands.

Two possible forms of "unity-coupled" circuit are given in Fig. 716. The upper circuit is that used in the transmitter illustrated. It is the simpler of the two. The lower circuit has the added refinement of grid clips, with which the grid excitation can be varied.

The rather unusual mechanical arrangement of the transmitter shown in Figs. 714 and 715 was used for the particular purpose of demonstrating that it is by no means essential to mount all of the transmitter equipment on a base board. Indeed, this example illustrates that definite advantages may often be secured by departing from the "breadboard" type of lay-out. In this case, as we see from the circuit, there are three leads from each end of the tank coil — one to the tuning condenser, one to a tube plate and one to the opposite tube's grid. By putting the tubes on either side of the coil with the tuning condenser underneath, we are able to make these leads shorter, and more nearly symmetrical than would have been possible with a "breadboard" lay-out. The use of wooden wedges under the tube sockets, so tilting the tubes, provides space for the larger diameter coils while still retaining short leads to the tube terminals. The grid-leak and radio frequency choke are mounted vertically beside the tuning condenser. The grid-leak, being tubular, provides a convenient conduit for the filament leads running from the tube sockets to the clips on the base. The antenna coil, mounted by one end on a G.R. insulator, may be swung to one side to vary the coupling with the tank coil. A clip, not shown in the illustrations, serves to make the second contact for the antenna coil.

The coils for such a transmitter present the only constructional problem. In this instance, the two connections to the center of the coil are made to two G.R. pins mounted in a strip of bakelite bolted to the inductance. These plug into sockets mounted in another strip attached to the wooden platform. Connections between the ends of the tank coil and the plates are made with narrow brass strips, soldered to the coil ends and drilled to slip over the plate terminals of the tube sockets. The grid coil, of "push-back" wire, has lugs soldered to its outer ends for connection with the grid terminals. Changing coils is obviously not as simple a process in this transmitter as in the others described.

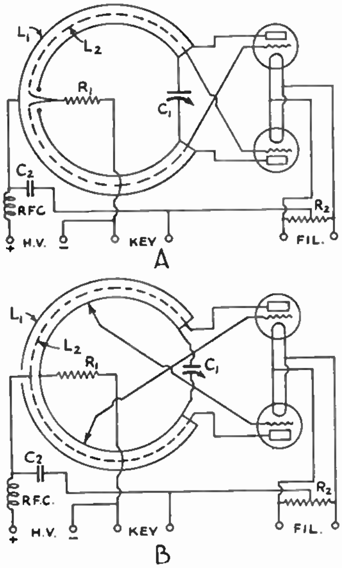


FIG. 716 — TWO CIRCUIT ARRANGEMENTS FOR A UNITY-COUPLED TRANSMITTER

That shown at "A" is the circuit used in the transmitter illustrated.

C_1 — 500-$\mu\mu$fd. National EM-500 variable condenser.
C_2 — 2000-$\mu\mu$fd. mica type fixed condenser.
R_1 — 15,000-ohm gridleak, 10-watt type.
R_2 — 100-ohm center-tapped resistor.
R.F.C. — No. 36 wire wound for a length of 2½ inches on a ½-inch diameter wooden or bakelite rod.
L_1 — Six turns of ¼-inch copper tubing with turns 2" inside diameter for the 7000-kc. band. Dimensions of coils for other bands can be obtained from the coil table appearing near the end of this chapter.
L_2 — Wound with "slip-back" wire inside L_1 — same number of turns.
Antenna Coil — Not shown in circuit — four or five turns, similar diameter to plate coil.

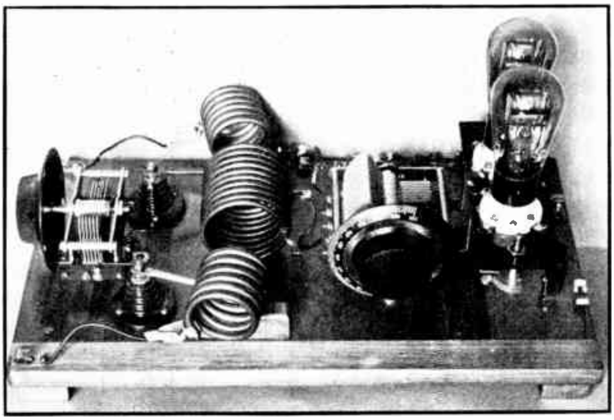


FIG. 717 — A TYPICAL PUSH-PULL AMPLIFIER

This unit may be excited from either of the push-pull oscillators described or from one of the crystal-controlled units to be detailed later in the chapter. The neutralizing condensers and grid chokes form part of the input assembly to be seen at the right of the baseboard.

Building an Amplifier

The sincere and progressive amateur will not long be content with a self-controlled, self-excited transmitter. Its construction will have given him valuable experience and its operation will have provided plenty of interest. As he becomes more discriminating, the amateur will appreciate the weaknesses of his first simple transmitter and will certainly seek some more advanced type of outfit. One possible first step is the construction of an amplifier to be driven by the self-controlled oscillator which comprised the simple transmitter. With such an amplifier, the power output of the transmitter can be increased and its frequency stability improved. No longer will vibration of the feeder or antenna result in a "floppy" signal. The amplifier will not only be suitable for operation with the old self-controlled oscillator, of course. It can be used with still greater effectiveness with a crystal oscillator.

Fig. 717 shows one typical form of push-pull amplifier. It bears a close resemblance to the transmitter shown in Fig. 711, the chief differences being in the grid circuits of the two tubes. Particular note should be taken of the neutralizing condensers C_3 and C_4. These are mounted on the bakelite strip running across the grid end of the amplifier. It will be seen that, unlike the circuit of Fig. 712, by-pass condensers are fitted from the center-tap of the plate coil to the filament center-tap and also from the junction of the two grid r.f. chokes to filament. These condensers usually improve the performance of any push-pull oscillator or amplifier but they are not essential in ordinary circumstances. The remaining features can well be followed by examining the circuit and the two photographs.

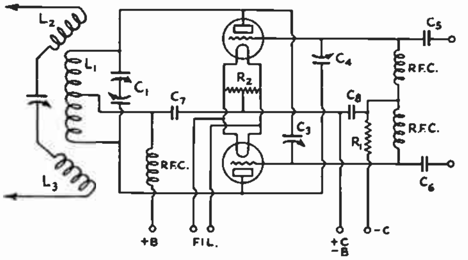


FIG. 718 — THE CIRCUIT OF THE PUSH-PULL AMPLIFIER

L_1 — Center-tapped plate coil. See coil chart for suitable specifications.
L_2, L_3 — Split antenna coil. Six turns of 1/4" copper tubing for each — turns 2½ inches inside diameter.
C_1 — Cardwell Type 156-B split-stator variable condenser, 250-μμfd. effective capacity. An ordinary single-stator condenser of the same capacity could also be used.
C_2 — The condenser between L_2 and L_3. 150 or 250-μμfd. receiving type variable condenser.
C_3, C_4 — Midget condensers, preferably double-spaced, having a capacity of approximately 25-μμfd.
C_5, C_6 — 500-μμfd. mica type fixed condensers.
C_7, C_8 — 2000-μμfd. mica type fixed condensers.
R_1 — 5000-ohm fixed resistor, 1 watt type.
R_2 — 100-ohm center-tapped resistor.
R.F.C. — National Type 100 radio frequency chokes. Chokes similar to that described under Fig. 86 could be used.

Excitation for the Amplifier

In order to drive this amplifier we must have some means of supplying the two grids with radio frequency voltages 180 degrees out of phase. The transmitters illustrated in Figs. 711 and 715, shorn of their antenna coils, will serve the purpose splendidly. The grid terminals of the amplifier are run to clips on the tank coil of the oscillator — each clip being placed at or near the outside or plate ends of the coil. Since the center of the oscillator tank coil is grounded for r.f., the voltages at opposite ends of the coil will then have the proper phase relationship for exciting the push-pull tubes. If we wish to drive the amplifier from a single-tube oscillator such as that shown in Fig. 78, the problem is a little more difficult. Three methods of doing it are shown in Fig. 720. At "A" is the scheme which we have just described for a push-pull oscillator. "B" shows how a single tube oscillator could be modified to give voltages 180 degrees out of phase. Instead of grounding one end of the plate tank (as far as r.f. is concerned) the plate supply lead is moved to the center of the tank coil. The proper r.f. voltage then becomes available from the ends of the tank. An alternative is to use inductive coupling as shown at "C". In this case, a new tuned circuit is connected across the grids of the amplifier and loosely coupled to the oscillator tank. If desired, the center of the new coil may be grounded. The diagram "D" is a modification of the last one and indicates how the grid circuit may be simplified when inductive coupling is used. Instead of using shunt feed for bias to the amplifier grids, therefore being obliged to provide grid condensers, the grids are connected directly to the ends of the new coil and bias is fed to the center point. All of these methods are satisfactory in practice but the push-pull oscillator and the connection "A" is probably to be preferred for a self-controlled oscillator amplifier transmitter. The amplifier under consideration could be driven from a crystal oscillator, of course, but an intermediate "buffer" amplifier would be very desirable. Such a combination will be discussed later in the chapter.

Tuning and Neutralizing

One important advantage of the oscillator-amplifier arrangement is that it permits the oscillator to run lightly loaded. Particularly does this apply when the oscillator is self-controlled. One of the push-pull oscillators, driving the amplifier

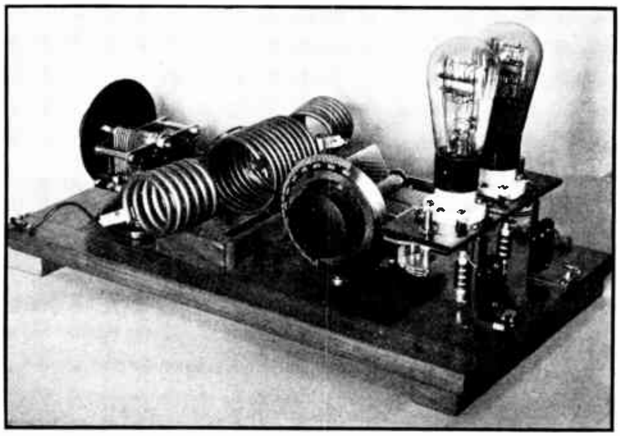


FIG. 719 — ANOTHER VIEW OF THE PUSH-PULL AMPLIFIER

The important components of the amplifier grid circuit are to be seen clearly in this view. The plate tank coil rests on two bakelite rods running across the baseboard. It would be possible, of course, to mount the coil on stand-off insulators as in the transmitter shown in Fig. 711.

just described might well be operated with about half the plate voltage which would have been employed had the oscillator been feeding the antenna directly. The result of this lowered voltage, of course, is that the tube runs cooler and that frequency stability is improved. Suitable methods of obtaining low voltage for the oscillator from a relatively high voltage plate supply are to be found in Chapter Ten.

Aside from this reduction in plate voltage, the adjustment and tuning of the oscillator should be done in just the way described previously. Since the oscillator determines the frequency stability for the whole transmitter, it is essential that all tuning be done carefully. It is as well to have the grid leads to the amplifier attached when the oscillator is being tuned but the amplifier plate supply should be disconnected. Just as soon as the oscillator has been adjusted to give a steady signal on the required frequency (as checked by the monitor and frequency meter) the preliminary neutralizing of the amplifier may be undertaken. For this work, the tuning lamp previously described should be coupled closely to the amplifier plate coil. With the plate supply disconnected from the amplifier but with the oscillator running, the neutralizing condensers should now be set at zero and the amplifier plate tank condenser rotated until maximum indication is obtained with the tuning lamp. At this stage the neutralizing condensers should be adjusted in small steps (both of them together) until no indication is obtained. At this time, the amplifier plate tank should be retuned carefully and it is probable that the lamp will show the presence of r.f. at some slightly different setting of the tank condenser. Now the neutralizing condensers should be adjusted again until the bulb goes out. The idea is to keep adjusting the neutralizing condensers until there is no sign of r.f. at any setting of the plate tank condenser.

More accurate neutralizing can be obtained by connecting a small thermo-coupled galvanometer across a few turns of the amplifier plate coil and using it as an indicator of r.f. in the tank circuit. The method is the same as neutralizing with the lamp. Be sure to remove the meter before turning on the plate voltage. Otherwise, it is certain to be burnt out.

This method of making neutralizing adjustments is the best for all neutralized amplifiers and the operator of any transmitter containing an amplifier which is supposed to be neutralized should practice the procedure until he is completely familiar with it. The amplifier is never completely neutralized until there is no indication of r.f. in the tank circuit.

With neutralization of the amplifier completed, the plate voltage can be connected to the amplifier and the key closed. With the antenna disconnected, the amplifier tank circuit should be tuned until the plate milliammeter of the amplifier indicates *minimum* plate current.

It may be that the frequency of the oscillator has been changed somewhat during the neutralizing process and it should be carefully checked with the frequency meter before the antenna is tuned to resonance. The frequency may be corrected by retuning the oscillator and amplifier tank circuits. No further adjustment of the neutralizing should be required. After the frequency has been given a final check the antenna circuit may be connected and tuned to resonance. Unlike the antenna tuning with a self-excited transmitter, the antenna condenser should be adjusted for maximum antenna current.

Oscillator-Amplifier Combinations

The push-pull oscillator and push-pull amplifier just described is, of course, only one of a great many possible arrangements. In this connection, it will be as well to study the chart of typical tube lay-outs given in Fig. 721. It will be noted that when self-controlled oscillators are used, it is common practice to operate the oscillator on the desired frequency and all amplifiers as "straight" amplifiers. Because crystals in the crystal oscillator are relatively expensive and because they rarely operate well on the higher frequency bands, frequency doubling tubes are very common in the crystal-controlled transmitter. It is only with their aid that we are able to obtain effective operation on the most popular amateur bands.

A Crystal-Controlled Transmitter

A simple yet entirely satisfactory crystal-controlled set is that shown in Fig. 722. It is suitable only for low-powered operation by

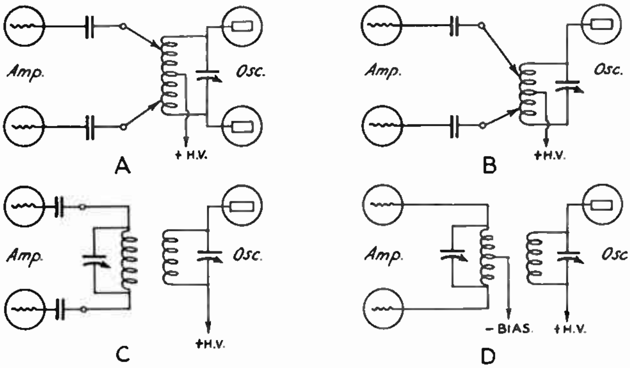


FIG. 720 — SHOWING VARIOUS METHODS OF DRIVING A PUSH-PULL AMPLIFIER

They are discussed in the text.

itself but it is a unit with which we may feed other and more powerful amplifiers.

It is, in fact, exactly the same sort of unit we would use for the preliminary stages of even the highest powered amateur transmitter.

A study of Figs. 722 and 723 will reveal the extreme simplicity of the set. It will be seen that the antenna coil, fixed on a swinging arm attached to the back of the base, can be coupled either to the oscillator tank coil or the amplifier tank coil. Since the amplifier is a doubler (operating at twice the oscillator frequency) this allows transmission on two frequency bands.

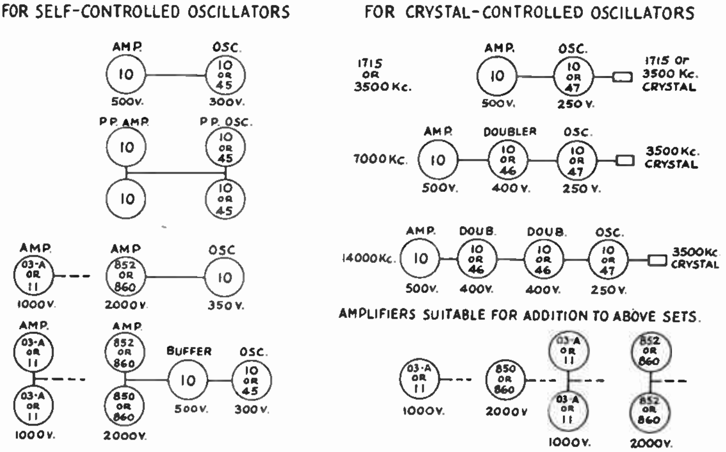


FIG. 721 — ILLUSTRATING A VARIETY OF PRACTICAL TUBE COMBINATIONS FOR THE OSCILLATOR-AMPLIFIER TRANSMITTER

In Fig. 722, the oscillator occupies the right-hand half of the board. The socket for the 47 oscillator tube is placed at the rear edge of the baseboard, which measures 6 x 16 inches. Near the right-hand edge and just to its right is a socket mounting for the plug-in crystal holder. The filament center-tap resistor, R_1, is just behind the tube socket. The oscillator tuning condenser, C_1, is mounted at the front edge of the board, the plate blocking condenser, C_3, being fastened to the board between C_1 and the tube socket. The oscillator inductance, L_1, is at the left. These are the only oscillator parts mounted on top. Underneath are the r.f. choke, the grid leak, R_3, the dropping resistor for the 47 screen voltage, R_4, and the screen by-pass condenser, C_6. These are placed where it is most convenient to meet the connections coming through from the upper side of the baseboard, and their relation to each other has no particular significance. The filament and plate connections from the power supply are brought in through Fahnestock clips.

Between L_1 and L_2 is a single-pole double-throw porcelain-base switch, connected as shown in Fig. 723, for the purpose of connecting the oscillator to the doubler. The blade is connected to the stator plates of C_1, and one of the jaws to the buffer grid condenser. A single-pole single-throw switch would obviously be satisfactory. This switch disconnects the doubler when the set is to be used on the 3500-kc. band. A piece of bus-wire run along the top of the baseboard at the rear connects the center-taps of the two filament resistors together. The plate-voltage for the doubler is fed in by means of a Fahnestock clip on the rear edge of the board.

A quite simple scheme is used for coupling the antenna coil to the tank coil of either stage. This coil, like the other two, is wound on a piece of bakelite tubing, and this in turn is fastened to a piece of brass strip, the other end of which is held to the rear edge of the baseboard by a wood-screw midway between the two coils. By making the brass supporting strip the proper length and carefully centering the wood-screw, the antenna coil can be swung from one tank coil to the other, and any degree of looseness of coupling can be obtained simply by positioning the antenna coil correctly with respect to the tank coil being used. A pair of flexible wires from the ends of the coil make connection to two Fahnestock clips on the rear edge of the board, these serving as terminals for the antenna or feeder connections.

Tuning the Crystal Transmitter

After the power supply connections have been made to the set, the crystal should be plugged in and the oscillator tested. To do this open the switch S (thus disconnecting the doubler), and move the antenna coil as far away from the oscillator coil as possible. A switch or telegraph key should be placed in the negative lead from the power supply so the plate current can be cut off without turning off the filaments. Close the switch or key and turn C_1 until there is a pronounced dip in oscillator plate current, indicating oscillation. Generally the plate current will be about 50 milliamperes non-oscillating, and will drop to 20, approximately, when oscillating. The more active the crystal the lower will be the plate current with the tube oscillating.

It is very much worth while to get a good crystal, especially for a small set of this sort in which the oscillator must be keyed and from which it is desirable to get as much power as possible. A poor crystal is a bad investment, no matter how "cheap" it may be; get one from a reliable concern which will back up its product. If the set is to be used only in the 3500-kc. band, any frequency within the band will be satisfactory. If the set is to be used on 7000 kc. as well, the frequency must be between 3500 and 3560 kc. to keep within the 7000–7300-kc. limits when doubling. Similarly, if 14-mc. operation is to be tried at some future date, the crystal frequency must be between 3500 and 3600 kc.

Once the oscillator is functioning, the antenna coil may be coupled to it and the antenna or feeders tuned to resonance. If too much coupling is used the oscillator may stop working, in which case the coupling must be backed off.

There is one other factor which must be considered when working on 3500 kc. It is necessary to have the oscillator key properly, and to make certain that this is accomplished the signal should be monitored. If dots are missing or if the keying sounds chirpy, the tuning must be readjusted until the keying is clean and the oscillator starts every time. This may necessitate a slight reduction in antenna current.

Operating the Doubler

Tuning the doubler is much the same as the procedure used with the oscillator. The antenna should be disconnected from the coupling coil or the latter placed midway between L_1 and L_2 and the switch *S* closed. In this case the milliammeter should be in the plate circuit of the doubler. Start the crystal oscillating — the neon lamp will be useful at this point to indicate oscillation if no milliammeter is available for the oscillator plate circuit — and note the rise in the doubler plate current. Then tune C_2 for minimum plate current, the minimum point indicating resonance. The plate current with C_2 set off resonance will be determined by the oscillator strength; with the oscillator condenser, C_1, set for maximum output the off-resonance plate current will be from 100 to 150 milliamperes, and at resonance should drop to 30 or 40 ma. Always keep C_2 set at resonance because under other conditions the plate power is all dissipated in the doubler tube itself and the tube will get hot. This may be the cause of grid blocking, a condition in which the grid emits electrons and causes still higher plate current, with the result that the tube may be ruined.

The antenna coil should be coupled to the doubler tank coil and tuned in just the same way as has been described previously. The plate current with the antenna coupled should be 50 to 60 milliamperes.

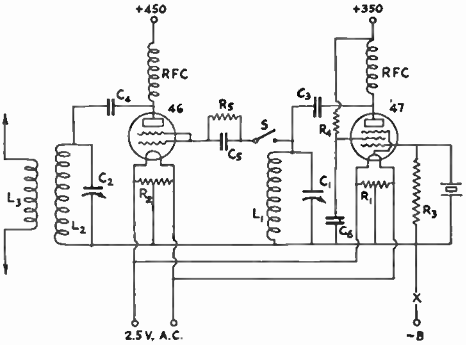


FIG. 723 — THE CIRCUIT OF THE SIMPLE CRYSTAL TRANSMITTER

C_1 — Oscillator tuning condensers; 140-μμfd. midget condenser, Hammarlund.
C_2 — Doubler tuning condenser; same as C_1.
C_3 — Oscillator plate blocking condenser; 500-μμfd. mica condenser.
C_4 — Doubler plate blocking condenser; same as C_3.
C_5 — Coupling condenser; 100-μμfd. mica condenser.
C_6 — Screen by-pass condenser; .001-μfd. mica condenser.
R_1, R_2 — Filament center-tap resistors; 20 ohms, center tapped.
R_3 — Oscillator grid leak; 5000 ohms, 5 watt.
R_4 — Screen dropping resistor; 50,000 ohms, 5 watt.
R_5 — Doubler grid leak; 20,000 ohms, 2 watt.
L_1 — Oscillator tank coil; 21 turns of No. 14 enamelled wire on 2" bakelite tube, spaced with string between turns to occupy 2 inches.
L_2 — Buffer tank coil; 11 turns same construction as L_1 but spaced to occupy 1½ inches.
L_3 — Antenna coupling coil; 13 turns No. 14 enamelled wire, close-wound on 2" bakelite tube.
S — Single-pole switch.
X — Key. See text.

The simplest method of keying the oscillator is putting the key in the −B lead from the power supply. Other methods will be found described in Chapter Eleven.

From what we have said about amplifier combinations, it will be understood that this crystal oscillator and amplifier would constitute an entirely satisfactory driving unit for the push-pull amplifier shown in Fig. 717. It will be necessary, however, to use the coupling scheme shown at "C" or "D" in Fig. 720 since one end of the amplifier is grounded for r.f.

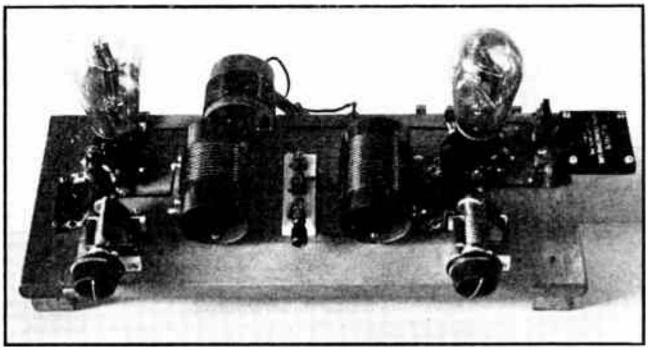


FIG. 722 — A SIMPLE CRYSTAL OSCILLATOR AND AMPLIFIER

This unit constitutes a low-powered transmitter by itself. It may also serve as the preliminary unit in a high-powered crystal transmitter.

A 100-Watt Transmitter

As an example of a high-powered crystal-controlled transmitter arranged in one unit, we will consider the set shown in Figs. 724 and 725. Its circuit contains some features not treated in the others described. In this transmitter the plates of the first two tubes are parallel-fed (as with the low-power Hartley transmitter) to permit the use of series feed in the grid circuits of the following tubes. The crystal oscillator tube obtains its bias from a grid leak, R_1, and grid leaks also are used to provide part of the bias on the second and third tubes. A 90-volt battery should also be used to provide some fixed bias to prevent the amplifier tubes from drawing excessive plate current if the excitation fails.

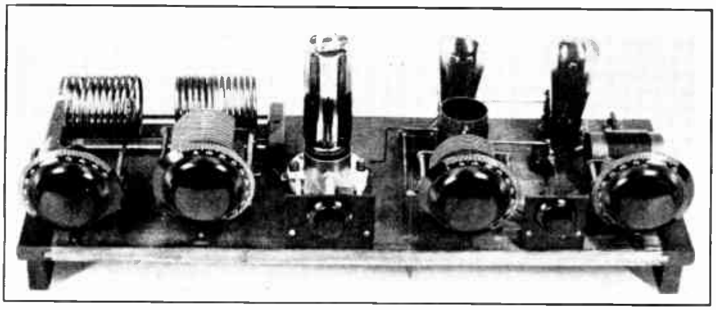


FIG. 724 — A THREE-TUBE CRYSTAL-CONTROLLED TRANSMITTER

It will operate in the 3.5-, 7- and 14-mc. bands with a single crystal. The crystal oscillator is at the right, followed by the Type 10 buffer-doubler and the 03-A output tube. The variable condensers, going from right to left, are the oscillator tank condenser, buffer neutralizing condenser, buffer tank condenser, 03-A neutralizing condenser, 03-A tank condenser, and antenna tuning condenser. The two neutralizing condensers are mounted on small bakelite panels to insulate them from the baseboard. The 03-A tank condenser is mounted on a strip of bakelite for insulation purposes, since both ends are at high r.f. potential. The longer leads in the transmitter are one-eighth inch copper tubing, used for the sake of rigidity, while the short leads are ordinary bus wire. The coils rest on glass rods. The filament by-pass condensers for the oscillator and doubler are mounted on short vertical pieces of copper tubing directly behind the tubes. The plate blocking condensers for the first two stages are located near the plate terminals on the sockets holding the tubes. All other fixed condensers and all r.f. chokes and bias resistors are mounted underneath the baseboard. Binding post strips at the back of the board furnish means of connecting to power and bias supplies.

The second Type 10 tube in the set is used as a straight amplifier or "buffer amplifier" on 3500 kc. or as a 7000-kc. doubler. This is accomplished by proportioning the capacity of C_6 and the inductance of L_2 so that the 7000-kc. band is covered at the low-capacity end of the condenser scale and the 3500-kc. band at the other end. This tube is neutralized by means of C_6 and the lower portion of L_2. It is neutralized in the regular way on 3500 kc. and the setting of the neutralizing condenser left untouched when C_6 is shifted to 7000 kc. The tap from L_2 to the grid of the 03-A should be placed so that the second Type 10 draws normal plate current on the 7000-kc. band when the 03-A is receiving excitation.

The plate circuit of the 03-A amplifier is the same as has been described before, and the method of neutralizing and tuning is also the same. This tube operates as a straight amplifier on 3500 and 7000 kc. and as a doubler on 14,000 kc. It should be neturalized on 14,000 kc. as well as on the other two bands, since this improves the efficiency. Usually there will be enough second-harmonic output from the second Type 10 tube to make it possible to neutralize the 03-A by regular methods on 14,000 kc.

The condensers marked C_2 shown in dotted lines on the plate-supply side of the first two tubes are necessary when a voltage divider across the 500-volt power supply provides the 250 volts for the crystal oscillator. Their purpose is to prevent r.f. leaking between stages, which may make it impossible to neutralize the second tube. They may be omitted if separate power supplies are used for all stages.

Other Combinations

It is obviously impossible to describe in one chapter all the possible tube combinations which can be built into amateur transmitters. It would be difficult to cover the subject adequately in a book even larger than this one. New arrangements are constantly appearing in *QST*, however, and the latest developments in transmitter construction are chronicled there.

As a general rule it is advisable, when crystal control is being used, to have the output amplifier — the one which feeds the antenna — operate as a straight amplifier, not as a doubler, if maximum output is to be secured. A straight amplifier operates at higher efficiency than a doubler, thus making it possible to put more power on the plate of the tube without exceeding its rated plate dissipation. This is especially desirable when a small tube such as a Type 10 is being used as an output amplifier, since the power output is at best comparatively small.

There may be cases, however, when the use of a doubler as an output amplifier is justified; for instance, when the transmitter is to work on three bands and must be quickly shifted from one band to the other. A satisfactory set-up can be made with three tubes, but if a fourth is added to comply with the principle that the output tube should be a straight amplifier, switching from band to band becomes more complicated. Tubes of

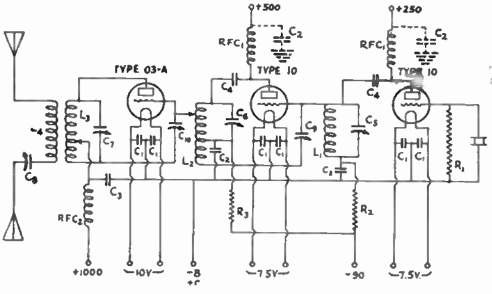


FIG. 725 — THE THREE-TUBE TRANSMITTER-CIRCUIT

C_1 — .004-μfd.
C_2 — .002-μfd.
C_3 — .002-μfd., 5000-volt rating.
C_4 — 250-$\mu\mu$fd.
C_5 — 250-$\mu\mu$fd. variable.
C_6 — 350-$\mu\mu$fd. variable.
C_7 — 250-$\mu\mu$fd. variable double-spaced. (The one shown in the photograph is a Cardwell 43-plate receiving condenser with alternate plates removed.)
C_8 — 500-$\mu\mu$fd. variable.
C_9 — 13-plate midget.
C_{10} — 50-$\mu\mu$fd. double-spaced condenser (Cardwell 410-B).
L_1 — 21 turns of No. 12 enamelled wire on 2-inch bakelite tube.
L_2 — 10 turns of No. 12 enamelled wire on 2-inch bakelite tube with slight spacing between turns. Neutralizing coil consists of 6 additional turns, close-wound, 1/4-inch from tank coil.
L_3 — 3500 kc. — 20 turns of 3/16-inch copper tubing, 2½-inch dia.
7000 kc. — 12 turns of 3/16-inch copper tubing, 2½-inch dia.
14,000 kc. — 7 turns of 3/16-inch copper tubing, 2½-inch dia. Spacing between turns approximately equal to half the diameter of tubing.
L_4 — 11 turns same.
R_1 — 20,000 ohms, 2-watt rating.
R_2 — 50,000 ohms, 2-watt rating.
R_3 — 10,000 ohms, 5-watt rating.
RFC_1 — 3-inch winding of No. 36 s.s.c. on ½-inch form.
RFC_2 — 3-inch winding of No. 32 s.s.c. on ½-inch form.

the 75-watt and larger sizes will give satisfactory output when used as doublers, although not as great as with straight amplification.

Keeping these points in mind, the amateur should be able to work out an almost limitless number of practical combinations along the lines of those shown in Fig. 721. Instead of attempting to describe any further complete transmitters, we will consider two typical types of output amplifiers which could be used in conjunction with the oscillator-amplifier units already presented.

A Single-Tube Amplifier

A single-ended 100-watt amplifier is shown in Figs. 726 and 727. It uses a Type 03-A or Type 11 tube. An 852 may be substituted if desired, no changes being required in the circuit diagram. The appearance of the amplifier will be slightly altered from that shown, of course, but the same general layout may be followed. In contrast to the direct coupling methods previously shown, this amplifier is intended to be inductively coupled to the exciting tube. A coil and condenser which will tune to the frequency on which the amplifier is to operate are connected in parallel across the terminals marked "input" in the diagram, and the coil is coupled inductively to the tank coil of the preceding amplifier in much the same way as in Fig. 720 at "D". A high *L-C* ratio should be used in this coupling circuit for best results. The coupling should not be too close; a few trials will show which degree of coupling transfers maximum energy to the grid circuit of the 03-A.

The amplifier is neutralized and its output circuit tuned in exactly the way described previously.

This amplifier may be capacitively coupled to the exciting tube by moving C_4 to the grid side of the input circuit, between the terminal and the connection between the grid and the neutralizing condenser. The grid r.f. choke will then be connected directly to the grid of the tube. In such case C_4 should be 100 $\mu\mu$fd.

The bias voltage to use will depend upon the type of tube chosen. Approximate values will be 90 volts for a Type 03-A, 135 volts for a Type 11, and 180 volts for an 852, assuming rated plate voltages for each of the tubes.

Push-Pull for High Power

Figs. 728 and 729 illustrate a typical example of the way in which a pair of 852's may be arranged in push-pull to provide a powerful final amplifier. The circuit is very similar to that of the smaller amplifier shown in Fig. 718 but because of the

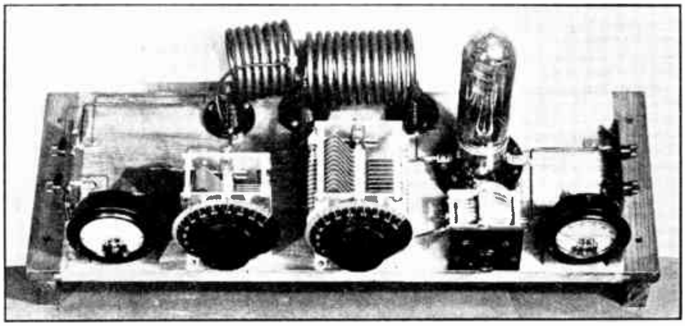


FIG. 726 — AN AMPLIFIER UNIT USING A 100-WATT TUBE

It employs a Type 03-A or Type 11 tube. At the front of the board, from left to right, are the antenna ammeter, antenna tuning condenser, plate tank condenser, neutralizing, condenser and plate milliammeter. The plate tank coil is mounted on two stand-off insulators directly behind the tank condenser. The antenna coil is pivoted from a single stand-off insulator so the coupling between the two coils can be varied. Filament, grid and plate by-pass condensers and plate and grid r.f. chokes are under the baseboard. The connections are brought out to a terminal strip underneath the board at the back.

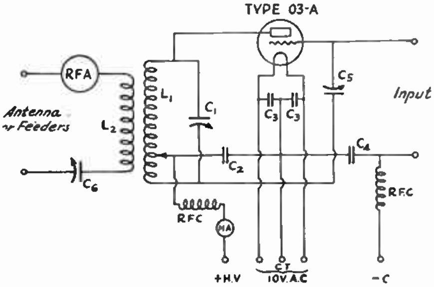


FIG. 727 — THE 100-WATT AMPLIFIER CIRCUIT

C_1 — 250-μμfd. transmitting condenser.
C_2 — .002-μfd. or larger mica by-pass condenser, 5000-volt rating.
C_3 — .004-μfd.
C_4 — .002-μfd.
C_5 — 100-μμfd. condenser, transmitting type.
C_6 — 250–500-μμfd. variable.
L_1 — 3500 kc. — 12 turns of ¼-inch copper tubing, 5-inch diameter.
7000 kc. — 12 turns of ¼-inch copper tubing, 2½-inch diameter.
14,000 kc. — 5 turns of ¼-inch copper tubing, 2½-inch diameter.
All three coils made with turns spaced to make total length 4½ inches.
L_2 — 7 turns of ¼-inch copper tubing, 2½-inch diameter.
RFC — "Compromise" chokes, consisting of a three-inch winding of No. 32 d.s.c. on half-inch form.
MA — 0–500 d.c. milliammeter.
RFA — 0–4 thermo-couple ammeter.

higher voltages to be used, there are important differences in the components. A feature of the unit is the big tank condenser, especially designed for high voltage operation. The two neutralizing condensers, in this case, are built on to the tank condenser and are operated by a single shaft. Naturally, they could be separate units, separately tuned. Grid condensers and shunt feed of the grids make it possible to excite the unit from the tank circuit of an amplifier such as that of Fig. 717 without any intermediate tuned circuit. Even a single 10 tube as a straight amplifier would provide sufficient excitation but it would be necessary to arrange the tank of that amplifier in the manner shown at "B", "C" or "D" in Fig. 720. Tuning and neutralizing of this amplifier would be carried out as described for the small push-pull amplifier. Extreme care is necessary in handling the equipment because of the high voltages used. This precaution, indeed, is necessary in the handling of any transmitter. Carelessness can hardly fail to result in a severe, perhaps fatal, shock.

Meters

The meters shown in the diagrams that we have discussed so far are really necessary to adjust the circuit properly for best efficiency. After the set is once adjusted and in operation, meters are useful but not necessary. We should have as many meters in the set as we feel we can afford. A filament voltmeter is of first importance. If we do not use a filament voltmeter or some indication of the operating temperature of the filament, the life of the tube may be much shortened by improper operation. An indicating device for the filament is, therefore, a matter of economy. Next we need an antenna ammeter. The antenna ammeter can be placed at the point in the antenna circuit where the antenna current is greatest (at the voltage node or current loop) but its indication will be useful wherever it is and the exact location is not extremely important. If we can afford it we should have a plate milliammeter of the proper range. All meters should be selected with regard to the tubes employed and the current and voltage that we may expect in the different circuits of the transmitter. With these three meters we can get along very well indeed in operating our transmitter. A plate voltmeter can be used if it is available but is not very useful after the circuit is once adjusted. Another milliammeter for the grid circuit may be purchased after all the above have been obtained.

Transmitter Assemblies

As we have already mentioned, it is by no means necessary to arrange the apparatus in the transmitter in the manner shown in the illustration. Many other excellent schemes are possible. The board on which the apparatus is mounted can, for instance, be arranged in a vertical position, with the wiring, transformers, chokes, etc., behind it and the remaining apparatus in front. Alternatively the apparatus can be mounted chiefly on a baseboard, with the meters

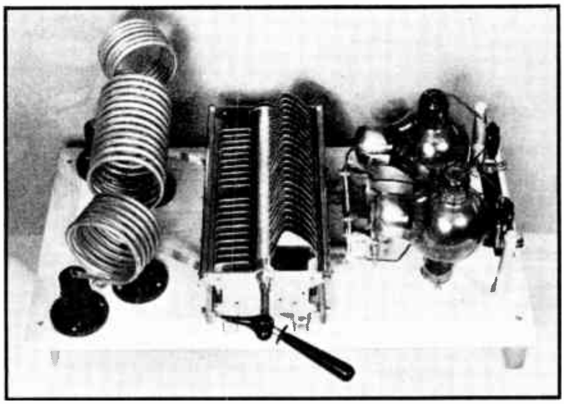


FIG. 728 — A TYPICAL EXAMPLE OF THE USE OF 852 TUBES IN A PUSH-PULL AMPLIFIER

Grid chokes and coupling condensers can be seen at the right of the tubes, supported on a strip of bakelite. The tank and antenna coils are supported on large G.R. stand-off insulators — the coils being fitted with the large size G.R. plugs. Heavy copper strip furnishes the connection between the tank coil and condenser.

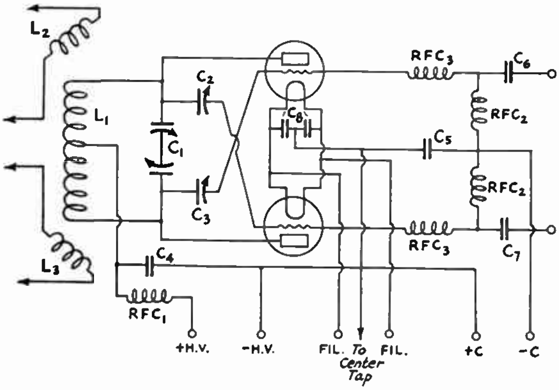


FIG. 729 — CIRCUIT OF THE HIGH-POWERED PUSH-PULL AMPLIFIER

L_1 — See coil chart. The coil shown in the illustration is for 7000 kc. It has 12 turns of ¼-inch tuning with 3-inch inside diameter turns.
L_2, L_3 — Six turns each, 3-inch diameter.
C_1 — Cardwell special type 16-B splitstator condenser, 100μμfd. effective capacity, with neutralizing condensers attached.
C_2, C_3 — See above. Cardwell Type 519 condensers would serve as separate neutralizing condensers. The capacity required is approximately 8 or 10μμfds. with about ¼-inch spacing between plates.
C_4, C_5 — 1000-μμfd., 5000 volt fixed condensers.
C_6, C_7 — 100-μμfd. 5000 volt fixed condensers.
C_8 — 1000-μμfd. receiving type fixed condensers.
RFC_1 — Four-inch winding of No. 30 wire on a 1-inch tube.
RFC_2 — Three-inch winding of No. 36 wire on ½-inch wooden or bakelite rod.
RFC_3 — These are for the suppression of parasitic oscillations. They may not be found necessary. Ten turns of No. 14 wire wound on a pencil (the pencil being removed) will be suitable.

and controls on a vertical panel in front of it. The panel could be of bakelite or hard-rubber or may be made of well-dried wood. The important points to watch in arranging the apparatus are to make sure that the leads, particularly in the tuning circuits, are short; to see that the coils are well clear of the condensers or other large metal bodies; and to arrange the parts in such a way that the controls are convenient and all apparatus is accessible.

Other Bands

In many of the transmitters described earlier in this chapter specifications have been given only for coils for the 3500-, 7000- and 14,000-kc. bands. It is true that the majority of amateurs do most of their work in these bands, but there is also much activity in the other bands, particularly that between 1715 and 2000 kc.

Specifications for coils suitable for any band can be obtained from the coil table below. In this table, coils are given for three sizes of tuning capacity. The highest capacity will generally be used in self-controlled oscillators, the other values being suitable for cyrstal oscillator and amplifier tank coils. Considerable tolerance is permitted in the specifications as given since the coils are designed to hit the various bands with the associate condenser set at about 75 per cent. of its maximum capacity. A study of the table will soon enable the amateur to estimate the necessary coils for odd turn diameters, odd spacing and conductors other than those specified.

SOME SUGGESTED COIL SPECIFICATIONS

Band	1750			3500			7000			14,000		28,000	
Max. condenser capacity — μμfds.	500	250	100	500	250	100	500	250	100	250	100	250	100
*¼" c.t., i.d. 1½"	—	—	—	—	—	—	9	17	—	5	11	2	4
¼" c.t., i.d. 2"	—	—	—	18	—	—	6	10	22	4	7	—	3
¼" c.t., i.d. 2½"	—	—	—	12	—	—	5	7	15	3	6	—	2
¼" c.t., i.d. 3"	—	—	—	10	17	—	4	6	12	—	5	—	—
¼" c.t., i.d. 4"	20	—	—	7	11	24	—	—	8	—	—	—	—
¼" c.t., i.d. 6"	12	20	—	—	—	—	—	—	—	—	—	—	—
*3/16" c.t., i.d. 1½"	—	—	—	—	—	—	8	13	—	5	10	2	4
3/16" c.t., i.d. 2"	—	—	—	16	—	—	5	9	20	4	7	—	3
3/16" c.t., i.d. 2½"	—	—	—	11	20	—	4	6	14	3	5	—	2
3/16" c.t., i.d. 3"	27	—	—	9	15	—	—	—	10	—	4	—	—
3/16" c.t., i.d. 4"	18	32	—	—	10	22	—	—	—	—	—	—	—
No. 12 wire, spaced [1] 1½"	—	—	—	16	28	—	6	9	19	4	7	—	3
No. 12 wire, spaced [1] 2"	34	—	—	10	19	40	4	7	13	3	5	—	2
No. 12 wire, spaced [1] 2½"	20	45	—	8	14	29	—	5	10	2	4	—	2
No. 14 wire, d.c.c. 1½"	30	53	—	10	17	35	—	7	11	3	6	—	2
No. 14 wire, d.c.c. 2"	20	35	75	8	12	24	—	5	9	2	4	—	—
No. 14 wire, d.c.c. 2½"	16	25	53	7	10	19	—	4	7	—	3	—	—

* Spacing between turns (not centers) is ⅛" for these coils. Abbreviations — Copper tubing, c.t.; inside diameter, i.d.;
[1] — Spacing between turns, in this case, equals wire diameter.

Condensers

The performance of any transmitter can be impaired seriously if the insulation between points of high voltage is poor. A common location for trouble of this type is in the condensers. Without any external indication, there can be radio-frequency leaks through the insulation which will make it impossible to obtain a clean note from the transmitter. In some cases the signal emitted under such conditions is a rough "hash" and no amount of tuning will improve it. A great deal of trouble will be avoided if the best condensers available are built into the set at the start.

The variable condensers for transmitters operating from a plate supply of 500 volts or less may be of high-grade receiver type. For transmitters operating from higher voltages than these, special transmitting condensers are desirable. Several makes of such condensers are well advertised. They are available in many capacities and voltage ratings.

The fixed condensers in other parts of the set also are important. Mica or glass dielectric is satisfactory for these, and several types of suitable condensers are available. Receiver-type condensers, providing they are rated at not less than 500 volts, can be used in transmitters employing the Type 10 tube but special transmitting condensers will be necessary when higher plate voltages are used.

Unsteady Signals

One of the chief problems in transmitters other than those of the crystal-control type is to maintain a steady frequency. First there is the frequency creep due to heating of the tube or other apparatus in the set. This can be reduced to a minimum by tuning the set for greatest efficiency. The greater the antenna power for a given input the less will be the heating of the tube. The aim is, therefore, to keep the input at or below the rated value and to tune the set until the tube operates with the least heating. With a good antenna most tubes can be operated at the rated input without the plate showing any color. With any tube the plate should never be allowed to get hotter than a dull red. This is most likely to happen during the preliminary adjustment when the tube stops oscillating or is operating in an inefficient manner. For this reason, during adjustment, it is advisable to have the key or a convenient switch so arranged as to permit shutting off the plate power quickly when necessary.

The detuning of the antenna circuit mentioned in the paragraphs on tuning does not result in appreciably lowered efficiency in the tube. When it is said that the greatest antenna current should be obtained for a given input to keep the tube coolest it is meant that the greatest antenna current *with the antenna detuned in the manner described* should be obtained. When the antenna is detuned the plate current drops. The grid excitation should therefore be adjusted so that the normal plate current will be obtained with the antenna circuit in the detuned condition. Detuning the antenna is unnecessary when an oscillator-amplifier transmitter is used because the frequency is then set by a separate tube which is isolated from the antenna. With such transmitters the antenna circuit may be tuned to take maximum power from the output tube.

Another common cause of frequency instability is vibration or swinging of the antenna or feeders. The effect of such vibration or swinging is reduced considerably by the detuning of the antenna circuit but it is essential that the antenna be supported in such a way that it is steady even in a high wind. This point will be given consideration in the chapter on antennas.

Leaky insulation also is often a serious offender in this regard. Not only can a leak destroy the character of the note but it can be responsible for a wobbly frequency. Trouble of this type often can be detected by removing the antenna circuit and listening to the transmitter in the monitor. Sometimes the leak is visible in the form of a thin arc. If the leak is through bakelite a swelling on the surface of the insulation often will be noticed.

Perhaps the most common cause of all is vibration of the coils or wiring. A vibration which results in serious frequency instability often is too slight to be noticeable. The coils and wiring should be watched very carefully during operation to make sure that the movements of keying, the humming of a transformer or the vibration of a generator are not transmitted to the set. Mounting the set on rubber sponges often will aid in the elimination of the trouble.

It is only by careful and prolonged attention to such details that the performance of the transmitter can be maintained at a high standard. It is fine to aim at a neat station, an elaborate lay-out, or an imposing antenna. Of infinitely greater importance than these things, however, is the signal — the only part of the station that the whole world can examine.

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phone transmission. It not only causes unnecessary interference with other stations working on adjacent frequencies in the same band but also can cause interference with services operating on greatly different frequencies. An amateur 'phone working on the 3500-kc. band is even likely to cause interference on the broadcast band, as a result of the frequency "wobbulation" accompanying modulation of an oscillator and the consequent radiation of spurious frequencies over a band of hundreds of kilocycles. Frequency modulation is also a likely cause of distorted reception because the waves radiated on different frequencies travel over separate paths and arrive at the receiver out of phase with each other. Modulation of the oscillator in an amateur transmitter is therefore poor practice and is not recommended because any practicable method of modulation applied to an oscillator is bound to cause frequency modulation as well as amplitude

The types of modulation systems used in modern transmitters of high modulation capability may be classified generally in two groups, one in which the modulating signal is applied to the control-grid circuit (grid-bias modulation) or screen-grid circuit (screen-grid modulation) of the modulated r.f. amplifier, and the other in which the plate circuit of the r.f. tube is supplied with modulated power (plate modulation).

Grid-bias modulation operates to vary the bias voltage of the r.f. tube at signal frequency, affecting the amplifier's power output accordingly. Screen-grid modulation operates to vary the screen-grid voltage and hence the output of an amplifier using a four-element tube. In both of these systems the r.f. excitation and direct plate voltage are constant. Relatively small modulating power is required but the carrier power output must be limited to a small percentage of the maximum of which the amplifier is capable,

Chapter Eight

RADIOTELEPHONY

Although radiotelephony is closely akin to c.w. telegraphy and the 'phone transmitter is commonly considered as simply a c.w. set with additional equipment to give voice modulation to its output, 'phone not only is much more complex than c.w. in point of apparatus involved but also demands a sharply different and more rigorous technic; for the 'phone transmitter not only must have radio-frequency equipment typical of the good c.w. set and audio-frequency equipment to accomplish voice modulation, but also there must be proper coördination

imum amplitudes of a modulated wave to the average amplitude, expressed in percent. When the variation in amplitude is symmetrical above and below the unmodulated carrier amplitude, as shown in "A" and "B" of the first figure, the average amplitude is the same as the carrier amplitude and *the percentage of modulation is the ratio of the difference between the maximum amplitude and the carrier amplitude to the carrier amplitude, multiplied by 100.* That is,

$$M = \frac{i_{\text{mod}} - i_{\text{car}}}{i} \times 100$$

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usually necessitating an r.f. output amplifier tube rating of at least four times the transmitter's carrier power rating.

Plate or Heising modulation, more economical for low-power transmitters and hence most popularly used by amateurs, utilizes an audio-frequency power amplifier to modulate the plate input of an r.f. amplifier whose power output varies as its plate power input. For a modulation capability of 100%, the modulator must be capable of practically undistorted audio-frequency power output equal to 50% of the modulated amplifier's steady (d.c.) power input; or, to put it differently, the modulated amplifier's steady plate power input is twice the modulator's maximum audio-frequency power output.

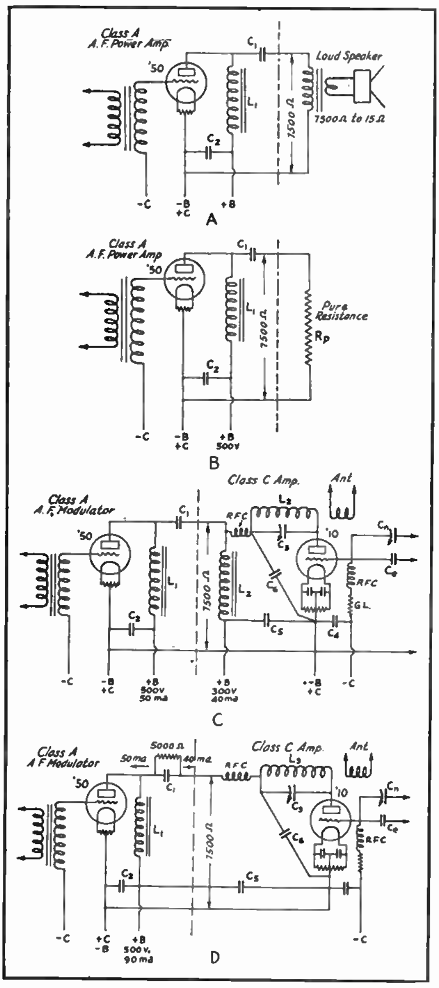

FIG. 82 — THE MODULATOR IS AN AUDIO-FREQUENCY AMPLIFIER SUPPLYING POWER TO THE PLATE CIRCUIT OF THE MODULATED RADIO-FREQUENCY AMPLIFIER

The schematic diagrams *A*, *B*, *C* and *D* of Fig. 82 show how the operation of a typical Type 50 Class A audio-frequency power amplifier is the same when it is used to furnish power to a loud speaker, to a resistor or, as a modulator, to the plate circuit of a radio-frequency amplifier.

In *C* and *D* it is essentially an audio-frequency power amplifier "impedance-coupled" to its load, its power output being superimposed on the direct power supplied to the r.f. stage. The modulator's dynamic characteristic, determined from its plate curves by the method shown in the following section, is such that with suitable excitation it will deliver approximately 5.4 watts when its plate voltage is 500 volts, its negative grid bias is 100 volts and its load resistance is 7500 ohms. This power output is sufficient to modulate 95%, approximately 12 watts input to the r.f. amplifier plate circuit *when the latter is equivalent to a pure resistance of 7500 ohms.*

The Modulated R.F. Amplifier

This condition obtains when the modulated stage operates as what is known as a Class C amplifier; that is, so that its power output is proportional to its plate power input, the plate current and output current varying as the plate voltage between the limits of nearly zero plate voltage and twice the mean plate voltage. This is accomplished by operating with a negative grid bias more than sufficient to reduce the plate current to zero with no excitation (usually twice "cut-off" bias) and by supplying the grid with r.f. excitation sufficiently ample to cause plate current saturation. As shown in the graphical representation of this operating condition, Fig. 83, large amplitudes of plate current flow during positive excitation peaks. The plate output wave shapes are quite distorted and "kick" the tank circuit on alternate half-cycles only. But the wave form in the output circuit is nearly sinusoidal because of the tank circuit's "flywheel" effect. This action is analogous to that of a single-cylinder two cycle gas engine whose crank has nearly harmonic motion because of the smoothing effect of the flywheel, even though the impulses are delivered to the mechanism during but a small part of each revolution. In a push-pull Class C amplifier (or oscillator) the two plates alternate in supplying energy and the tank receives a "kick" on both halves of the cycle, this action being analogous to that of a two-cylinder two-cycle engine in which an explosion occurs at every half-revolution of the crank. The radio-frequency harmonic content in the output, including the antenna circuit, is even less with a push-pull Class C amplifier than with a single-ended one, the even harmonics canceling, and push-pull output amplifiers are therefore advisable where the final stage is modulated.

When the amplifier's operation is truly Class C, its plate circuit input resistance, as viewed

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One of the chief problems in transmitters other than those of the crystal-control type is to maintain a steady frequency. First there is the frequency creep due to heating of the tube or other apparatus in the set. This can be reduced to a minimum by tuning the set for greatest efficiency. The greater the antenna power for a given input the less will be the heating of the tube. The aim is, therefore, to keep the input at or below the rated value and to tune the set until the tube operates with the least heating. With a good antenna most tubes can be operated at the rated input without the plate showing any color. With any tube the plate should never be allowed to get hotter than a dull red. This is most likely to happen during the preliminary adjustment when the tube stops oscillating or is operating in an inefficient manner. For this reason, during adjustment, it is advisable to have the key or a convenient switch so arranged as to permit shutting off the plate power quickly when necessary.

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Chapter Eight

RADIOTELEPHONY

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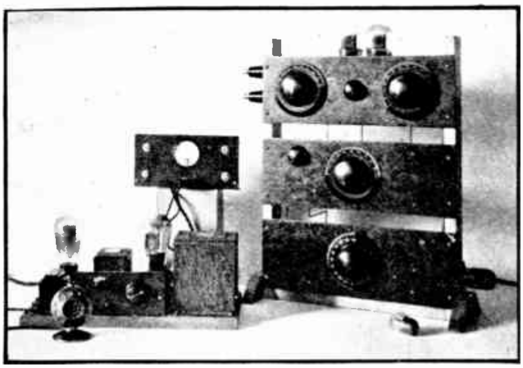


A TYPICAL LOW-POWER 'PHONE TRANSMITTER

Built for operation in the 1715-kc. band, this outfit can be used for both c.w. and 'phone work. It has a carrier output of approximately 25 watts and can be built for a reasonable sum.

Modulation

Modulation, as it concerns us here, is the process by which the amplitude of the transmitted radio-frequency wave is varied in accordance with the sound waves actuating the microphone. When the wave is detected or demodulated by a suitable receiver, as explained in Chapter Four, there should result a true reproduction of the original modulating signal. Since the variation in amplitude of the radiated wave is identical with that of the current in the transmitting antenna it is both proper and convenient to discuss modulation in terms of this current.

By definition, *percentage modulation is the ratio of half the difference between the maximum and minimum amplitudes of a modulated wave to the average amplitude, expressed in percent.* When the variation in amplitude is symmetrical above and below the unmodulated carrier amplitude, as shown in "A" and "B" of the first figure, the average amplitude is the same as the carrier amplitude and *the percentage of modulation is the ratio of the difference between the maximum amplitude and the carrier amplitude to the carrier amplitude, multiplied by 100.* That is,

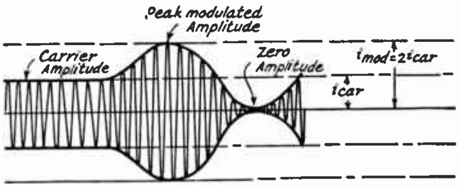
$$M = \frac{i_{\text{mod}} - i_{\text{car}}}{i_{\text{car}}} \times 100$$

In case of unsymmetrical modulation such as that suggested by "C," the average amplitude is no longer the same as the unmodulated amplitude and distortion results, even though the modulating signal is a pure tone. This effect is known as "carrier shift" because it is equivalent to a shift in average amplitude, sometimes being upward as in "C" and sometimes downward. Either way it causes distortion and a broad signal.

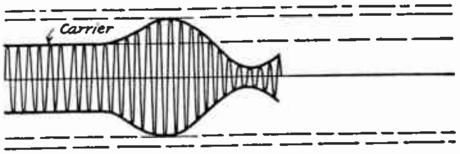
The process of modulation, involving combination of the carrier radio frequency and the modulating audio frequency, produces two additional frequencies coexistent in the output. These are the side-band frequencies, the carrier plus the modulating frequency (the upper side band) and the carrier minus the modulating frequency (the lower side band). At amateur-band frequencies, present technic requires the transmission of the carrier and both side bands although it is theoretically possible to communicate with the carrier and only one side band transmitted, or even with the carrier suppressed.

The radiated power is considered to be divided between the carrier and the side bands. Considering the case of 100% modulation shown in A, Fig. 81, since the maximum current amplitude (peak current) is twice the carrier amplitude, the *instantaneous peak power* must be four times the carrier power because the antenna resistance is constant and the power is therefore proportional to the square of the current. Using effective current values, the antenna power at 100% modulation, as with a sustained sinusoidal signal, is 1.5 times the unmodulated carrier power. The additional or side-band power in the antenna with 100% modulation is, therefore, 50% of the unmodulated carrier power. The antenna current indicated by the r.f. ammeter will be the square root of 1.5 or 1.226 times the unmodulated value, although complex tones, such as voice and music, may cause somewhat more than 22.6% increase in antenna current. It is apparent that the modulating system, whatever its type, must be able to effect a 50% increase in the transmitter's output power if the set is to have a modulation capability of 100%. Since the effectiveness of a modulated wave as measured by receiver response depends on the *variation* in amplitude, it is desirable that the transmitter's modulation capability be high. As a specific instance, a 10-watt carrier modulated 100% (modulation factor 1.0) is practically as effective as a 40-watt carrier modulated 50% (modulation factor 0.5), the carrier power required for a given variation in wave amplitude being inversely proportional to the square of the modulation factor. Transmitters having high modulation capability are especially desirable for amateur work because they utilize to the utmost the carrier power available, their useful signaling range most nearly approaches their useless interference (heterodyning) range, and carrier overloading of r.f., amplifier and detector tubes in the receiver is minimized.

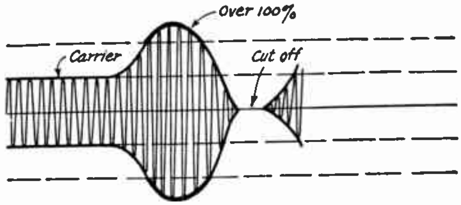
When high values of modulation factor are used, particular care must be exercised to guard against the frequency instability condemned in the preceding chapter. It has been shown that frequency "wobbulation" is a serious defect in c.w. transmission and it must be realized that frequency modulation is far more objectionable in 'phone transmission. It not only causes unnecessary interference with other stations working on adjacent frequencies in the same band but also can cause interference with services operating on greatly different frequencies. An amateur 'phone working on the 3500-kc. band is even likely to cause interference on the broadcast band, as a result of the frequency "wobbulation" accompanying modulation of an oscillator and the consequent radiation of spurious frequencies over a band of hundreds of kilocycles. Frequency modulation is also a likely cause of distorted reception because the waves radiated on different frequencies travel over separate paths and arrive at the receiver out of phase with each other. Modulation of the oscillator in an amateur transmitter is therefore poor practice and is not recommended because any practicable method of modulation applied to an oscillator is bound to cause frequency modulation as well as amplitude modulation, even though the modulation factor be low. Even when a radio-frequency amplifier following an oscillator is modulated, precautions are necessary to insure against affecting the oscillator's frequency. An extremely stable oscillator circuit is necessary, preferably isolated from the modulated stage by a buffer amplifier.



A - 100% MODULATED



B - LESS THAN 100% MODULATED



C - OVER MODULATED

FIG. 81 — GRAPHICAL REPRESENTATION OF A MODULATED WAVE

Methods of Modulation

The types of modulation systems used in modern transmitters of high modulation capability may be classified generally in two groups, one in which the modulating signal is applied to the control-grid circuit (grid-bias modulation) or screen-grid circuit (screen-grid modulation) of the modulated r.f. amplifier, and the other in which the plate circuit of the r.f. tube is supplied with modulated power (plate modulation).

Grid-bias modulation operates to vary the bias voltage of the r.f. tube at signal frequency, affecting the amplifier's power output accordingly. Screen-grid modulation operates to vary the screen-grid voltage and hence the output of an amplifier using a four-element tube. In both of these systems the r.f. excitation and direct plate voltage are constant. Relatively small modulating power is required but the carrier power output must be limited to a small percentage of the maximum of which the amplifier is capable, usually necessitating an r.f. output amplifier tube rating of at least four times the transmitter's carrier power rating.

Plate or Heising modulation, more economical for low-power transmitters and hence most popularly used by amateurs, utilizes an audio-frequency power amplifier to modulate the plate input of an r.f. amplifier whose power output varies as its plate power input. For a modulation capability of 100%, the modulator must be capable of practically undistorted audio-frequency power output equal to 50% of the modulated amplifier's steady (d.c.) power input; or, to put it differently, the modulated amplifier's steady plate power input is twice the modulator's maximum audio-frequency power output.

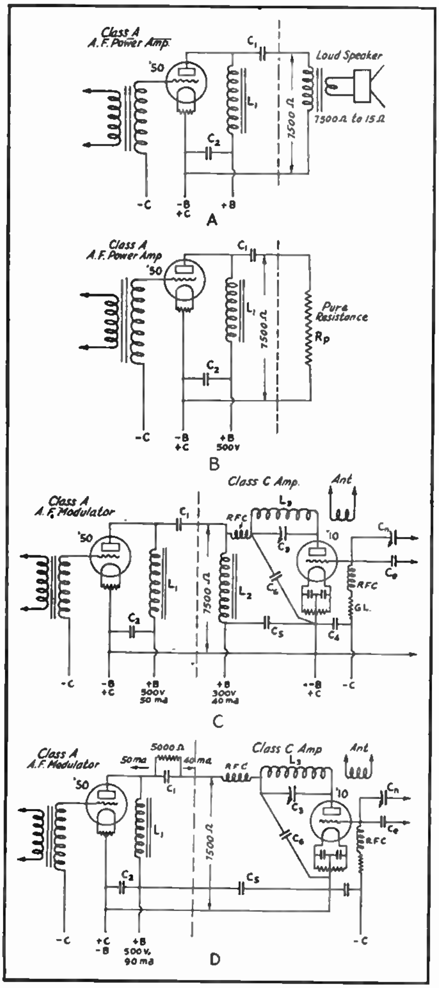


FIG. 82 — THE MODULATOR IS AN AUDIO-FREQUENCY AMPLIFIER SUPPLYING POWER TO THE PLATE CIRCUIT OF THE MODULATED RADIO-FREQUENCY AMPLIFIER

The schematic diagrams *A*, *B*, *C* and *D* of Fig. 82 show how the operation of a typical Type 50 Class A audio-frequency power amplifier is the same when it is used to furnish power to a loud speaker, to a resistor or, as a modulator, to the plate circuit of a radio-frequency amplifier.

In *C* and *D* it is essentially an audio-frequency power amplifier "impedance-coupled" to its load, its power output being superimposed on the direct power supplied to the r.f. stage. The modulator's dynamic characteristic, determined from its plate curves by the method shown in the following section, is such that with suitable excitation it will deliver approximately 5.4 watts when its plate voltage is 500 volts, its negative grid bias is 100 volts and its load resistance is 7500 ohms. This power output is sufficient to modulate 95%, approximately 12 watts input to the r.f. amplifier plate circuit *when the latter is equivalent to a pure resistance of 7500 ohms.*

The Modulated R.F. Amplifier

This condition obtains when the modulated stage operates as what is known as a Class C amplifier; that is, so that its power output is proportional to its plate power input, the plate current and output current varying as the plate voltage between the limits of nearly zero plate voltage and twice the mean plate voltage. This is accomplished by operating with a negative grid bias more than sufficient to reduce the plate current to zero with no excitation (usually twice "cut-off" bias) and by supplying the grid with r.f. excitation sufficiently ample to cause plate current saturation. As shown in the graphical representation of this operating condition, Fig. 83, large amplitudes of plate current flow during positive excitation peaks. The plate output wave shapes are quite distorted and "kick" the tank circuit on alternate half-cycles only. But the wave form in the output circuit is nearly sinusoidal because of the tank circuit's "flywheel" effect. This action is analogous to that of a single-cylinder two cycle gas engine whose crank has nearly harmonic motion because of the smoothing effect of the flywheel, even though the impulses are delivered to the mechanism during but a small part of each revolution. In a push-pull Class C amplifier (or oscillator) the two plates alternate in supplying energy and the tank receives a "kick" on both halves of the cycle, this action being analogous to that of a two-cylinder two-cycle engine in which an explosion occurs at every half-revolution of the crank. The radio-frequency harmonic content in the output, including the antenna circuit, is even less with a push-pull Class C amplifier than with a single-ended one, the even harmonics canceling, and push-pull output amplifiers are therefore advisable where the final stage is modulated.

When the amplifier's operation is truly Class C, its plate circuit input resistance, as viewed from the modulator output, will be equal to the mean plate voltage divided by the plate current. Also, the product of the plate voltage and current is the unmodulated power input, equal to twice the modulator's maximum audio power output for 100% modulation. Regardless of the type, size or number of tubes used in the Class C amplifier, its mean plate voltage and plate current will be the same for a given modulator whose operating conditions remain unchanged. Hence the amplifier plate current of 40 ma. at 300 volts should be used to give the 7500-ohm load for the modulator shown in *C* and *D*, no matter what tube is used in the Class C amplifier. Coupling between the modulator and r.f. amplifier plate circuits to satisfy these requirements can be accomplished in several ways. One method, as shown in *C*, is to use two chokes, L_1 and L_2, having high impedance at audio frequencies so as to prevent loss of modulator power output through the supply circuits, and a coupling condenser, C_1, of low impedance at audio frequencies. This can be simplified by the arrangement shown in *D*, using but one choke, the difference in plate voltage being taken care of by the dropping resistor shunting C_1. Both of these arrangements are used in practical units described in this chapter. A coupling transformer would be more suitable for a push-pull type modulator, as is illustrated by an example further on.

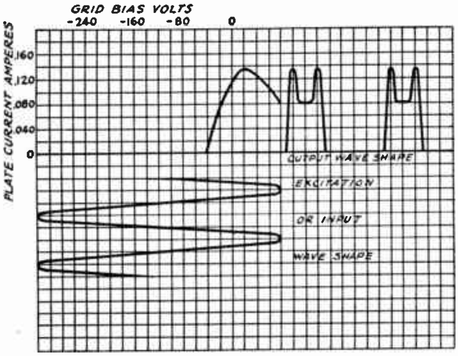


FIG. 83 — CLASS C AMPLIFIER INPUT AND OUTPUT WAVE SHAPES

Class A Modulator Characteristics

The Class A modulator, identical in operation to the familiar audio-frequency power amplifier commonly used in broadcast receivers and public address systems, operates so that the plate output wave shapes are essentially the same as those of the exciting grid voltage, as shown in Fig. 84. It is operated with a negative grid bias such that the plate current is the same with and without excitation, the alternating grid excitation voltage and load resistance being such as to make its dynamic characteristic essentially linear. As generally used, the grid must not go positive on the excitation peaks and the plate current must not fall so low on the more negative half-cycles of the excitation voltage as to cause distortion due to the lower curvature of the characteristic. The operating conditions for tubes popularly used as Class A modulators in amateur transmitters are given in the table and can be determined from the plate characteristic curves of the modulator tube, those for a Type 849 being illustrated in Fig. 85. The general method is as follows:

Assuming that the tube is to be operated at maximum rated plate voltage (3000 volts) and plate power dissipation (300 watts), the mean (d.c.) plate current is the plate dissipation in watts divided by the plate voltage, or 100 ma. The intersection of the 3000-volt and 100-ma. coördinates fixes the operating point on the plate characteristic curves, the negative grid bias for this point being 132 volts. With normal filament voltage of 11 volts a.c. and the grid return to the filament center tap, the maximum amplitude of the grid excitation (peak grid swing) is nearly 127 volts, being less than the bias voltage by half the filament voltage. The next step is to draw the load line, passing through the operating point and intersecting the −5.5- and −259-volt bias curves. If it is intended to operate the modulator at maximum output with not more than 5% distortion, this line must be such that its length to the left of the operating point is no more than 11/9 of its length to the right of this point, as has been shown by Weaver, "Use of Distortion Rule," *QST* November, 1929. In this case the load line, passing through the operating point, intersects the grid-swing limit curves at approximately 4900 volts (E_{max}), 10 ma. (I_{min}) and 900 volts (E_{min}), 210 ma. (I_{max}). The optimum load resistance for the modulator is the total plate voltage swing ($E_{max}-E_{min}$), divided by the total plate current swing ($I_{max}-I_{min}$). That is,

$$R_p=\frac{4900-900}{0.210-0.010}=20{,}000\text{ ohms}$$

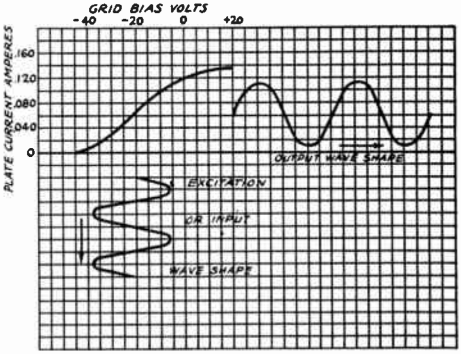


FIG. 84 — INPUT AND OUTPUT WAVE SHAPES OF A CLASS A AMPLIFIER OR MODULATOR

The audio power output is equal to ⅛ of the product of the total plate voltage and total plate current swings:

$$\text{Power output} = \tfrac{1}{8}(E_{\max} - E_{\min})\ (I_{\max} - I_{\min})$$
$$= \tfrac{1}{8} \times 4000 \times 0.20 = 100 \text{ watts.}$$

As shown previously, for 100% modulation the r.f. amplifier's steady (d.c.) plate input should be exactly twice the modulator's maximum audio output. Knowing this and the required modulator load resistance, the proper plate supply voltage and current for the modulated amplifier can be calculated. By Ohm's Law,

$$I_b = \sqrt{\frac{P_o}{R_p}} \text{ and } E_b = \frac{P_o}{I_b}$$

$$\text{or } E_b = \sqrt{P_o \times R_p} \text{ and } I_b = \frac{P_o}{E_b}$$

where P_o = unmodulated power input to r.f. stage = twice modulator power output, watts.
R_p = optimum load resistance for modulator, ohms.
I_b = mean current to r.f. amplifier plate, amperes d.c.
E_b = r.f. amplifier mean plate voltage, d.c.

For the example of the Type 849 modulator,

$$I_b = \sqrt{\frac{200}{20{,}000}} = 0.1 \text{ amp.} = 100 \text{ ma.}$$

$$E_b = \frac{200}{0.1} = 2000 \text{ volts.}$$

If the plate power is supplied to the modulator and Class C amplifier through a common choke, as shown in *D* of Fig. 82, a voltage-dropping resistor is necessary to reduce the amplifier plate voltage to the proper value. Its resistance is equal to the difference between the modulator and amplifier plate voltages divided by the amplifier plate current in amperes. Its power dissipation rating should be equal to the square of the amplifier plate current multiplied by the resistance. Since it is in the path of the audio power from the modulator to the amplifier it should be by-passed by a condenser having relatively low reactance for the lower speech frequencies in comparison with the resistance. A capacity of 2μfd. or more will be satisfactory for amateur sets. Because the plate choke is in parallel with the modulator load circuit it must offer a high impedance at the lowest modulating frequencies and have low distributed capacity and resistance. A choke is recommended that has an effective inductance of at least 30 henries with the total modulator and amplifier plate supply current flowing through it.

The tubes most suitable for use as Class A modulators are those having large audio output power ratings, this rating being a direct indication of a tube's capability as a modulator. They are usually characterized by low plate impedance and amplification factor, those given in the table being representative of the most suitable types generally available. The operating conditions recommended in this table have been determined by the foregoing method and tested by experience. They should be followed closely.

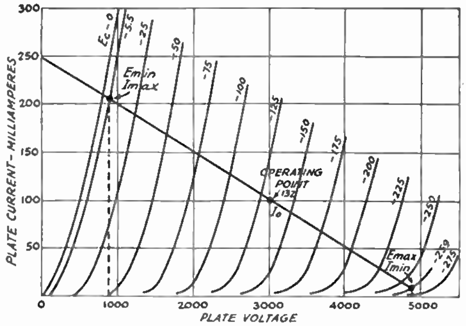


FIG. 85 — THE OPERATING CONDITIONS FOR A CLASS A MODULATOR ARE DETERMINED FROM ITS PLATE CHARACTERISTIC CURVES

The Class B Balanced or Push-Pull Modulator

A more economical and efficient type of modulator than the Class A type has been recently developed. It is known as the Class B type and uses two tubes in a push-pull or balanced circuit. With it much higher audio output can be obtained for a given plate dissipation and emission rating than with the Class A modulator. The Class B modulator operates so that the plate power input (and output) depends on the excitation. When there is no signal the plate current is nearly zero and when the excitation is maximum the efficiency and output are high, comparatively large output being obtainable without exceeding the rated plate dissipation. The factors that limit the output are the excitation available, the filament emission and the plate dissipation on the output peaks. Its operation is shown by the mutual and grid characteristics of Fig. 86, these being for a pair of Type 46 tubes used in the unit described later. Plate current flows only during the positive half of the excitation cycle, the output wave shapes for each tube being essentially half cycles. It is necessary, therefore, to use two tubes in a balanced circuit with a special output transformer, the combined output wave shape being then the same as the excitation. The grids go positive on the excitation peaks, necessitating an exciting amplifier of the power type in contrast to the voltage amplifier used to excite the Class A modulator. The operating conditions are determined from the curves shown. Because of the design of the tubes no grid bias is required when the two grids are connected together for Class B operation. The grid voltage and excitation power required can be supplied by a Class A amplifier using a single Type 46 tube with 250 volts on its plate, the coupling transformer having a total primary to total secondary turns ratio of 1 to 1, the secondary being center-tapped. On the output side, the power delivered is approximately 20 watts, which is sufficient to modulate completely 40 watts input to a suitable Class C amplifier. The plate efficiency at maximum output is nearly 50%, the maximum d.c. plate input being 110 ma. at 400 volts. The output transformer is designed to couple the modulator to a 4000-ohm load, that is, the plate circuit of a Class C amplifier using a pair of Type 10 or other small tubes with a plate input of 100 ma. at 400 volts. To suit this load to the modulator's output requirements the transformer has a total primary to secondary ratio of 1 to 0.8. The method of determining these operating characteristics is detailed in *QST* for November and December, 1931. The reader should refer to these articles for the details which must be curtailed here because of space limitations.

The three-element tubes most suitable as Class B modulators are those of the medium- and high-amplification-factor type, such as the Type 10, 841, and 03-A. The input and output transformers must be specially designed for the particular type of tube used. Transformers for Class B modulators using two Type 10 or Type 03-A tubes are available from manufacturers. The latter combination has an audio output rating of 200 watts and is capable of 100% modulating 400 watts input to a Class C amplifier using 1000-volt or 2000-volt type tubes. The Class B modulator demands a plate power supply of good regulation because of the varying plate power input. Methods of obtaining satisfactory regulation are shown in Chapter Ten.

Speech Amplifier and Modulator Assemblies

The design and construction of a speech amplifier and modulator unit is quite similar to that of a good audio-frequency power amplifier and the same practice should be followed. The speech amplifier section should be capable of delivering the necessary grid swing to the modulator without overloading or distortion. The value of voltage amplification necessary is set hy the grid requirements of the modulator and the voltage across the secondary of the microphone transformer. The latter, in turn, is determined largely by the type of microphone used. As a general rule, Type 50, Type 11, or 842 Class A modulator tubes (grid swings up to 100 volts) will require one stage of transformer-coupled speech amplification — using a Type 01-A, 12 or 27 tube — with a single-button or sensitive double-button carbon microphone. A stretched-diaphragm double-button microphone will necessitate an additional transformer-coupled stage. Higher-power modulators such as the Type 849 and 845 (peak grid swings up to 190 volts) will need two stages of speech amplification for single-button microphones, the second stage using a Type 10 tube with 350 volts on its plate and the first stage being the same as the single-stage amplifier for lower-power modulators. A three-stage amplifier using tubes such as the Type 27 or 12 in the first two stages and a Type 10 in the last stage will be necessary for high-power modulators when using an insensitive type double-button microphone. Condenser type microphones which incorporate a stage or two of amplification will operate satisfactorily with the same type of speech amplifier used for double-button carbon microphones.

The tubes of the speech amplifier are operated as linear audio-frequency amplifiers and the electrode voltages given in the tube table of Chapter Five should be followed. The peak grid swing to the modulator can be limited to the value where distortion begins by adjustment of the gain control across the secondary of the microphone transformer.

When two or more stages of speech amplification are used particular care must be taken to prevent "motor-boating" and distortion resulting from inter-stage feed-back. The coupling transformers should be isolated from each other and all supply circuits should be adequately by-passed. It is advisable to keep the modulation reactor well away from the other audio equipment when more than one stage of speech amplification is used since the strong magnetic field about the choke is quite likely to induce feed-back in nearby audio transformers. As a further precaution all transformer cases should be connected to the negative side of the plate supply and grounded. One lead of the microphone circuit should also be grounded and a shielded microphone cable is advantageous, particularly for eliminating radio-frequency pick-up in the microphone leads. R.f. overloading of the grid circuits of the speech amplifier and modulator is one common cause of "singing" and every precaution to eliminate it will prove worthwhile. Liberal use of radio-frequency chokes in the power and bias supply leads, particularly the high-voltage leads between the modulator and Class C amplifier, together with removal of the audio-frequency equipment from the vicinity of the radio-fre-

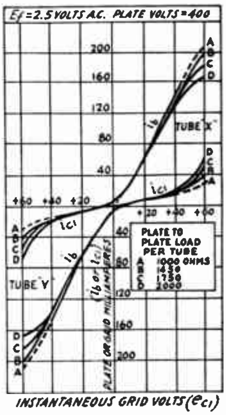
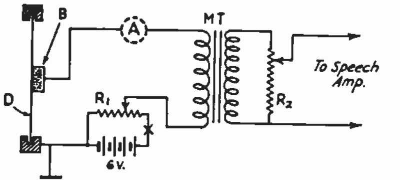


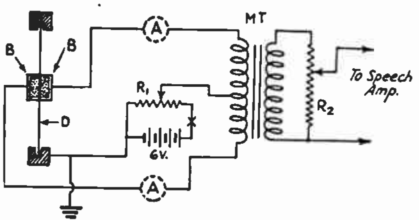
FIG. 86 — DYNAMIC CHARACTERISTIC OF TWO TYPE 46'S IN PUSH-PULL AS A CLASS B AMPLIFIER WITH FOUR VALUES OF LOAD RESISTANCE

quency units, can go a long way towards eliminating troubles from radio-frequency overloading. Complete shielding of the speech amplifier and modulator unit (using iron or steel shields) is decidedly good practice.

When modulator or speech-amplifier tubes are operated in parallel or push-pull, a non-inductive resistor of about 100 ohms should be connected in the grid lead to each tube to prevent parasitic ultra-high frequency oscillation and consequent overloading of the grids. Such resistors are also helpful in reducing grid overloading from induced r.f.



SINGLE-BUTTON MICROPHONE



DOUBLE-BUTTON MICROPHONE

FIG. 87 — CARBON BUTTON MICROPHONES OF TWO TYPES

The diaphragms are designated by D and the buttons by B. R_1 may be 200 ohms and the gain control R_2 a 100,000-ohm potentiometer. The microphone frame should be grounded and the leads should be shielded to prevent r.f. pick-up.

Microphones and their Care

A good microphone is a decided asset to any amateur 'phone transmitter although the possession of even the best microphone obtainable is no guarantee of perfect transmission. Inexpensive single-button carbon-grain microphones, similar to those used for wire telephony, are used successfully by many amateurs and are capable of transmitting very intelligibly when used with a properly adjusted outfit. The microphone transformer for this type should have a primary impedance of 100 or 200 ohms and is quite reasonable in cost. Excellent double-button carbon-grain microphones admirably suited to amateur use are now available at reasonable prices and are generally used in the better amateur stations. The double-button microphone transformer should have a center-tapped primary, usually of 200 ohms impedance. The double-button microphone is considerably less sensitive than the single-button type and therefore requires a speech amplifier of greater voltage gain, as has been explained previously. Condenser-type microphones are considered the best for faithful response over a wide range of frequencies but their high cost (including the special amplifier they require) makes their use by amateurs quite limited.

Carbon-grain microphones, both single- and double-button, convert sound waves into pulsating electrical current by the variation in the resistance with pressure between carbon granules in contact with a metal or graphite diaphragm which is caused to vibrate by the sound waves striking it. In the single-button microphone, one connection is made to the diaphragm and the other is made to the cup containing the carbon granules, called a button. The microphone terminals are connected in series with a battery and the primary winding of a transformer. The current through the primary is a pulsating direct current which induces alternating current in the secondary winding, the resultant alternating voltage across the secondary being applied to the grid circuit of the speech-amplifier tube. In the double-button microphone there is a carbon element on each side of the diaphragm. The buttons are connected to the two ends of the primary winding of the microphone transformer and the diaphragm is connected in series with a battery to the center of the winding, as shown in Fig. 87. The granules in one button are compressed and their resistance is reduced while the granules on the other side loosen and their resistance is increased when the diaphragm is vibrated, with the result that there is an increase in current flow between one button and the diaphragm while there is a decrease in current flow between the other button and the diaphragm. The current flow through the common circuit and the battery will remain constant if the buttons have been properly adjusted. The diaphragm of the "high-quality" double-button microphone is "stretched" to make its natural resonant frequency well up in the audio-frequency range, usually to some value above 7000 cycles. This makes the microphone's sensitivity comparatively low but improves its frequency characteristic. More sensitive double-button microphones have an "unstretched" carbon or graphite diaphragm.

Condenser microphones utilize an entirely different principle — that the variation in electrostatic capacity between two plates causes a change in the potential difference between them. In the microphone one of the plates is thick and incapable of vibration but the other is of thin metal, tightly stretched, separated from the fixed plate by about a thousandth-inch. A high d.c. potential is applied between the plates and the variation in the potential which results when the thin plate vibrates in response to a sound wave is applied across the grid circuit of an amplifying tube. The voltage variation is extremely small and a two-stage microphone amplifier is necessary to bring it up to the value obtainable from a double-button carbon microphone. This amplifier is usually attached to the microphone stand.

A microphone of any type is a piece of apparatus deserving careful handling if it is to do its intended work properly. It should never be moved or even touched while current is flowing through it because the slightest jar will give the diaphragm a jolt far greater than that caused by a loud sound. The carbon microphone should never be operated with excessive current through the buttons because the heat generated by high current may fuse the carbon granules together, causing "freezing." A current of not more than 10 or 15 milliamperes per button is usually safe and the microphone battery voltage should be adjusted to give this value of current when the microphone is first connected. The transmitter plate milliammeter can be used in making the adjustment. The current to each button of a double-button microphone should be of the same value and sometimes adjustment of the pressure on the buttons may be necessary to make it so. This adjustment must be made very carefully, preferably by an experienced microphone repairman.

If a carbon microphone should become "frozen" the granules may be loosened by lightly tapping the frame with one finger *after the microphone battery circuit has been opened*. The microphone should be suspended by springs in a frame or hung from the ceiling in preference to having it unprotected from shock and vibration on the operating table. A good shockproof mounting will eliminate a lot of the "background" noise which afflicts many amateur outfits. A light cloth sack pulled over the microphone will keep out insects and dust as well as protect the diaphragm from corrosion by moisture condensed from the speaker's breath. An ordinary conversational tone should be used and it is better to talk "across" rather than directly at the microphone because breath striking the diaphragm gives the speech a hissing characteristic.

Practical Transmitter Construction and Adjustment

Three amplifier-modulator units are illustrated as examples of practical arrangements for low-power amateur transmitters. The first is an excellent modulator for one Type 10 or 45 Class C amplifier and is designed for use with a single-button microphone. The second makes an excellent modulator for a Class C amplifier using two Type 10 or 45 tubes in push-pull or parallel and is designed for use with a double-button microphone. When operated according to specifications either is capable of 95% modulation of a suitable Class C amplifier. The first unit, a photograph of which is shown in Fig. 88, might be used to modulate the single-ended amplifier of a low-power crystal-controlled transmitter. The second unit is especially suited to modulation of the push-pull amplifier described in Chapter Seven. The construction of both units is based on the principles outlined in the preceding paragraphs and their specifications are given beneath the circuit diagrams, Figs. 89 and 810. Each utilizes the Type 50 as a modulator and Type 27 tubes as speech amplifiers. The output of one is provided with a double choke for coupling to the plate circuit of the modulated amplifier and the other is designed to use a single modulation choke which is connected in the positive supply lead to the unit but is not incorporated in the assembly. Both units are intended for operation with rectified a.c. plate supply, a.c. filament supply and battery grid bias.

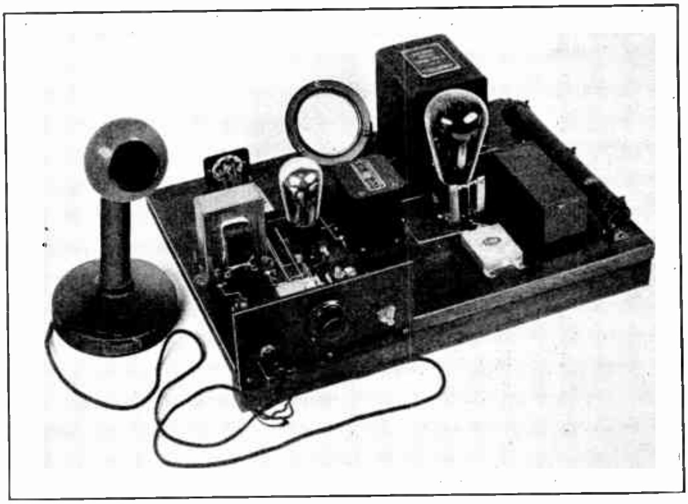


FIG. 88 — A SUITABLE SPEECH AMPLIFIER AND MODULATOR FOR THE LOW-POWER 'PHONE

It will modulate a single Type 10 or 45 Class C amplifier 95% and should be used with a single-button carbon microphone. The microphone jack, gain control and microphone battery switch are on the front panel. The microphone transformer and Type 27 speech amplifier are behind this panel with the Type 50 modulator tube, double plate choke, dropping resistor and by-pass condenser at the right.

The positive high-voltage output terminal is connected to the corresponding terminal of the modulated amplifier stage and to that stage only. The negative high-voltage connection is common to all units of the transmitter, as is also the positive grid bias. It is advisable, however, to run separate leads from each unit of the transmitter to the negative tap on the plate supply and to the positive tap on the bias supply, to reduce inter-stage coupling. The modulator plate supply should deliver 500 volts of pure d.c. and should have a current capacity of about 100 ma. for the single-tube modulator transmitter or 200 ma. for the transmitter using the two-tube modulator. The d.c. plate voltage for the Class C amplifiers will be reduced to about 300 volts by resistors R_4 and R_2 when the respective modulated amplifiers are adjusted to draw their proper values of mean plate current. This adjustment is extremely important and must be made exactly.

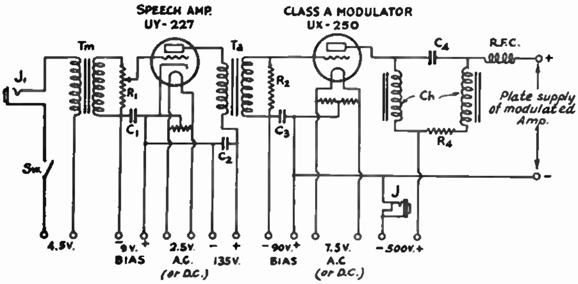


FIG. 89 — CIRCUIT OF THE LOW-POWER MODULATOR ILLUSTRATED IN FIG. 88

Tm — Microphone transformer.
Ta — Audio frequency amplifying transformer.
Ch — National type 80 double B eliminator choke.
C_1 — 1-μfd. by-pass condenser.
C_2 — 1-μfd. 300-volt by-pass condenser.
C_3 — 1-μfd. by-pass condenser.
C_4 — 1-μfd. 1000-volt audio coupling condenser.
R_1 — 200,000-ohm Frost potentiometer.
R_2 — 250,000-ohm resistor, grid leak type.
R_3 — 100-ohm filament center-tap resistors.
R_4 — 5000-ohm Ward-Leonard No. 507-A resistor, 90 ma., 44 watts
R.F.C. — Silver-Marshall type 277 or Aero type C-248 choke.
J — Closed circuit milliammeter jack.
J_1 — Open circuit microphone jack.

The proper value of negative grid bias for a three-element tube used as a Class C amplifier is easily calculated by dividing the plate voltage value by the tube's amplification factor and multiplying by 2. Since the plate voltage on the Class C amplifier in this case is 300, the proper value of bias for Type 10 tubes (amplification factor 8) is about 90 volts and that for Type 45 tubes (amplification factor 3.5) is about 180 volts. It is advisable to make the bias a little higher than that computed by the above method because actual cut-off bias is always slightly greater than that calculated. It is not necessary to use battery bias alone for Class C amplifiers, and a combination of battery and automatic grid-leak bias is recommended. This may be obtained by connecting a transmitting grid leak in series with battery bias sufficient to reach cut-off. A 10,000-ohm grid-leak will be satisfactory for both Type 10 and 45 tubes as well as for most of the larger tubes.

Once the bias has been set, the next step is to switch on the transmitter and tune the circuits to one of the bands authorized for amateur 'phone. This process is exactly the same as the

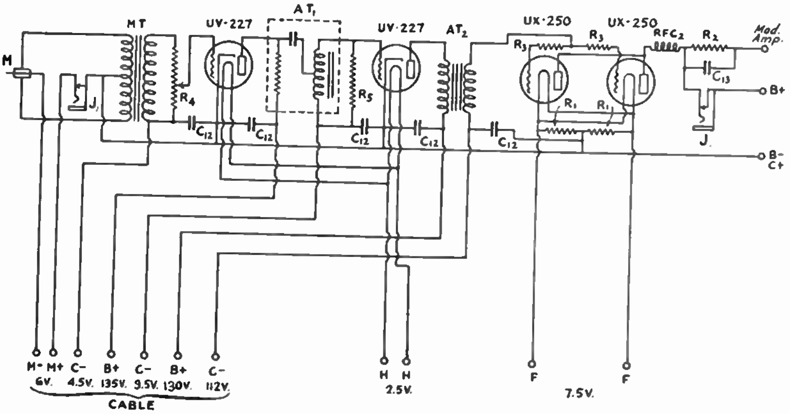


FIG. 810 — SCHEMATIC CIRCUIT OF A UNIT USING TWO TYPE '50 TUBES IN PARALLEL AS CLASS A MODULATORS

It is intended for use with a double-button microphone and is similar in construction to the low-power modulator.

C_{12} — 1-μfd. by-pass condenser.
C_{13} — 2μfd. audio by-pass condenser.
R_1 — 75-ohm filament resistor.
R_2 — 2500-ohm plate voltage dropping resistor.
R_3 — 100-ohm grid resistor.
R_4 — 100,000-ohm gain control (potentiometer).
R_5 — 100,000-ohm resistor.
AT_1 — Silver-Marshall No. 255 Audio Transformer
AT_2 — Audio-frequency transformer 3 1
J_1 — Plate current jack.
J_2 — Microphone current jack.
M — Double-button microphone.
MT — Microphone transformer.

tuning of a c.w. transmitter and has been completely covered in Chaper Seven. It is recommended that a dummy antenna like the one shown in Fig. 811 be used in place of the radiating antenna in order to reduce interference to other stations while the transmitter is being given its preliminary adjustment. It is always evidence of good technical practice as well as of amateur courtesy to use such a non-radiating load for transmitter experiments which actually do not require a radiating antenna. Following this, adjust the antenna tuning and coupling so that the Class C amplifier plate current is exactly the value specified in the table for the operating conditions and tube combination being used (40 ma. for the single modulator or 80 ma. for the two-tube unit). *Do not attempt to tune for maximum antenna current.* The amplifier's plate-current value is the index of proper operating conditions, let antenna current be what it may. If it should be impossible to make the plate current as much as the value specified, even with "tight" antenna coupling and all circuits tuned to resonance, the excitation to the modulated amplifier is insufficient and must be increased by increasing the output of the preceding stage either by adjusting its bias, increasing its plate voltage or, perhaps, by slightly increasing the plate voltage and output of the oscillator.

Class C modulated amplifiers require more excitation than similar power amplifiers in c.w. telegraph transmitters and a surplus of excitation is always desirable. An approximate check on the sufficiency of the excitation can be made by short-circuiting the voltage dropping resistor in the modulator unit. This will increase the amplifier power input and antenna current, the increase in the latter being directly proportionate to the increase in plate voltage or plate current if the excitation is sufficient. When these preliminaries are finished the transmitter is ready for modulation.

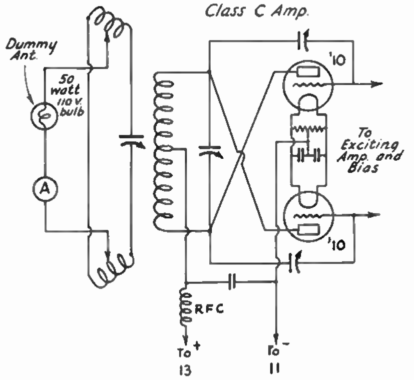


FIG. 811 — A DUMMY ANTENNA SHOULD BE USED FOR TRANSMITTER TESTING

The amplifier shown has circuit constants corresponding to those of the low-power push-pull amplifier described in Chapter Seven. Coupling to the load circuit is varied by adjustment of the taps on the antenna coils. The plate input terminal numbers correspond to the output markings of the Class B modulator unit.

The milliammeter should be connected in the plate supply lead to the modulator unit, through which also flows the plate current for the modulated amplifier. The value of current indicated is the sum of the plate current for both modulator and amplifier tubes, the modulator current being the difference between the total and the known amplifier current. This should be 50 ma. for the single Type 50 modulator or 100 ma. for the two Type 50's in parallel. Sounding a prolonged "Oh-h-h" into the microphone, slowly advance the gain control from minimum to maximum until the plate milliammeter begins to show an increased reading. This indicates distortion and the gain should be reduced slightly. The antenna ammeter should show an upward deflection of about 25% for complete modulation

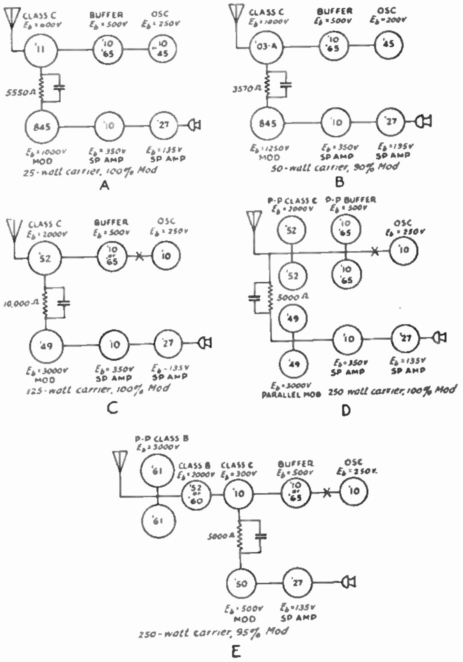


FIG. 812 — SUGGESTIONS FOR TRANSMITTER COMBINATIONS USING CLASS A MODULATORS BASED ON THE DATA GIVEN IN THE CLASS A MODULATOR-AMPLIFIER TABLE

The speech-amplifier arrangements are for single-button microphones; double-button microphones will require an additional stage ahead of the first one shown. The oscillators may be crystal-controlled or self-controlled and should operate on the carrier frequency. Frequency multipliers will be necessary for output frequencies higher than the oscillator frequency and they may be inserted at the points designated X on the diagrams.

but the modulator and amplifier d.c. plate current should be unchanged.

A decrease in antenna current with modulation may mean that the modulator bias is improper, that a modulator tube is defective, or that the modulator is "over-loaded."

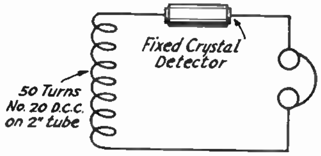


FIG. 813 — CRYSTAL DETECTOR MONITOR

The quality of the transmission can be checked by listening on the vacuum-tube monitor tuned to zero beat with the carrier; the speech should be clear and distinct even with the monitor tube oscillating. If the speech sounds "mushy" it is an almost certain indication of frequency modulation — which can be prevented by the methods outlined in the early part of this chapter. A handy monitor for continuously checking the speech quality is the crystal detector rig whose schematic circuit is shown in Fig. 813. It will give signals of good strength with the coil almost anywhere in the immediate vicinity of the transmitter and is also useful for exploring the modulator, plate-supply and house wiring for r.f. picked up from the transmitter. When the frequency stability and quality have been checked the transmitter is ready to go on the air.

The third unit, shown is a Class B modulator and speech amplifier intended for use with an amplifier using two Type 10 or 46 tubes. Its operating conditions were given previously. Construction and specifications are shown by the photograph and diagram, Fig. 815. The general arrangement is quite conventional, the special input and output transformers being the only unusual features.

Adjustment of the transmitter using this modulator is generally similar to that of the sets using Class A modulators except that the modulator plate current is not constant. The modulator plate milliammeter reading is a fairly accurate measure of the performance, indicating maximum modulation and output when it "kicks" to about 110 ma. The speech amplifier is operated as Class A, a single power supply of the broadcast-receiver type being sufficient for both the speech amplifier and modulator. The input is designed for a sensitive single button microphone. An additional amplifier stage will be necessary (a Type 27 tube may be used) with a double-button carbon microphone.

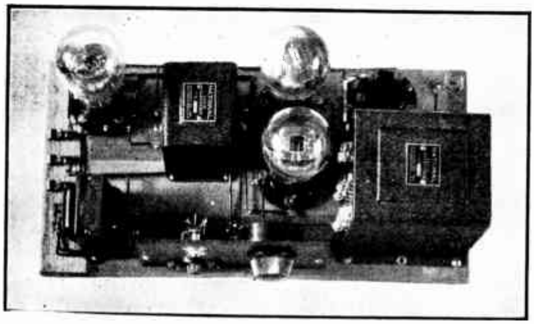


FIG. 814 — THE CLASS B MODULATOR UNIT

The speech amplifier tube is at the rear left corner of the baseboard. A small panel at the front edge holds the microphone switch and gain control. The microphone transformer is just to the left of the panel.

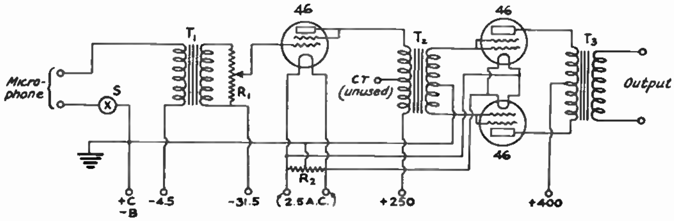


FIG. 815 — WIRING DIAGRAM OF THE CLASS B MODULATOR

T_1 — Single-button microphone transformer.
T_2 — Class B input transformer; turns ratio, total primary to total secondary, 1 to 1.
T_3 — Class B output transformer; if secondary is not tapped the turns ratio from total primary to secondary should be 1 to 0.79. (National Type BI and BO.)
R_1 — 500,000-ohm potentiometer.
R_2 — 20-ohm center-tapped resistor.
S — Single-pole single-throw switch.

A Low-Power 1715-kc. 'Phone Transmitter

The radio-frequency portion of a 1715-kc. transmitter designed for use with the Class B modulator unit just described is shown in Figs. 816 and 818. It uses a Type 46 tube as a High-C oscillator, a second 46 as a buffer amplifier, and two 46's in parallel as a Class C amplifier. The general construction is evident from the photographs. The complete circuit diagram is given in Fig. 817. No detailed description will be given here because the adjustment and operation of the transmitter is exactly as outlined with other transmitters of similar design already described in Chapter Seven. It is presented simply to illustrate how a typical amateur 'phone transmitter of low cost and moderate power output would be built.

The transmitter is built on a series of three panels, each measuring 5 by 14 inches, mounted one above the other on wooden uprights. The apparatus for the oscillator (to the right of the right-hand dotted line in Fig. 817) is placed on the lower panel; that for the buffer amplifier on the center panel; and the Class C amplifier (everything to the left of the left-hand dotted line) on the uppermost panel. The filament and plate supply connections are brought out to a 5-prong socket mounted on one of the uprights; a 5-wire cable soldered in the pins of an old tube base plugs into this socket to make connections.

Two power supplies will be required for the complete transmitter, one for the modulator and one for the r.f. part. These may be made as described in Chapter Ten, using voltage dividers to obtain the lower voltages required.

A fully-detailed description of the transmitter will be found in the July and August, 1932, issues of *QST*.

Class B Linear R.F. Amplifiers

The power output of a low-power 'phone transmitter may be increased by adding a suitable linear r.f. amplifier operating on the same frequency as the modulated amplifier. One suitable unit for operation with either of the transmitters just described is the high-power push-pull amplifier described in Chapter Seven. There would be little gain in adding a linear amplifier of lower power because the carrier power output of a tube used as a linear amplifier is but quarter the carrier power output obtainable from the same tube used as a modulated Class C amplifier.

The construction of a linear amplifier is much the same as that of any other power amplifier excepting the provisions for adjusting its grid excitation and for obtaining good grid regulation. These are, respectively, adjustable input coupling and a resistor shunting the grids.

The Class B linear amplifier operates so that its power output is proportional to the square of the grid excitation voltage, and with 100% modulation the unmodulated carrier output is one-fourth the peak or rated maximum output. The Class B output rating of a push-pull amplifier using a pair of 852 tubes is 60 watts carrier and 240 watts peak.

Fig. 819 illustrates the relation between excitation-voltage and plate-current wave shapes. The negative grid bias must be of cut-off value, approximately equal to the mean plate voltage divided by the amplification factor of the tube, or about 180 volts for the Type 852 at a plate voltage of 2000 volts d.c.

The procedure for putting a Class B linear amplifier into operation is first to adjust its unmodulated excitation until the antenna current is the maximum obtainable and then to reduce the excitation until the antenna current becomes half that value. This adjustment is made by altering the coupling between its input circuit and the tank of the modulated amplifier (by means of a tap on the latter) or by varying the value of a resistor connected between the grids of the linear amplifier tubes, grid shunting resistance, or by varying both coupling and resistance. Since the primary function of the resistor is to stabilize the load across the output of the exciting amplifier during the swing of the excitation voltage, it is better as well as more convenient to keep the resistance fixed and make use of the coupling adjustment only. A variable resistor having a total resistance of 10,000 ohms will be satisfactory. It should be non-inductive and should be capable of dissipating 25 watts. Each change in coupling will necessitate retuning of the exciting amplifier's tank circuit and, possibly, the output tank and antenna circuits. *It is essential that all circuits be tuned to exact resonance before reliable readings can be taken for any adjustment.* If the carrier excitation is adequate, the total d.c. plate current at excitation coupling for maximum antenna current should be about 240 ma. (120 ma. per tube) and at half maximum antenna current the total d.c. plate current should be about 120 ma. (60 ma. per tube) with 2000 volts on the plates. The antenna current reading should increase about 25% with complete modulation of the carrier, but the plate current should remain constant.

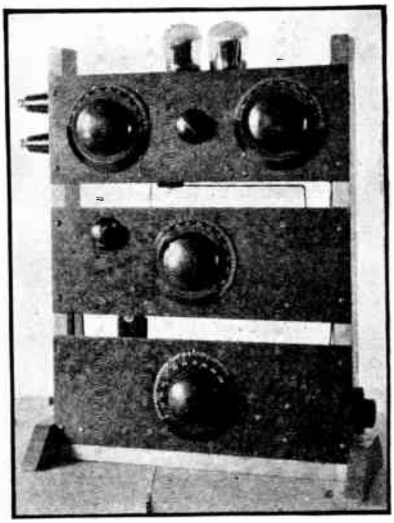


FIG. 816 — A FRONT VIEW OF THE 1715-KC. TRANSMITTER

The Class B modulator of Fig. 814 is well suited to use with this transmitter.

Accurate Performance Measurement

A more accurate check on transmitter performance than that possible by the methods which have been described can be made with a simple adaptation of the peak vacuum-tube voltmeter which is known as the modulometer, the circuit of which is shown in Fig. 821. The peak value of

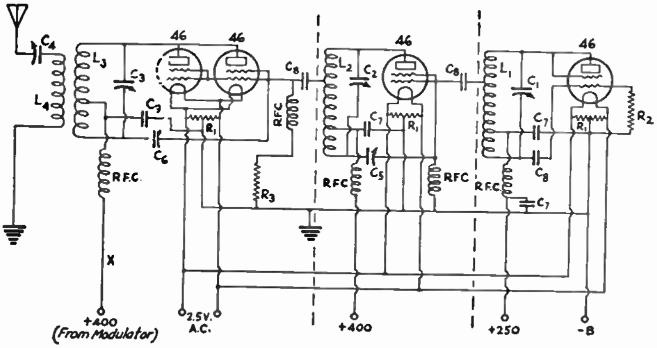


FIG. 817 — WIRING DIAGRAM OF THE RADIO-FREQUENCY END

C_1 — 500-μμfd. variable condenser.
C_2, C_3, C_4 — 250-μμfd. variable condensers.
C_5 — 100-μμfd. midget condenser.
C_6 — 50-uμfd. midget condenser.
C_7 — 005-μfd. fixed condensers.
C_8 — 250-μμfd. fixed condensers.
C_9 — 001-μfd. fixed condenser.
R_1 — 20-ohm center-tapped resistor.
R_2 — 50,000-ohm, 1-watt resistor.
R_3 — 1000-ohm, 2-watt resistor.
RFC — Radio-frequency chokes, Silver-Marshall Type 275 or equivalent.
L_1 — 17 turns of No. 12 enamelled wire, spaced to occupy 2½ inches on 2½-inch diameter form, tapped at 5th turn from grid end. Buffer excitation tap at 10th turn from plate end.
L_2 — Plate portion: 30 turns No. 18 enamelled, spaced to occupy 1½ inches on 2½-inch diameter form, tapped at 23rd turn from plate end for excitation to following stage. Neutralizing portion: 12 turns same spaced to occupy ¾-inch on same form, ½-inch away from plate portion.
L_3 — 38 turns of No. 14 enamelled wire, spaced to occupy 3½ inches on 2½-inch diameter form, tapped at center.
L_4 — 30 turns of No. 18 enamelled wire on 1½-inch diameter form; no spacing between turns.

an a.c. voltage applied to the grid circuit of the tube is equal to the negative d.c. bias voltage required to balance it and bring the plate current milliammeter indication back to the same value as with no grid excitation. This reading of the plate milliammeter is known as the "false zero" and may be the first scale division above true zero. To obtain it the tube is operated at a set value of minimum bias determined by adjusting the potentiometer R_3. The additional bias required to balance grid excitation voltage of 9-volt or less amplitude and bring the plate current back to false zero, is determined by adjustment of the potentiometer R_2 and is measured by the d.c. voltmeter V. Additional bias in series with that across R_2 is necessary for measurement of amplitudes of more than 9 volts. It is connected to the "Additional Bias" terminals shunted by the voltmeter V_1. The sum of the readings of V and V_1 then gives the value of the peak voltage being measured. The "Additional Bias" terminals should be shorted when no battery is connected.

Percentage modulation measurements are made with S_2 thrown to the left. The coil L_2 is coupled to the output circuit of the transmitter and the r.f. current through the circuit causes a voltage drop across R_1 which is directly proportional to the current through the resistor. Variations in the amplitude of the antenna current will therefore cause proportionate variations in the r.f. voltage across R_1 and the amplitude of the positive half-cycles of this voltage is measured by the peak voltmeter.

It is necessary to supply the speech amplifier input circuit (microphone transformer primary) with audio frequency of constant amplitude for these measurements and an audio oscillator such as that described in Chapter Two will do very nicely, the primary terminals of the microphone transformer being connected in place of the 'phones. The transmitting antenna should be replaced by a dummy antenna, of course. The maximum modulation capability of the transmitter is checked with the gain control advanced to the point where distortion occurs. With the pick-up coil coupled to the antenna inductance, the coupling should be adjusted so that the amplitude of the voltage across R_1 measures 5 or 6 volts. The gain control is then

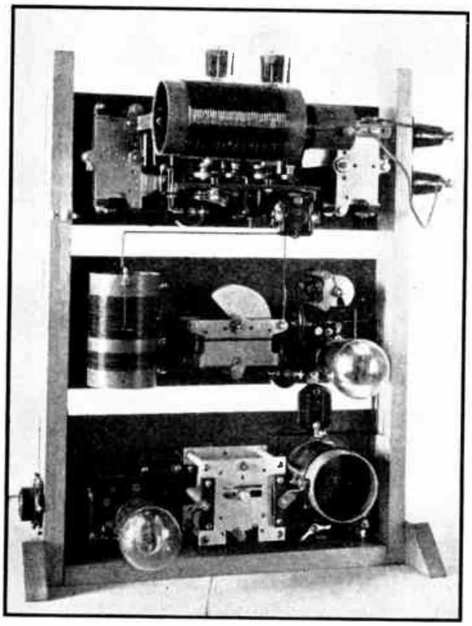


FIG. 818 — FROM THE REAR

This photograph shows how the parts are arranged on each of the three panels.

set at zero, leaving the carrier unmodulated, and a second measurement is made. The percentage of modulation is the difference between the two voltages divided by the unmodulated carrier voltage, multiplied by 100:

$$M = \frac{E_{\text{mod}} - E_{\text{car}}}{E_{\text{carr}}} \times 100$$

M is the percentage of modulation, E_{mod} is the voltage with modulation, and E_{carr} is the voltage for the unmodulated carrier.

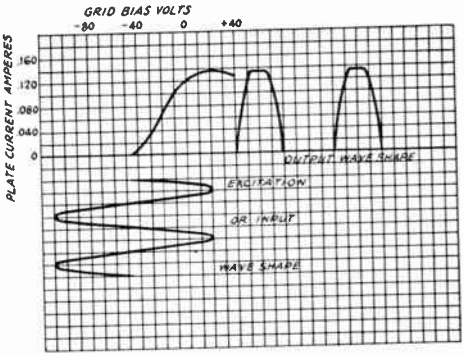


FIG. 819 — INPUT AND OUTPUT WAVE-SHAPES OF A CLASS B R.F. LINEAR AMPLIFIER

Those of a Class B modulator or audio power amplifier would be similar.

The gain of the speech amplifier is found by measuring the audio voltages on the grid of the first speech amplifier tube and on the grid of the modulator, the ratio of modulator grid voltage to the speech-amplifier grid voltage being the voltage gain of the amplifier. A performance curve for the transmitter can be made by plotting the percentage of modulation for various values of speech-amplifier signal voltage against the signal voltage values.

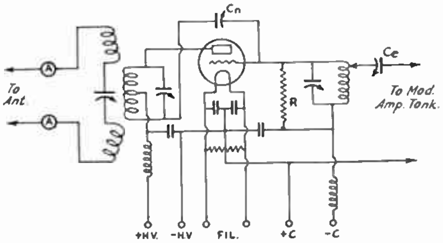


FIG. 820 — CIRCUIT OF A SINGLE-ENDED CLASS B LINEAR R.F. AMPLIFIER

The non-inductive grid-regulation resistor, R, should be capable of dissipating 50% of the exciting amplifier's power output. The excitation can be regulated by the coupling condenser, C_e, or by adjustment of the regulating resistor or a tap on the exciting amplifier tank coil. The circuit values can be as usual for the frequency and power. The method of adjustment for Class B operation is the same as that of the push-pull amplifier.

Audio-frequency feed-back in the speech amplifier is detected by making measurements of the signal voltage on the grid of one of the amplifier tubes with the modulator plate voltage "on" and "off." If the signal amplitude is greater with the modulator "on," there is feed-back. Radio-frequency pick-up is similarly detected, the r.f. excitation (oscillator) being switched on and off, an increased amplitude with the carrier "on" indicating r.f. in the audio circuits. Audio- and radio-frequency feed-back can be eliminated by following the suggestions given in earlier parts of this chapter.

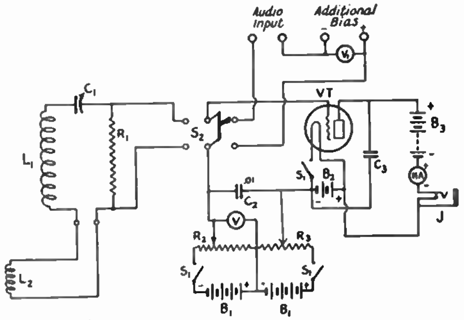


FIG. 821 — SCHEMATIC CIRCUIT OF THE MODULOMETER

L_1 — For 3500 kc. use 40 turns of No. 28 d.c.c. wire on a Silver-Marshall plug-in coil form. The same number of turns wound in a 2-inch diameter "hank" would serve as well.
L_2 — Pick-up coil. 2 or 3 turns of lamp cord, any size convenient.
C_1 — 100-μμfd. midget variable condenser. Any variable will do.
C_3 — .01-μfd. fixed condenser.
C_2 — 1000-μμfd. fixed condenser.
R_1 — 1500-ohm Ward-Leonard resistor No. 507–55. Any good "non-inductive" resistor of 1500 or 1000 ohms might be used.
R_2 — 200-ohm wire-wound potentiometer.
R_3 — 2000-ohm potentiometer.
B_1 — 9- and 4.5-volt "C" batteries.
B_2 — 2 dry cells in series (3 volts).
B_3 — Small size 22.5-volt "B" battery.
S_1 — Triple-pole single-throw switch.
S_2 — Double-pole double-throw battery type switch.
V — 0–10 volt d.c. voltmeter.
V_1 — 0–120 volt d.c. voltmeter.
MA — Weston Model 375 Student Type Galvanometer or 0–1 d.c. milliammeter.
J — Closed-circuit phone jack.
VT — Type '99.

Practical Operating Hints

The radiotelephone transmitter may require some "trouble-shooting" at times and a short summary of the symptoms of the more usual ailments will be useful. The troubles cited will not occur if the design and adjustment are according to the information previously given in this chapter, however.

"Downward" modulation, indicated by a decrease in antenna current when the carrier is modulated, is caused by a reduction in power output with modulation when there should be an increase in power output. It may be due to any of the following: Improper modulator bias; insufficient Class C amplifier bias; insufficient Class C amplifier r.f. grid excitation; excessive Class C amplifier plate current, causing overloading of the modulator. If a linear amplifier is used following the Class C modulated amplifier, downward modulation will result with 100% modulation if the carrier excitation to the linear amplifier is greater than that giving one half the maximum antenna current obtainable or if the bias on the linear amplifier is less than that required for plate current cut-off.

In an improperly designed transmitter, downward modulation may be the indication of a poor modulation choke or an audio-frequency by-pass across the modulation reactor. A too-large radio-frequency by-pass in the plate circuit of the Class C amplifier will cause this trouble. The capacity of this condenser should be not greater than .002 μfd. and circuits not requiring such a by-pass condenser are preferable where high modulation frequencies are used, as in television transmission.

Transmitter Power Supply

The filament supply for amateur transmitters is usually alternating current for the modulator and radio-frequency tubes, and either a.c. or d.c. for the speech amplifier tubes. The plate power for the speech amplifier may be from B batteries or a B substitute while that for the modulator and radio-frequency tubes is usually from d.c. generators or a.c. rectifiers. The power supply for the oscillator and buffer amplifier stages should be separate from that used for the modulator and Class C amplifier because modulation invariably causes some fluctuation in the modulator and Class C amplifier supply voltage, particularly with the Class B modulator, unless extraordinary precautions are taken to guard against it. The plate supplies described in Chapter Ten will be satisfactory if the particular features pointed out therein as desirable for telephony are incorporated.

The negative grid bias for low and medium power transmitters can be obtained from dry B batteries. Rectifiers are satisfactory for supplying grid bias to some audio-frequency units but, because of their poor regulation, are not so well suited to supplying bias for the r.f. power tubes or Class B modulators. D.c. generators make the most satisfactory grid bias supplies for high-power r.f. amplifiers, particularly for Class B linear amplifiers, and for Class B modulators.

Chapter Nine

ULTRA-HIGH FREQUENCY WORK

UNTIL the end of 1931, the amateur bands higher in frequency than 28,000 kc. were virtually unoccupied. Equipment and methods which were satisfactory on the lower frequency bands had proved entirely unsuitable for the 56-mc. and 400-mc. bands to which the amateur has access. Experimental work on the 56-mc. band had been in progress in League's laboratory for many years, but it was not until 1931 that the technique was sufficiently advanced to allow reliable and completely satisfactory communication. Upon the publication in *QST* of the designs for practical 56-mc. transmitters and receivers, amateurs throughout the world became active. At the present time, operation on the very high frequencies of this band is considered one of the most interesting activities in which the amateur can engage. Because the equipment necessary for this work differs considerably from that used on the lower frequency bands, we will devote this chapter to a description of it.

Operation on the 400-mc. band is still in the very early experimental stages. Activity in that territory is limited, at the moment, to the experimental work of scientifically inclined and technically qualified men who labor in the hope that 400 mc. may someday soon become a field for routine amateur communication. Reports of the work and data on equipment and methods appear from time to time in *QST*.

What to Expect

It is important that the amateur about to undertake 56-mc. work should understand that the band is suitable at present exclusively for short-distance communication. The lower frequency bands provide ample opportunity for long-distance working, and the amateur interested only in DX should restrict his endeavors to that territory. The particular value of the 56-mc. band to the amateur is that, in contrast to the other bands, it does not seem to permit communication over distances much greater than can be covered visually. It is this very characteristic of the band which has allowed groups of amateurs in various parts of the country to talk with each other night after night without interfering in any way with the next group 40 or 50 miles away from them. This means, of course, that amateurs located in a valley or in a heavily populated flat area will be limited to communication over just a few miles from their home station. Many such amateurs would have no use for 56-mc. apparatus. Others, however, either have stations located on high points or are interested in the operation of a portable station on some hill top. To these amateurs, the band is of great value and interest.

As a guide to the approximate distance which can be covered reliably on 56 mc. we will cite a simple formula which is used to obtain the visibility over flat country for various heights above the surrounding terrain. It will not be generally applicable in amateur work because of the difficulty of allowing for the interference of smaller hills, but it will serve to give an approximate idea of the ranges to be expected. The formula is:

$$D = 1.32\sqrt{x}$$

D is the distance in miles; x is the height, in feet, of the observer above the surrounding country. Should we wish to find the visible range between two elevated points, we make a separate calculation for each point and add the result. Reliable 56-mc. communication often can be obtained over ranges slightly greater than this visible range. It is not usually to be expected, however.

One important feature of 56-mc. work is that very low power is satisfactory in the transmitter. If the two stations are within working range, extremely low power suffices to give a strong signal. An increase of power at the transmitter gives stronger signal in such cases, but it is not effective in extending the working range to any appreciable extent. Because of these facts, the usual amateur 56-mc. apparatus is low-powered and extremely simple. Powerful and complicated equipment could be used, but its cost would hardly be justified by the improvement in performance.

Suitable Apparatus

The usual type of transmitting equipment used on the lower frequency bands can be made to function on 56 mc. With anything other than a crystal-controlled transmitter, however, it is extremely difficult to obtain even fairly good frequency stability. Crystal control, of course, presents a great many problems. With the usual 3500- or 7000-kc. crystal, a whole row of doubler stages is necessary to reach 56,000 kc. The only alternative at present is to use a special tourmaline crystal — which can be ground to operate on 28 or 56 mc. Unfortunately, such crystals are very expensive. Self-controlled oscillator-amplifier transmitters are satisfactory for the work, and probably will see wide use in the near future. It is usually necessary, though, to operate the oscillator with the same order of input as the amplifier in order to obtain sufficient excitation.

This is no particular disadvantage in a transmitter operated at a fixed location but it is a severe handicap for the portable station.

Receivers of the usual type, when fitted with suitable coils, will often operate on 56 mc. Their lack of frequency stability and their "trickiness" in general do not allow satisfactory autodyne reception of even the crystal-controlled transmissions. Autodyne reception of signals from a self-controlled transmitter is almost completely impractical with present equipment.

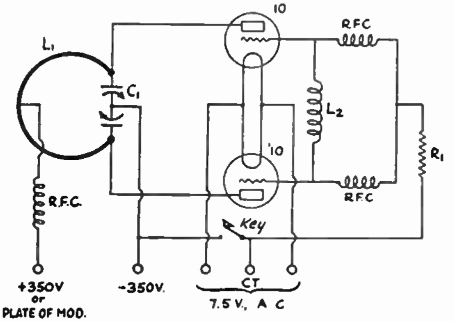


FIG. 91 — A 56-MC. OSCILLATOR CIRCUIT

L_1 — Single turn of ¼-inch copper tubing, 4 inches in diameter, mounted on stator terminals of tank condenser.

L_2 — 4 turns No. 14 enameled antenna wire, 1" in diameter, and about 2" in length. Turns are squeezed together or separated until set oscillates with minimum plate current at the desired frequency of operation.

C_1 — National split-stator condenser, Type TMP-100. Net maximum capacity (sections in series) 100 μμfd.

RFC — 18 turns of No. 24 d.c.c. on ½-inch wooden dowel, 1/16-inch spacing between turns.

R_1 — 10,000-ohm non-inductive grid-leak, 5-watt size or larger.

All these factors have resulted in the adoption of a special technique for 56-mc. work. At present, modulated signals are used exclusively in transmission, the transmitter itself being a simple self-controlled self-excited unit or a self-controlled oscillator-amplifier. For reception, the super-regenerative receiver has been almost universally adopted. This type of receiver operates particularly well on the very high frequencies, is extremely sensitive to modulated signals and has the broad admittance characteristic necessary for the reception of a signal which suffers severe frequency instability. Modulated self-controlled self-excited transmitters would be quite intolerable on the lower frequency bands because of the frequency modulation and the resulting interference with other stations. They are permitted on the 56-mc. band at present because there is no indication that the interference problem will become a serious one in the immediate future.

Transmitters for 56 mc.

The circuit of an oscillator suitable for use at a fixed station is shown in Fig. 91. The resemblance to the circuit given in Fig. 712 of Chapter Seven is very obvious. Built into a "breadboard" lay-out, it will resemble the transmitter shown in Fig. 92. The tuning and general adjustment of this unit will be carried out in the manner suggested for the lower frequencies with the difference that it will be impractical to make use of a monitor for checking the signal emitted. This, however, is not a matter of much consequence since good frequency stability is not essential.

Finding the Band

If the transmitter is built according to the specifications and tuned to resonance with an antenna which has been carefully cut to the correct length, there is little danger that the transmitter frequency will not lie in the immediate vicinity of the amateur band. It is very desirable, however, to take further precautions to insure that the frequency is what it should be. This is one way to check the frequency:

Put the receiver on the 14-mc. band and tune it to a frequency between 14,000 and 15,000 kc. by beating the detector oscillation against the proper harmonic of your frequency meter. The detector should be oscillating vigorously. Now start up the 56-mc. oscillator and tune the tank circuit carefully, starting from maximum capacity and going up in frequency. Do this slowly and listen for signs of a fairly loud signal in the 'phones or speaker, disregarding any weaker ones. When you find it, tune the oscillator "right on the nose" and make a record of the dial setting. This should be near the maximum capacity setting of the tank condenser (for a duplicate of the set illustrated). Of course it is possible that the oscillator frequency might be some harmonic other than the fourth of the oscillating detector, or that a harmonic of the oscillator might be beating with a harmonic of the receiver. The first possibility might be probable but the second is very remote providing the oscillator setting chosen was that

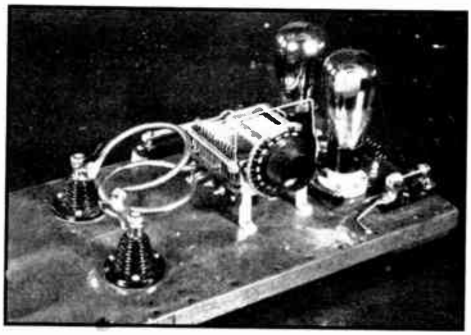


FIG. 92 — A TYPICAL 56-MC. OSCILLATOR SUITABLE FOR OPERATION AT A FIXED STATION

The various components can be located by reference to the circuit of Fig. 91. The antenna coil is a half turn mounted over the plate coil.

for the loudest signal. The harmonics of the transmitter will be so weak in comparison to the fundamental that there is little danger of making this mistake.

Operating the Set

A suitable modulator for a transmitter of this type is that shown in Fig. 815 of Chapter Eight. Alternatively, the unit shown in Fig. 810 of that chapter could be used.

The antenna to be used will be planned and arranged exactly in the manner specified in Chapter Twelve for the lower frequencies. Since a half-wave antenna for this band is so small, it is common practice to construct it of copper tubing or a metal fishing rod instead of wire. Such antennas are ideal for outdoor operation. When the transmitter is operated at home, it is as well to use the antenna ordinarily operated on the lower frequencies. The added height provided by it will be of considerable help in most cases. The antenna will be operated at one of its very high harmonics, of course, and careful adjustment will be necessary. When a half or whole wave antenna is employed, it is usually found that the best performance is obtained with the antenna vertical.

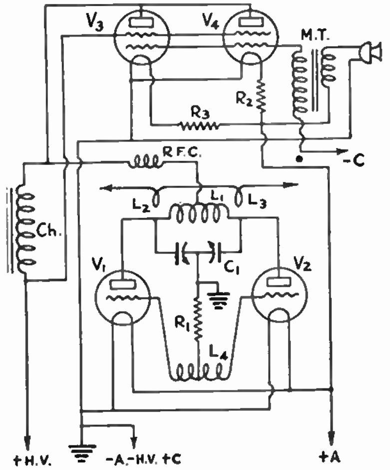


FIG. 93 — THE CIRCUIT OF THE PORTABLE TRANSMITTER ILLUSTRATED IN FIG. 94

C_1 — Type 406B 25-plate Cardwell receiving condenser with stator split and plates removed to give 5 stator and 4 rotor plates in each section.
R_1 — 50,000-ohm Electrad wire-wound resistor.
R_2 R_3 — 2-ohm fixed filament resistors for Type 47 modulators; 12-ohm resistors for Type 33 modulators.
L_1 — 5 turns 1 inch inside diameter of 1/8-inch diameter copper tubing or wire.
L_2 L_3 — One turn each 3/4-inch diameter of similar conductor.
L_4 — 7 turns spaced 1/8 inch of 22 d.s.c. wire on 1/2-inch bakelite tube. Adjustment of turns and spacing may be necessary.
R.F.C. — 35 turns of 30 gauge d.s.c. wire on former 5/16-inch diameter. Turns spaced approximately twice diameter of wire.
M.T. — Microphone transformer made from old audio transformer with primary removed. New primary of 300 turns of 30-gauge d.s.c. wire.
CH. — Choke rated at 150 ma., 10 to 30 henrys.
V_1 to V_4 — See text.

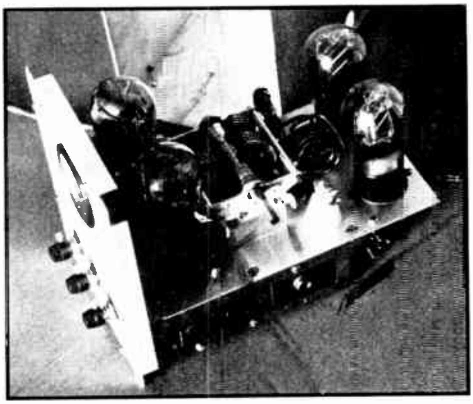


FIG. 94 — THE PORTABLE TRANSMITTER WITH THE OUTSIDE CASE REMOVED

In operation the unit is enclosed in an aluminum box, holes being provided for access to the tuning condenser and the feeder terminals.

Portable Transmitters

A somewhat similar circuit, rearranged for use in a portable transmitter is that shown in Fig. 93. In this instance, a pair of pentode tubes serve as the modulator and are built into the same unit as the oscillator. Fig. 94 shows one example of the way in which the apparatus of this circuit may be assembled. For portable operation, Type 01-A tubes could be used for the oscillators and Type 33 tubes for the modulator. A plate voltage between 135 and 200 volts would then be suitable. For operation at a "home" station or in other cases where higher voltage is available, Type 71-A and Type 47 tubes could be used with a plate voltage between 200 and 300. In the illustration it will be seen that the two tubes of the oscillator are immediately behind the panel and mounted in ordinary tube sockets. Behind them is the split-stator condenser made up from a Type 406B Cardwell. As modified, it has five stator plates and four rotor plates in each section. It is so mounted in aluminum angles that the shaft runs laterally. A slot in the end of the shaft and a hole in the "can" allow the condenser to be set with a screwdriver. Behind the condenser and mounted directly on its terminals with lugs is the tank inductance. The feeders or antenna are coupled to it inductively with the aid of a split two-turn coil mounted on insulators. The particular insulators used were of Isolantite. G. R. sockets, through brass angles mounted on these insulators, serve as receptacles for plugs on the feeder or antenna leads. Two three-quarter-inch holes in the "can" allow for their passage. Because of their height and the limited space, the modulator tubes fit in sub-panel sockets of the type used on broadcast receivers. The radio frequency choke is mounted under the tank condenser — above the base. The only remaining apparatus on top of the base is the fixed-tune grid coil. It is wound on a piece of ½-inch bakelite tubing supported with machine screws.

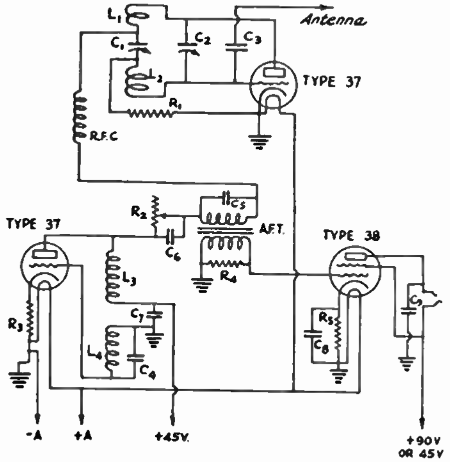


FIG. 95 — THE CIRCUIT OF THE SUPER-REGENERATIVE RECEIVER ILLUSTRATED IN FIG. 96

The tubes are indicated in the same relative position as they are mounted in the set.

C_1 — 105 µµfd. Cardwell Type 404B variable condenser.
C_2 — 15 µµfd. Cardwell "Balancet" midget condenser.
C_3 — Antenna coupling condenser — see text.
C_4 — .0025 µfd. fixed condenser.
C_5 — .004 µfd. fixed condenser.
C_6, C_8 — 1 µfd. fixed condenser.
C_7 — .1 µfd. fixed condenser.
C_9 — .001 µfd. fixed condenser.
R_1 — 2 megohm gridleak.
R_2 — 50,000 ohm Frost No. 2890 variable resistor.
R_3, R_5 — 2,000 ohm carbon type fixed resistors.
R_4 — 150,000 ohm carbon type resistor (or gridleak type).
L_1, L_2 — Each seven turns of 16 gauge wire ⅜ in. inside diameter with turns spaced the diameter of wire.
L_3, L_4 — 1400 and 900 turns, respectively, of No. 34 silk-covered wire wound on a ⅜″ dowel between cardboard disks spaced ¼″.

"Grounds" indicated on the diagram represent connections to the metal chassis of the set.

On the underside of the base there are located the supply cable connector plate the microphone transformer (between the two modulator sockets) the speech choke and the grid leak. The three control switches serve to open or close the filament, microphone and plate circuits. The remainder of the panel, as can be seen in other photographs, is devoted exclusively to the small 0- to 200-ma. meter which reads the total plate current of the four tubes.

Receivers for 56-mc. Work

It is considered at the present time that there are only two types of receivers suitable for operation on 56 mc. They are the super-regenerative and super-heterodyne sets. Though probably more effective than the super-regenerative receiver, the super-heterodyne has not yet found any degree of popularity. The probable reason is that its complexity and cost appear to be out of all proportion with its performance. The super-regenerative type is simple, inexpensive, sensitive and completely reliable. Its use at the moment is almost universal.

Since super-regeneration plays such an important part in this work, it might be well to outline its principle of operation. We all know that the sensitivity of a regenerative receiver increases very rapidly as the point of oscillation is approached, but that the point of oscillation constitutes the limit to which this amplification may be carried in the usual receiver. In the super-regenerative system the application of an auxiliary super-audible frequency voltage on the grid or plate of the regenerative tube allows relatively terrific regeneration without the paralyzing self-oscillation which would ordinarily occur. In the particular version of the system to be described, the regenerative detector is

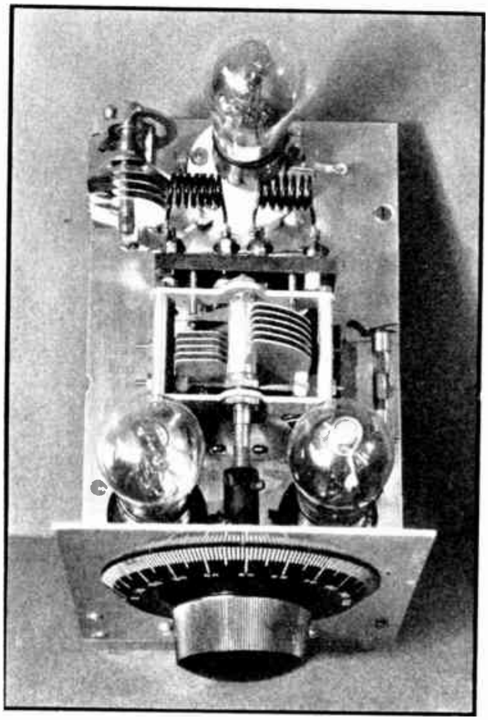


FIG. 96 — A TYPICAL SUPER-REGENERATIVE RECEIVER

As in the construction of the portable transmitter, sheet aluminum is used throughout. The receiver, in operation, fits in an aluminum box. Should the amateur so desire, he may build this type of receiver on a baseboard or in any other orthodox manner. The aluminum chassis and box play no important part in the performance of the equipment.

"plate modulated" by the long-wave oscillator and the detector plate voltage is therefore swinging back and forth at the frequency of that oscillator. On the positive peaks the voltage is of an order which would ordinarily make the detector oscillate violently. Such oscillation has no time to develop, however, before the plate voltage swings down on the next half-cycle of the auxiliary oscillator. Strictly speaking, an oscillation may develop during the positive half cycles but its amplitude is of such a low order as to be of little consequence. Operated in this condition, a regenerative detector may provide amplification many million times greater than that of the simple regenerative detector operated just below oscillation.

Figs. 95 and 96 illustrate a receiver employing these principles. The upper tube is the detector. Its own circuit is a series-tuned series-feed Hartley. L_1 and L_2, the two sections of the inductance, each have 7 turns ⅜" inside diameter.

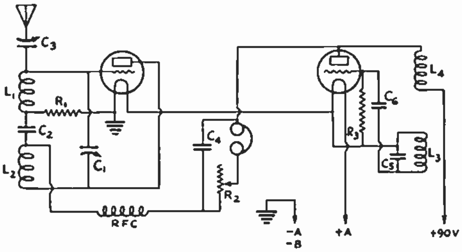


FIG. 97 — THE WIRING OF THE TWO-TUBE 56-MC. RECEIVER

C_1 — 20-μμfd. three-plate Hammarlund midget variable.
C_2 — 150-μμfd. fixed condenser.
C_3 — Trimmer condenser (mica dielectric) set near zero.
C_4 — .001-μfd. fixed condenser.
C_5 — .002-μfd. fixed condenser.
C_6 — .0005-μfd. fixed condenser.
R_1 — 1-megohm fixed resistor.
R_2 — 50,000-ohm variable resistor.
R_3 — 50,000-ohm fixed resistor.
RFC — 30 turns of No. 26 wire on ¼" rod.
L_1, L_2 — Each three turns of No. 16 enamelled antenna wire ½" inside diameter.
L_3, L_4 — 1400 and 900 turns, respectively, of No. 34 silk-covered wire wound on a ⅜" dowel between cardboard disks spaced ¼"

The tubes are Type 30 with a 4-volt "C" battery serving as filament supply.

An insulating coupling between the dial and tuning condenser is essential if "hand-capacity" effects are to be avoided.

The main tuning condenser C_1 is of 105 μμfd. maximum capacity. R_1 is the grid-leak used to complete the grid circuit and to maintain the grid at a satisfactory operating voltage. In the plate circuit of this tube we have the usual radio frequency choke, the primary of the audio transformer (with a large by-pass condenser) and the regeneration control resistor R_2. This, of course, is by-passed, the condenser being large enough to keep the resistor quiet in operation.

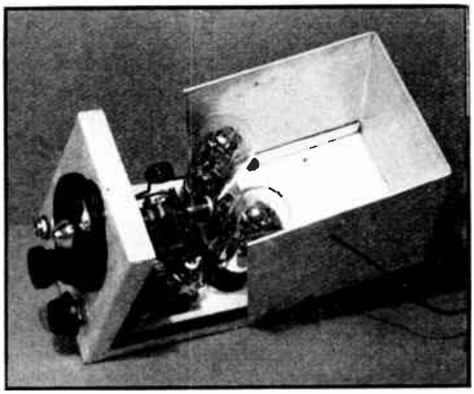


FIG. 98 — WITH THE COVER OPEN: A VIEW INSIDE THE TWO-TUBE SET

The low-frequency auxiliary oscillator comprises the tube at the left of the diagram, the inductances L_3, L_4, and the associated condensers. Examination of the wiring will show that this oscillator unit is connected to the detector unit in just the same way as a modulator would be connected to a modulated amplifier for plate modulation — L_3 being the equivalent of the speech choke.

The circuit of the pentode audio amplifier tube is quite conventional. Bias is obtained, as in the oscillator, with a resistor in the plate return to the cathode. A resistor R_4 across the secondary of the audio transformer serves to eliminate any tendency towards "fringe howl."

To allow a precise placement of the band on the main tuning dial C_2 is a convenience. It is, of course, so mounted as to be insulated from the metal base. C_3 is the usual antenna coupling condenser. It consists of two aluminum plates ⅜ in. by ½ in. spaced about $\frac{1}{16}$ in. and fitted to the grid terminal of the detector tube socket.

When a receiver of this type is operating correctly, there will be a continuous and quite loud rushing noise when signals are not being received. This noise will disappear just as soon as a carrier is tuned in. Almost any type of antenna will serve for reception. Generally speaking, however, it should be as high as possible.

A Two-Tube Receiver

Figs. 97 and 98 show a somewhat similar receiver built in very compact form without the audio amplifier. Its two tubes and associated apparatus fit comfortably in an aluminum box measuring 5 by 5 by 4 inches. The outer shell is made in two sections, the rear one swinging back to allow ready access to the set's insides. Most of the components are mounted on a shelf supported 1¼ inches above the bottom of the shell. The exact location of the parts is not of much consequence except in the r.f. portion of the circuit, kept above the shelf. The tuning condenser is poised rigidly on a bakelite strip

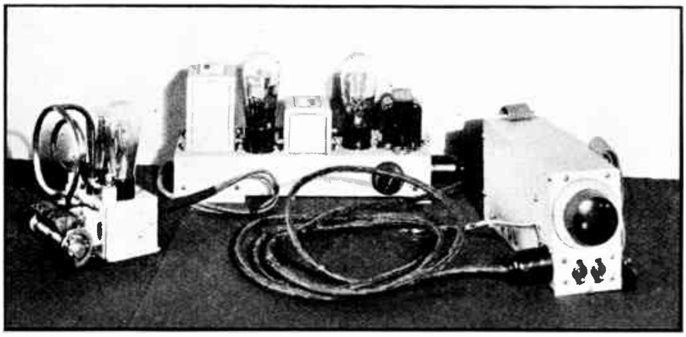


FIG. 99. — A COMPLETE 56-MC. STATION ARRANGED IN THREE UNITS

At the left is the oscillator arranged so that it may be mounted in a clear space, possibly many feet from the remaining apparatus. The Class-B modulator is at the rear, the receiver on the right. Two switches on the receiver serve to control the receiver filaments and the combined filaments of the oscillator and modulator. The station may therefore be controlled from the receiving position.

about ¾ inch above the shelf and the inductances are attached directly to the condenser frame and stator. No plug is provided for the battery cable. Instead, the cable leads run directly to the various points of contact within the set.

An Advanced 56-mc. Station

The amateur who takes up 56-mc. work seriously is certain to become interested in experimental work from various hill-top locations, from automobiles and possibly from airplanes. The equipment already described is suitable for this work but in some cases it may be found too bulky, too heavy or insufficiently economical of battery power. The equipment illustrated in Fig. 99 was designed with the idea of getting the highest possible output with low battery consumption. It was also planned so that it might be installed with similar convenience in an automobile, an airplane or at a "home" location.

In studying the general layout it will be well first to examine the outline circuit given in Fig. 910. It will be seen that all metal work is inter-connected and serves as the negative filament, negative plate and positive bias connection. The positive filament lead runs through to the two switches mounted on the receiver, one of which controls the receiver, the other the transmitter tubes and microphone. To allow operation in the field or in a 'plane, a 6-volt "Hot-Shot" is used as filament supply. Hence, Type 30, 49 and 31 tubes are used. The three 30's in the receiver and the three 49's in the modulator are grouped in series to run off the six volts. The two 31's of the oscillator are also in series, with an external resistor to give the necessary two-volt drop.

From Fig. 911 it will be seen that the oscillator is of the "unity-coupled" type described in Chapter Seven. The main tank is a single turn of ¼-inch copper tubing, the ends of which are connected directly to the tube plates and to the stators of the tuning condenser. Plate voltage is fed to the center of this coil on the piece of tubing seen between the two tubes in Fig. 912. At its lower end, this tube leads through a bakelite bushing in the aluminum base. The grid coil, of rubber-covered flexible wire, is threaded through the tank coil and the plate supply tube. Its outside ends cross over and go directly to the tube grids. Its inside ends join as they emerge inside the aluminum base and connect to one end of the grid-leak. This leak, the radio frequency choke and the by-pass condenser C_2 are located inside the base.

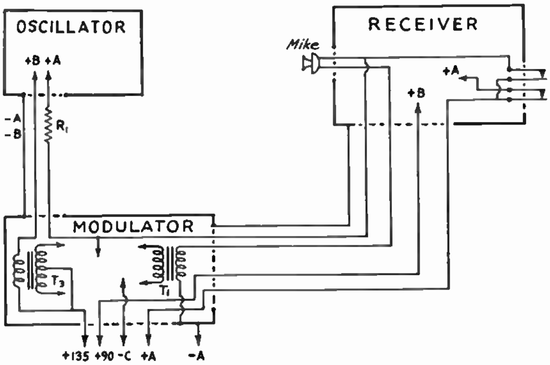


FIG. 910. — AN OUTLINE CIRCUIT SHOWING THE CABLED CONNECTIONS BETWEEN THE THREE UNITS OF THE STATION

The modulator unit is shown in Figs. 913 and

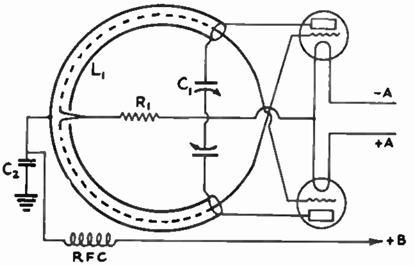


FIG. 911. — THE OSCILLATOR CIRCUIT

L_1 — One turn of ¼" copper tubing 3⅜" inside diameter.

C_1 — Hammarlund Type MCD-35-X variable condenser (33 μμfd. per section).

C_2 — .0001-μfd. fixed condenser.

R_1 — 100,000-ohm 1-watt fixed resistor.

RFC — About 20 well-spaced turns of No. 26 wire on ¼" dowel. The antenna coil, visible in photograph, is 2¼" inside diameter.

914. In design, it follows the principles covered in Chapter Eight and needs no detailed description. The two 49 modulators are connected for Class B operation. In this case, the "G" and "C" terminals are connected together and the tubes are operated without bias. With only the 135 volts of plate supply and about 8-ma. drain when idling, the modulator is capable of an undistorted output of 3.5 watts. Other simpler modulators could be arranged (such as a pair of Class A Type 33's). They could not be expected to give a comparable performance, however, and they would certainly be much more wasteful of plate current.

The receiver is obviously the most complex portion of the outfit though it is very similar to those already described.

The chassis is folded 1/16-inch aluminum. The rear portion is just an inch deep, but the section three inches back from the front panel is formed to provide a step two inches high. Supported on this step is a piece of 1/8-inch bakelite carrying the tuning condenser and coils. The space under the step is occupied by the audio transformer, supply cable plate and control switches. The radio-frequency choke is also tucked away in this particular spot. The three sub-base tube sockets, the interruption frequency oscillator inductances and a couple of fixed condensers slip in the remaining spaces under the chassis. Along one side is mounted a strip of bakelite containing four pin jacks. Holes in the aluminum, large enough to give good clearance of the jack heads, allow the insertion of headphones and microphone.

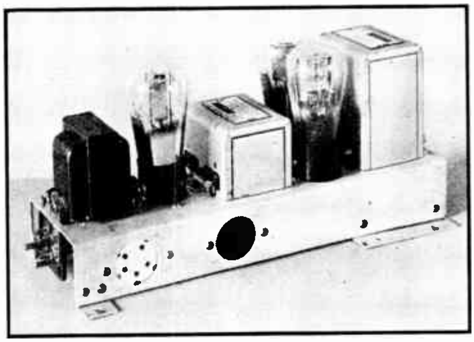


FIG. 913 — THE MODULATOR UNIT

The various transformers and tubes are mounted on a folded aluminum channel 12 inches long, 3½ inches wide and 1¾ inches deep.

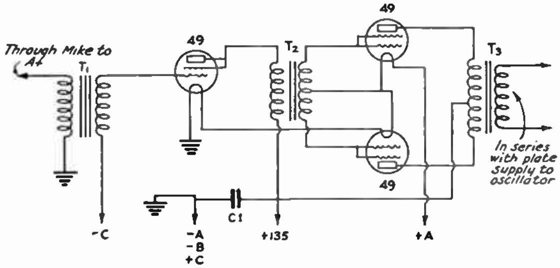


FIG. 914 — THE CIRCUIT OF THE MODULATOR UNIT

T_1 — Thordarson Type 2857 microphone transformer.

T_1, T_3 — Any small Class B transformers designed to operate with Type 49 tubes and to work into a 5000-ohm load.

C_1 — 1-μfd. fixed condenser.

The tubes are Eveready Type 49. A 22½-volt unit provides bias for the input tube.

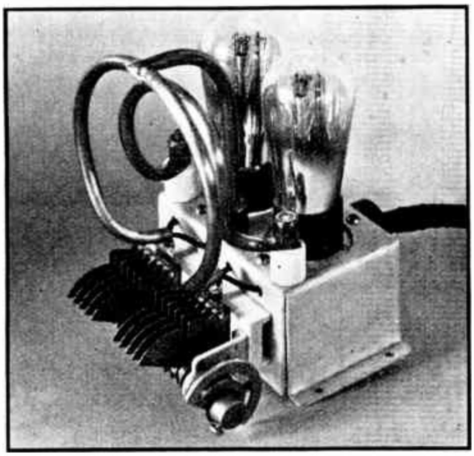


FIG. 912 — THE OSCILLATOR UNIT

The folded aluminum base on which the apparatus is mounted measures 2½ by 3½ inches on top and is 2 inches deep. The tank coil is soldered directly to the connecting lugs of the variable condenser stators. The antenna coil, seen behind the plate coil, is mounted on two small isolantite insulators.

Operating the Station

Upon tuning the oscillator to a suitable antenna, its plate current should rise from the normal value of about 8 or 10 ma. to about 28 or 30. The normal plate consumption of the speech amplifier-modulator unit, when idling, should be about 8 or 9 ma. The meter needle will hit peaks of about 50 ma. when the modulators are fully excited and working into the loaded oscillator. With normal speech, the modulator unit will handle the full output of an ordinary single button microphone. For 'plane work (when the operator is usually shouting close to the microphone) it will be necessary to reduce the gain (by putting a potentiometer in the grid circuit of the speech amplifier) unless some form of low output mike is used.

The receiver should present no problems of adjustment other than spacing of the coil turns to give the desired band coverage.

The antenna problem is one that will have a different solution in every location.

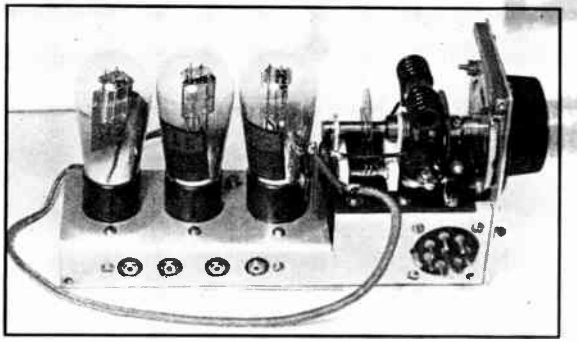


FIG. 915 — THE RECEIVER AND CONTROL UNIT

The tubes, left to right, are audio amplifier, interruption frequency oscillator and detector. Pin jacks for 'phones and microphone can be seen along the edge of the chassis. The box enclosing this unit measures 2⅝ x 4½ x 8½ inches. A larger box is suggested, however, because of the difficulty of finding sufficient room for the components — particularly the audio transformer.

For automobile or 'plane work, it is often convenient to use a half-wave vertical copper rod for the antenna, feeding it with quarter-wave tuned feeder. An alternative in these cases is to use a quarter-wave rod antenna operated against the frame of the automobile or 'plane. In this case, the antenna-ground system can be conveniently fed with a half-wave tuned feeder. Suitable feeders for the work may be made of ordinary twin lighting flex, untwisted and threaded through wooden spacers about 2 inches long.

Experiment Necessary

In describing these odd pieces of representative 56-mc. equipment, the idea has been to sketch the requirements for effective working. None of the apparatus can be considered as the ultimate. Ultra-high frequency work is a relatively new field and it seems certain that many present ideas will be drastically revised in the early future. It is possible that the super-heterodyne will displace the super-regenerator and that oscillator-amplifier transmitters will become essential. Time will tell. It is certain that because the 56-mc. band has not been explored in the same thorough manner as the lower frequency bands have been, it is a field of particular interest to the experimentally inclined amateur. We make a special plea for careful observation of all phenomena experienced in working on the band and would ask that amateurs experiencing unusual effects or obtaining ranges greatly in excess of the visible range should immediately report their results to League Headquarters.

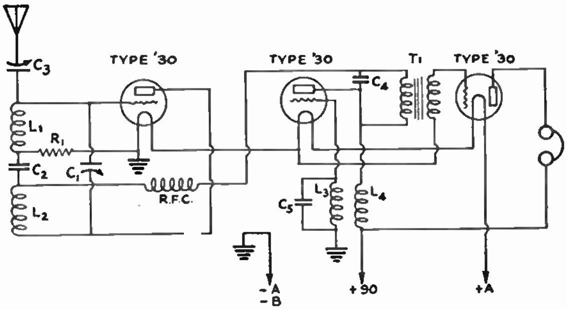


FIG. 916 — HOW THE RECEIVER IS WIRED

C_1 — Hammarlund Type MC-20-S three-plate midget condenser.
C_2 — .0001-μfd. midget fixed condenser.
C_3 — Two ½-inch square brass pieces about 1/16 inch apart.
C_4, C_5 — .002-μfd. midget fixed condensers.
L_1, L_2, — Each four turns of No. 14 wire ½-inch diameter.
L_3, L_4 — Sickles interruption oscillator coil unit. Should this not be available, the coils may be wound with 1400 and 900 turns, respectively, of No. 34 silk covered wire wound on a ⅜" dowel with cardboard disks spaced ¼" between the windings.
R_1 — 1 megohm fixed resistor.

Chapter Ten

POWER SUPPLY

THE transmitters described in the previous chapters are not complete and cannot operate until they are provided with a power supply. This power supply, though involving only simple apparatus in most cases, is always of the greatest importance. Care expended in its installation and adjustment will be well rewarded by improvement in the signal and in the over-all effectiveness of the transmitter.

The power supply system of any tube transmitter consists of two units — the supply for the tube filaments and the supply for the plate circuits. It is to the latter that we shall give first consideration.

The Plate Supply

If the transmitting tube is to function steadily and produce a pure musical signal at the receiving end, the plate supply must be steady direct current. This is of great importance. Rapid fluctuations in the plate supply voltage cause similarly rapid fluctuations in the antenna power. This, in turn, results in the production of modulation and added interference. Much more serious, however, is the fact that in the self-excited oscillator such voltage fluctuations cause not only power fluctuations but frequency fluctuations or frequency "flutter." The extent of this "flutter" can be reduced greatly by the use of a high value of capacity across the tank coils in the transmitter and by careful tuning adjustment (as described in Chapter Seven) but, with the possible exception of the crystal-control transmitter, the "flutter," the "mushy" note and the interference which accompanies it can never be completely avoided *unless the plate supply is pure d.c.*

DANGER—HIGH VOLTAGE!

It must be realized that the plate supply equipment of even a low-powered transmitter is a potential lethal machine. It is ever ready to deal out sudden death to the careless operator. A number of amateurs, indeed, have been killed by the output of their power supplies during the last few years. Many more have suffered severe injury. We cannot urge too strongly the observance of extreme care in the handling of power supplies and transmitters.

Another defect to be avoided in the plate supply is poor regulation (to be discussed in detail later) which results in the plate voltage changing with every change in load on the plate-supply system. Trouble of this sort gives rise to a sudden frequency change — a "chirp" — whenever the load is changed. It is when the transmitter is keyed that this effect becomes so apparent.

Frequency flutter is so undesirable and productive of so much unnecessary interference that the use of plate supplies which do not produce unmodulated direct current is definitely prohibited by the U. S. government regulations unless the transmitter is one in which flutter cannot occur. In practice this means that the supply must be pure d.c. on any form of oscillator, and that a.c. or rectified and partially filtered a.c. can be used only on the amplifier stages of a transmitter which is crystal-controlled or excited by a very stable self-controlled oscillator followed by a buffer amplifier, both of which must be supplied with pure d.c. Careful attention therefore must be paid to the power supply system or the transmitter cannot be operated legally.

Regulation

When we speak of the voltage regulation of a transformer, generator, rectifier, filter, or rectifier-filter combination we mean the variation in the voltage the device delivers with the "load" that it handles.

Suppose a rectifier-filter system delivers 350 volts, 45 ma., to a Type 10 oscillator with the key closed. We open the key and the voltage at the output terminals of the filter rises to 500 volts. The regulation from full load (key closed) to no load (key open) is the difference, or 150 volts. This regulation is often expressed as a percentage. Voltage regulation is the ratio of the difference between full-load and no-load voltage to the rated-load voltage.

In this case it is:

$$\frac{500-350}{350}=\frac{150}{350}=.428=42.8\%\ \text{regulation (rather poor)}$$

The tube load is not necessarily *full* load for this rectifier. If we design our rectifier-filter to give an output of 350 volts, 100 ma. (35 watts), and happen to be using it under-loaded we have 42.8% as a value of regulation for about half-load. A regulation curve for the outfit can be plotted showing what the percentage regulation or volts delivered will be for different loads.

The regulation of a battery depends on the internal resistance of the cells of which it is made up. This in turn depends on the depolarizer used and increases with the age of dry cells. The internal resistance of storage cells is very low and the regulation correspondingly good (small).

The voltage regulation with various types of rectifiers and filters will be considered farther along.

Dry Cells as Plate Supply

Dry-cell "B" batteries usually can be obtained in 22½- or 45-volt units for plate supply work.

The 22½-volt batteries (4" x 4¼" x 8" size) usually have about 570 milliampere-hours capacity when discharged intermittently at rates not in excess of 30 milliamperes. 200 hours of operating use can be expected when using such batteries with a small transmitter taking not more than 30 ma. At lower discharge rates even longer life can be expected. Of course the quality of the battery will have a great deal to do with this life. These figures are merely representative of some of the batteries available from reputable manufacturers.

Battery capacity will be reduced if batteries are kept in too dry a place, especially if they are not well sealed, because the electrolyte will dry out. In damp climates there is apt to be leakage between the cells of high-voltage batteries if precautions are not taken. In cold climates batteries keep very well but may show a temporary loss of voltage as the activity of the chemicals is decreased by coldness. In this case the voltage will rise as current is drawn from the batteries because of the heat generated internally.

The life of the battery will depend on its capacity. The "heavy-duty" type will give much better service than the smaller sizes, although the first cost is of course higher. Since they are designed for comparatively high discharge rates, however, there is probably more service per dollar in the heavy-duty batteries than in the standard sizes. For maximum service the batteries purchased should always be those of a reputable manufacturer.

Dry-cell batteries are not suited for use with larger sets than those using one Type 10 tube. The economy is rather poor beyond a 50 milliampere discharge rate.

Storage Cells

Storage cells are expensive and many of them are necessary for high-voltage power. Either Edison (alkaline) batteries or lead (acid) cells can be used. Equipment must be provided for charging them. Distilled water has to be added to replace that lost by evaporation. In cold climates they must be kept fully charged to prevent freezing of the electrolyte. After a few years the storage cells must be rebuilt or replaced and so the up-keep is also quite high.

"B"-Battery Substitutes

"B" substitutes are made to be used with receiving sets, but they enter the picture here because they can be used also with low-powered transmitters.

These battery "eliminators" are designed to connect to the 110-volt alternating current circuit. There are many types on the market, all containing a step-up transformer, rectifier, and filter. They differ from one another principally in the type of rectifier used and the means for determining and regulating the output voltages.

A few of the "B" substitutes give a good direct-current output at between three and four hundred volts with fairly good regulation. One of these on a small transmitter will give excellent results.

Motor-Generators and Dynamotors

A direct-current motor-generator is an excellent source of plate power for any transmitter. The rated output of the generator (watts) is equal to the product of the plate voltage (volts) and plate current (amperes). The terminal voltage should match the rated plate voltage of the transmitting tubes. It is convenient but not necessary to have a rheostat in the field of the generator to regulate the terminal voltage. The regulation of most of the motor-generators on the market is good. By using a series field winding or "compounding" a machine, an increase in load current makes the field in which the armature rotates stronger, which compensates for the several factors causing a drop in voltage. A machine having the same full-load and no-load voltages is known as "flat" compounded. If the full-load voltage is greater than the no-load voltage, the machine is "over-compounded." A motor-generator set is the simplest plate supply source but it is also probably the most expensive.

The motor that drives the generator can be direct-connected or belted. In any case it should drive the generator at about its rated speed. It should be rated at about 1¼ to 1½ times the generator capacity since it has to take care of its own and the generator's losses.

An a.c. supply with a filter is usually cheaper than the motor-generator set. However, a motor-generator of the right size will save the expense of big filters for the rectifier. A small filter to take out the commutator ripple is all that is necessary. The motor-generator set is mechanically noisy, which makes it unsuited to some jobs. However, it is usually very convenient if one has the ready money to spend on power-supply equipment.

A dynamotor is simply a double-armature machine with a common shunt field, running on one winding as a motor usually driven from a six- or twelve-volt storage battery. The high-voltage winding delivers several hundred volts to the plates of the transmitting tubes. With respect to ripple it is much the same as the generator but its voltage regulation is generally poorer.

The Rectifier-Filter Systems

Assuming that alternating-current power is available at 110 or 220 volts, a very effective high-voltage supply system can be built up from a high-voltage transformer, a rectifier system and a filter. The details of the transformer and the filter are to be given complete treatment later in the chapter and for the moment we will limit the discussion to the rectifier.

An understanding of how a rectifier functions may be obtained by studying Fig. 101. At (1) is a typical a.c. wave, in which the polarity of the current and voltage goes through a complete reversal once each cycle. The object of rectification is to transform this wave into one in which the polarity is always the same, although the *amplitude* of the current and voltage may vary continually. At (2) we have the secondary of a power transformer connected to a single rectifier element, represented by the arrow and dash enclosed in the circle. The rectifier is assumed to be "perfect," that is, current can only flow through it in one direction, from the arrow to the plate. Its resistance to flow of current in that direction is zero, but for current of opposite polarity its resistance is infinite. Then during the period while the upper end of the transformer winding is positive, corresponding to A in (1), current can flow to the load unimpeded. When the current reverses, however, as at (1) B, it cannot pass through the rectifier, and consequently nothing flows to the load. The drawing shows how the output from the transformer and rectifier looks. Only one-half of each cycle is useful in furnishing power to the load, so this arrangement is known as a "half-wave" rectifier system.

In order to utilize the remaining half of the wave, two schemes have been devised. At (3) is shown the "full-wave center-tap" rectifier, so called because the transformer secondary winding must consist of two equal parts with a connection brought out from the center. In (3), when the upper end of the winding is positive, current can flow through rectifier No. 1 to the load; this current cannot pass through rectifier No. 2 because its resistance is infinite to current coming from that direction. The circuit is completed through the transformer center-tap. At the same time the lower end of the winding is negative and no current can flow through rectifier No. 2. When the current reverses, however, the upper end of the winding is negative and no current can flow through rectifier No. 1, while the lower end is positive and therefore rectifier No. 2 passes current to the load, the return connection again being the center-tap. The resulting wave shape is again shown at the right. All of the wave has been utilized, and the amount of power which can be realized at the load is doubled. In order to maintain the same output voltage (instantaneous, not average) as at (2), however, each half of the transformer secondary must be wound for the same voltage as that furnished by the whole winding in (2); or, conversely, the total transformer voltage with the connections shown in (3) must be twice the desired output voltage.

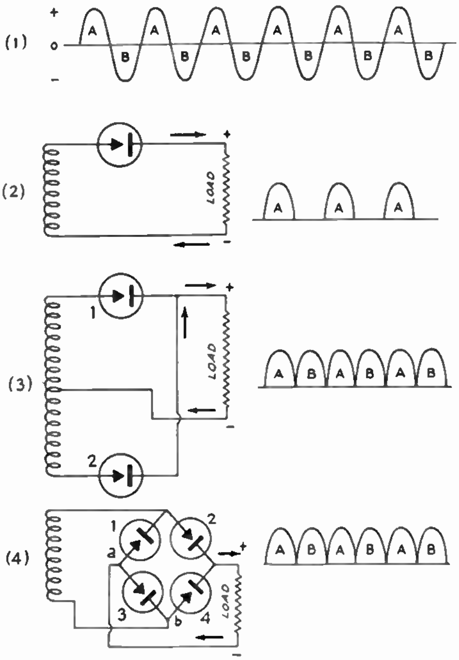


FIG. 101.—FUNDAMENTAL RECTIFIER CIRCUITS

At (1) is the conventional representation of the a.c. wave; (2) shows a half-wave rectifier; at (3) is the full-wave center-tap system; and (4) is the "bridge" rectifier. The output wave form with each type of rectifier is shown at the right.

If the transformer has no center-tap, or if the total voltage it furnishes is the same as the desired output voltage, scheme (4), known as the "bridge" rectifier, may be used to obtain full-wave rectification. Its operation is as follows: When the upper end of the winding is positive, current can flow through No. 2 to the load, but not through No. 1. On the return circuit, current flows through No. 3 back to the lower end of the transformer winding. It might be thought that current would at point *a* flow through No. 1 in addition to No. 3, and at point *b* through No. 4 as well as back to the transformer secondary, since the current is flowing in the proper direction to pass through them at these points. This does not occur, however, because these points are at a lower positive potential than the other sides of No. 1 and 4; and since current can flow only from a point of higher to a point of lower potential, these rectifiers pass no current in this case. When the wave reverses and the lower end of the winding becomes positive, current flows through No. 4 to the load and returns through No. 1 to the upper side of the transformer. The output wave shape is shown at the right. Although this system does not require a center-tapped transformer, and the voltage of the winding need only be the same as that desired for the load, four rectifier elements are required, so that the center-tap may actually prove to be more economical, all things considered.

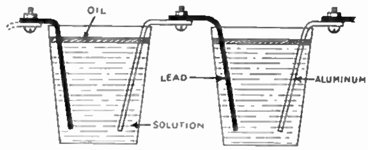


FIG. 102. — TYPICAL CHEMICAL RECTIFIER CELLS

Types of Rectifiers

The perfect rectifier would allow current to flow through it in one direction without loss of voltage and would have no leakage; that is, it would permit absolutely no current to flow through it in the opposite direction. The perfect rectifier has not yet been built and probably never will be, although some of the present-day rectifiers approach perfection, within their operating limits, in one or more respects. Several types of rectifiers are available, each having its own set of advantages and disadvantages. The most commonly used ones may be divided into five general classifications: electrolytic or chemical, thermionic, gaseous-conduction, hot-cathode mercury-vapor, and mercury-arc.

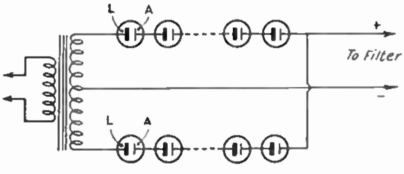
Chemical Rectifiers

Once the most popular of rectifiers for amateur transmitters, the chemical rectifier has now been almost entirely superseded by various types of tube rectifiers. Since tubes have become so reasonably priced, the chemical rectifier no longer has the advantage of cheapness. Its voltage drop and leakage are somewhat higher than with other types of rectifiers, but its output is not hard to filter. Chemical rectifiers are much more bulky than other types.

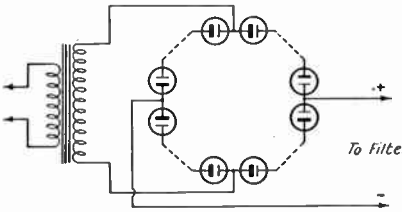
One type of chemical rectifier cell is shown in Fig. 102. A jelly glass or preserve jar holds the solution. The electrodes are usually lead and aluminum strips, their size being determined by the current which the rectifier must pass. A current density of 50 to 100 milliamperes per square inch of immersed aluminum surface should be used. For best results the electrodes and the components of the solution should be as nearly chemically pure as possible, and material of this sort is sometimes hard to obtain. Other disadvantages are that the rectifier must be formed initially, and reforming is necessary if it is allowed to remain idle for any length of time; water evaporates from the solution and must be replaced at more or less frequent intervals; and the solution sometimes creeps and makes a messy job. The connections for both the center-tap and bridge rectifier circuits are shown in Fig. 103.

In designing a chemical rectifier one must be sure to use sufficiently large jars to prevent undue heating of the solution. A dilute solution (½ oz. to a gallon of water) of sodium bicarbonate (baking soda) gives good results with low cost. The use of borax requires a saturated solution. A layer of transformer oil on top can be used to reduce evaporation. Lead and iron work well as auxiliary electrodes with a borax solution or with the dilute baking-soda solution.

The rectifying action of the lead-aluminum cell depends upon the formation of a rectifying film by electro-chemical action on the aluminum electrode when current is sent through the cell. Special care must be used in first forming an electrolytic rectifier, especially if the cells are formed in series across a high-voltage transformer. When the circuit is closed it is almost a dead short-circuit across the transformer secondary, and the current will be quite high until the film is partially formed. The unformed cells are not able to rectify effectively and so act as a short-circuit across the high voltage winding. If fuses do not blow, the transformer probably will burn up. A resistance or bank of lamps should be placed in



CENTER TAP RECTIFIER



BRIDGE RECTIFIER

FIG. 103. — CHEMICAL RECTIFIER CIRCUITS

One jar should be used for every 40 or 50 volts furnished by the transformer with solutions of borax or bicarbonate of soda. A transformer whose voltage is 550 each side of center-tap therefore requires about 24 jars, 12 on each side. With the bridge arrangement, two sets of jars are across the total transformer voltage, and although this voltage is cut in half for the same d.c. output voltage, the number of jars required remains the same, i.e., 24 jars will be necessary for a 550-volt transformer.

series with the primary of the plate transformer. Putting lamps in series limits the transformer load to one it can stand. As the rectifier begins to form, the series lamps get dimmer and larger lamps or more of them in parallel can be used until the rectifier will withstand the full voltage.

When a large filter is used there is a "back-voltage" or counter electromotive force from the charge left in the filter condensers which has an effect in the rectifier circuit as soon as the key is up. This voltage is applied to the rectifier at the same time the transformer is applying high voltage alternating current to it. This may make the voltage-per-jar too high so that some of the aluminum films break down, sparking and making a "noise" that does not filter out easily. A few more jars added to a rectifier usually will cure this trouble permanently. The transformer voltage that causes break-down is always the "peak" of the a.c. cycle, which is nearly one and one-half times the effective value of voltage at which a.c. circuits are rated.

Thermionic Rectifiers

Thermionic tube rectifiers, such as the Type 80 and 81, are used only for the lower voltages. However, like the chemical rectifier, they are entirely suitable for sets employing a Type 10 tube or those of lower voltage rating. A Type 81 rectifier will pass 85 milliamperes. With a pair of tubes in a full-wave circuit, the allowable current is 170 ma.

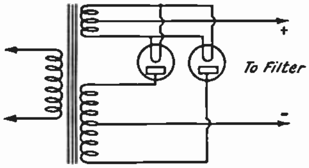


FIG. 104. — FULL-WAVE CENTER-TAP RECTIFICATION WITH THERMIONIC OR MERCURY-VAPOR TUBES

The connections for a full-wave rectifier using Type 81 tubes are shown in Fig. 104. The half-wave rectifier circuit requires only one tube and the transformer secondary need not be center-tapped, but since the output has only half as many "humps" per second as with a full-wave rectifier, it is more difficult to filter. Thermionic tubes are not recommended for use in a bridge rectifier, because their high resistance and lack of close uniformity prevent the tubes from dividing the load properly.

The Type 80 tube is a self-contained full-wave rectifier designed for low voltages. The applied voltage should not be greater than about 550 per plate, and the tube will pass 125 ma. It is thus suitable for sets employing a Type 10 or smaller tube where the voltage required is not over 500. The connections of the Type 80 tube in a full-wave rectifier circuit are shown in Fig. 105.

Thermionic rectifiers are very easily installed, are compact, noiseless in operation, require no particular attention, and will last a long time with reasonable use. Their cost is comparatively low, and they can be obtained at almost any radio store. The voltage drop through them is not so high as to present any particular difficulty with an amateur transmitter, and is of about the same order as the drop in a good chemical rectifier. They are not as good in this respect, however, as hot-cathode mercury-vapor rectifiers.

Gaseous-Conduction Rectifiers

Gaseous-conduction rectifiers, such as the Raytheon BH, can be used in transmitters employing a receiving tube as the oscillator, or for the low-power stages of an oscillator-amplifier transmitter where the voltage required is not more than about 300. At the present time these rectifiers are not manufactured for higher voltages. Since the tube has no filament, it is unnecessary to have an extra winding on the power transformer for rectifier tube filaments. In the field where such a rectifier can be employed, the other advantages are the same as those of thermionic rectifiers.

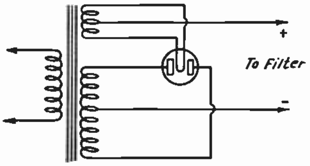


FIG. 105. — HOW FULL-WAVE TUBE RECTIFIERS ARE CONNECTED

This diagram can be used with Type 80, 82 and 83 rectifier tubes.

Hot-Cathode Mercury-Vapor Rectifiers

In many respects hot-cathode mercury-vapor rectifiers are the most satisfactory type for amateur plate-supply systems. They are similar to the thermionic type in having a filament and plate, but have a few drops of mercury sealed in the tube after evacuation. When the tube is in operation the mercury vaporizes and neutralizes the space charge. The voltage drop through the tube is consequently very low, being about 15 volts regardless of the plate voltage or current. As a result, properly designed power supplies equipped with mercury-vapor rectifiers can have excellent voltage regulation.

Mercury-vapor rectifier tubes are manufactured in many sizes, from low-voltage low-current tubes for receivers to large tubes capable of handling many kilowatts of high-voltage power. The table lists the types applicable to amateur transmitters.

The ratings on these rectifiers are somewhat different from those of thermionic rectifiers. The voltage which a thermionic rectifier will stand is limited almost entirely by the insulation in the tube itself, particularly between the wires in the glass stem. This is not the case, however, with mercury-vapor rectifiers, because as the voltage is increased beyond a certain critical value, known as the "arc-back" voltage, a heavy current will flow in the opposite direction and ruin the tube.

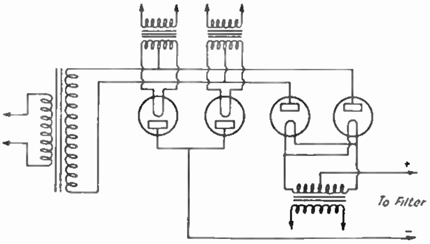


FIG. 106. — A BRIDGE RECTIFIER WITH MERCURY-VAPOR TUBES

This arrangement is used when the power transformer has no center-tap, or when the d.c. voltage required is greater than would be permissible with center-tap rectification to keep within the inverse peak voltage rating of the rectifier tube. Four tubes and three separate filament windings are necessary.

The maximum current which the tube can safely pass is limited by the filament emission. For these reasons, the tubes are rated at "maximum inverse peak voltage" and "peak current." The inverse peak voltage is the highest voltage which the tube can stand, applied in the opposite direction to normal current flow. The term "peak current" is self-explanatory.

The inverse peak voltage is the peak voltage furnished by the transformer, and in the case of a pure sine wave will be 1.41 times the *total* voltage across the transformer terminals. For instance, assuming a full-wave rectifier using a center-tapped transformer, if the transformer gives 1500 volts on each side of the center-tap, the total secondary voltage will be 3000, and the inverse peak voltage which each rectifier tube will have to stand will be 3000×1.41, or 4230 volts. The maximum safe *total* transformer voltage for tubes with a 7500-volt inverse peak rating is 5300 volts.

The peak current depends upon the type of filter employed or, more particularly, is determined by the layout of the input side of the filter. If a 2-μfd. or larger condenser is connected directly across the rectifier output, the ratio of peak current through the rectifier tubes to the d.c. output current is large, thus limiting the allowable load current to comparatively small values. It is better to use a filter in which a choke is connected between the rectifier tubes and the filter proper. A value of 10 henrys for this choke is good for all-around work. The effect of the 10-henry choke on the permissible load current is quite marked, especially in high-voltage rectifiers. The load current can be doubled or trebled with the same pair of rectifier tubes with a choke-input filter as against a condenser-input filter. It is unwise to use a condenser-input filter with mercury vapor tubes on voltages greater than 1000 because their life is likely to be shortened.

The inverse peak voltage with either the center-

RECTIFIER TUBE RATINGS

Tube Type	Fil. Volts	Fil. Amps.	Max. Voltage per plate (a.c. r.m.s.)	Max. Inverse Peak Voltage	D. C. Output Current in MA.	Peak Current in MA.	Type
80	5.0	2.0	350 400 550*		125 110 135		Full-Wave Thermionic
81	7.5	1.25	700		85		Half-Wave Thermionic
82	2.5	3.0	500	1400	125	400	Full-Wave Mer. Vapor
83	5.0	3.0	500	1400	250	800	"
866	2.5	5.0		7500		600	Half-Wave Mer. Vapor
872	5.0	10.0		7500		2500	"
Rectobulb R81	7.5		750		150		"
Rectobulb R3	10			7000	250		"
Rectobulb R4	5	10		7000		2500	"

* An input choke of at least 20 henrys inductance must be used at this voltage.

tap or bridge arrangement is the same (total transformer voltage times 1.41) so that with a given type of tube approximately twice the d.c. voltage allowable with center-tap rectification can be taken from a bridge rectifier without exceeding the inverse peak voltage rating. Hot-cathode mercury-vapor rectifiers lend themselves very well to the bridge arrangement, because the internal drop is small and the tubes match up well. Fig. 106 gives the bridge rectifier circuit.

In building up a plate-supply unit employing tubes of this type it should be remembered that the filament current is quite high. Not all tube sockets are suitable for currents greater than one or two amperes. Poor contact at the filament prongs, overheating of the connections and possible tube damage are to be avoided. Therefore the socket should be selected with care. A further important point to watch is the filament voltage at which the tubes operate. Satisfactory service and normal life are obtained only when the filament is held at the rated voltage.

In the mercury-vapor tubes having an exposed filament it is necessary to apply the filament voltage 20 or 30 seconds before the plate voltage, to permit the filaments to come up to their normal temperature before operation starts. In the case of the heater-type tubes a much longer delay is necessary between the application of the filament and the plate voltage because the cathode is heated indirectly. In actual operation of the station this delay would be a decided disadvantage and general practice is now to leave the rectifier filaments running continuously during periods when the station is being operated.

Mercury-Arc Rectifiers

The mercury-arc rectifier is well adapted to high-power amateur transmitters. Such rectifiers are capable of withstanding very much higher inverse peak voltages and peak currents than the smaller types of mercury-vapor tubes available to amateurs.

Like the hot-cathode mercury-vapor tubes, the rectifying efficiency of mercury-arcs is very high, since drop in plate potential within the tube is only about 15 volts. The overall efficiency, however, is lowered by an amount depending on the "keep-alive" circuit used and the instantaneous load values on the tube.

Since mercury arcs are not self-starting a "keep-alive" circuit is necessary in using this rectifier with amateur transmitting sets for telegraph work. An auxiliary electrode near the base of the tube is ordinarily provided for use in starting the arc by an initial flash on the main pool, and this starting arc is kept in operation continuously by "keep-alive" circuits so that the tube will be kept filled with mercury vapor even when the key is up as in intermittent telegraph work. The auxiliary and main mercury pools are connected through an inductance coil (to steady the keep-alive current and prevent the arc from going out) and a rectifier, to a source of low-voltage alternating current (about 50 volts on either side of the center-tap) as shown in Fig. 107. Tungar or Rectigon tubes such as are used in low-voltage battery chargers can be used or, lacking these, an electrolytic rectifier made up in two half-gallon battery jars will prove very satisfactory. In operating the tube the glass next to the "keep-alive" arc gets hot so that one should take the precaution of mounting the mercury-arc tube in an oil bath to a level somewhat above the mercury pools to protect the glass. Use light gas-engine oil of any kind convenient for cooling purposes.

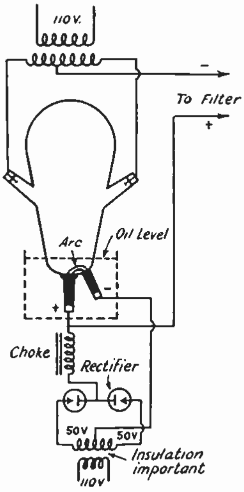


FIG. 107.—TYPICAL WIRING DIAGRAM FOR A MERCURY-ARC RECTIFIER

The outside ends of the high-voltage winding of the power transformer are connected to the two side arms. The positive high-voltage lead is taken off the lower auxiliary electrode. The "keep-alive" circuit for maintaining the arc in an operating condition during keying consists of the small transformer giving 50 volts each side of the center tap, a pair of Tungar rectifier tubes, and the choke. The secondary of the keep-alive transformer must be insulated for the full plate voltage.

The transformer supplying the "keep-alive" circuit must be well insulated because the filament circuit of the rectifier is at plate potential above ground. If no one-to-one ratio transformer with a center-tapped secondary is available for the "keep-alive" circuit, a 50-volt supply can be used with four large chemical rectifier jars connected in a bridge arrangement.

The choke can be built easily if a spare transformer winding of the necessary inductance is not available. Some resistance in series with the choke will help in limiting the current used in the "keep-alive" circuit to a value which will just keep the arc operating stably, preventing the wasting of power and getting away from the danger of overheating the glass at the auxiliary electrode. A choke having about 800 turns of No. 18 or No. 20 wire wound on a closed core 1¼" square (cross-section) will be suitable. The voltage used and the necessary adjustments are not critical. About 2 amperes "keep-alive" current is necessary for stability.

The connections of the mercury-arc rectifier in transmitting circuits resemble those of the other rectifiers. The diagram shows a typical arrangement. Most amateurs use the small 110-volt 10-ampere tubes successfully. So many styles and varieties of tubes are available that we cannot be too specific regarding any particular rectifier tube. In general, the tubes are not critical and a little careful experimenting will enable you to get one going at your station.

In handling the tubes, remember that mercury is heavy and it must be poured carefully to prevent cracking the glass. If a tube is defective due to a poor vacuum it will not operate. A tube having a good vacuum will give out a clicking sound when the mercury is shaken about carefully so that it splashes a little. If there is much air in a tube the mercury will oxidize on trying to start the arc. In mounting the rectifier tubes the glass should be clamped so that there is no mechanical strain on it or it is almost sure to fracture after a few hours of operation. To start the arc each time the plate supply is turned on the tube must be tilted mechanically so that the two pools of mercury will make contact and ignite the vapor. This may be done by rigging up a pivoted frame to hold the arc and providing it with a rope so that the operator can tilt the tube from the operating table. The tilting also can be done by electro-mechanical means using a solenoid and relays.

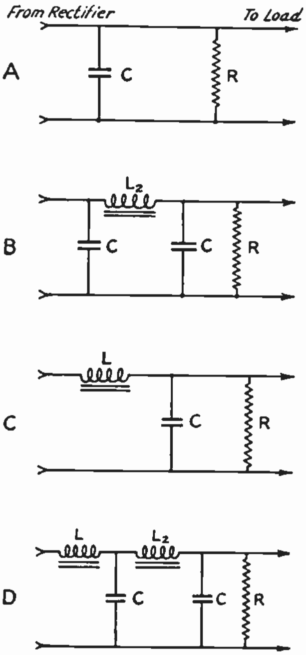


FIG. 108. — FILTERS

At A is the simplest type of filter — a single condenser of high capacity connected across the retifier output. With the addition of a filter choke and a second condenser this becomes the circuit of B. C is an elementary choke-input filter. The arrangement at D is recommended when mercury-vapor rectifier tubes are to be used. It will give excellent filtering and will assure long life to the rectifier tubes because the input choke limits the peak current to a safe value.

Designing the Filter

Once the type of rectifier has been decided upon, the next problem to be considered is the filter. The purpose of the filter is to smooth out the "humps" in the rectified a.c. so that the voltage applied to the transmitting tubes will be continuous and have no "ripple." As explained when the action of rectifiers was being considered, the rectifier output voltage is continually changing in value from zero to maximum and back to zero again, repeating these alternations at a rate which depends on the a.c. supply frequency and the type of rectifier; that is, whether half-wave or full-wave.

Filters may take a variety of forms, although those used for plate-supply work have been pretty generally reduced to one or two simple combinations. Condensers and iron-core choke coils of different values connected in various circuits will provide the necessary smoothing effect. The amount of inductance and capacity to use and the best ways of connecting them will depend on the particular problem in hand.

The simplest possible filter would be a single condenser, as shown in Fig. 108-A. Its operation can be understood by looking again at Fig. 101. When the voltage output wave from the rectifier is rising in value the condenser accumulates a charge, the total potential of which is equal to the maximum voltage of the rectified wave. This maximum voltage is approximately 1.4 times the effective or rated voltage of the secondary of the transformer. When the rectifier output voltage is decreasing the charge on the condenser begins to flow to the load. If the condenser is large enough the load voltage does not drop very much even when the rectifier output voltage is zero, because the discharging of the condenser fills in the valleys between the voltage peaks. The output from a simple filter like this is not pure d.c. but still has fair-sized a.c. ripple. The rate at which the condenser discharges depends upon the capacity of the condenser and the resistance of the load. The lower the load resistance, i.e., the more current that is taken from the rectifier-filter system, the greater the discharge rate of the condenser and as a result the lower will be the load voltage and the greater the ripple. Thus the voltage regulation with this type of filter is poor. Its characteristic is a high no-load voltage and comparatively low full-load voltage.

The ripple voltage remaining in the output can be reduced by using a filter choke and a second filter condenser connected as shown in Fig. 108-B. The choke, L_2, should have high reactance at the ripple frequency so that it will choke off such ripple voltage as remains across the first condenser. Its d.c. resistance, on the other hand, should be low so that the d.c. voltage drop through the choke will be small. The final filter condenser acts in the same way as the first condenser, taking the ripple that gets through the choke and smoothing it out in the same way. For filters used on 50- and 60-cycle power lines each of the condensers should have approximately 2 μfd. capacity and the choke should have about 30 henrys inductance. If the supply frequency is 25 cycles all these values should be doubled to give the same degree of filtering that would be obtained on the higher-frequency lines. This type of filter is almost universally used by amateurs and has become known as the "brute force" type. For transmitting purposes its output can be considered to be practically pure direct current.

So far the resistor marked *R* in these two diagrams has not been mentioned. It has nothing to do with the action of the filter in smoothing the ripple but is a useful adjunct to the power supply. Its purpose is to keep a small load on the plate supply system at all times so that the voltage across the filter condensers will not build up to the peak value of the rectifier output and so that the filter condensers will discharge quickly when the power supply is turned off. Good filter condensers will hold a charge for hours after the power is turned off, unless some provision is made for discharging them, and often cause disconcerting shocks and sometimes bad burns if the operator attempts to make adjustments to the power supply apparatus. Resistor *R*, which is called a "drain" or "bleeder" resistor, will allow the condensers to discharge instantly and prevent accidental shocks in addition to protecting the condensers from overload by keeping down the peak voltage. Its resistance should be such that the current through it will be from 10% to 20% of the current taken by the transmitting tube or tubes.

A filter with a condenser next to the rectifier is known as a "condenser-input" filter. As we have pointed out above, its voltage regulation will be poor because the output voltage depends upon the storage capacity of the first filter condenser. Worse than this, however, the condenser-input filter has another bad feature — it puts an abnormally heavy load on the rectifier tubes. The condenser offers very low impedance to the ripple frequency, and since the output of the rectifier is 100% ripple, a heavy current will flow in the circuit formed by the transformer secondary, the rectifier tubes and the first filter condenser. This current never gets to the load and therefore does no useful work, but constitutes a "dead" load on the rectifier tubes and thereby reduces the current which can be furnished to the load since the filaments of the rectifiers can pass only a certain amount of current safely. A condenser-input filter is particularly harmful to mercury-vapor rectifier tubes because of their low resistance and constant voltage drop. Thermionic rectifiers protect themselves to some extent from destructive currents because the voltage drop through them increases with the current and therefore partially limits the current, and because their resistance is a good deal higher than that of mercury-vapor tubes.

Voltage regulation can be improved and the load on the rectifier tubes decreased by using a filter with a choke between the rectifier and the first filter condenser as shown at Fig. 108-C. Because of its high impedance to the ripple frequency the choke limits the peak current through the rectifier tubes quite effectively. For a given transformer voltage, the d.c. output voltage from the rectifier-filter system is not as high with choke input as with condenser input at small loads, but both give about the same output voltage at heavy loads. With choke input the difference between the voltage at light loads and full load will be fairly small, however, indicating improved voltage regulation. The filter condensers do not have to be rated to stand peak voltages as they do with condenser-input filters, but can be rated at a little more than the full-load voltage.

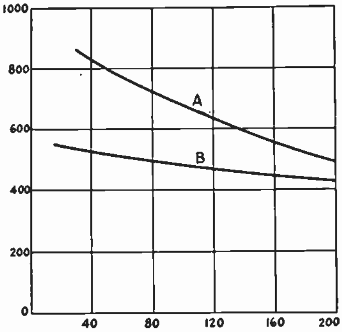


FIG. 109. — COMPARISON OF OUTPUT VOLTAGE — LOAD CURRENT CURVES FROM CONDENSER- AND CHOKE-INPUT FILTERS WITH THE SAME TRANSFORMER AND RECTIFIER

The voltage with choke input, Curve B, is nearly constant over a wide range of load currents. With condenser input, Curve A, the voltage is highly sensitive to changes in load, and although the output voltage is higher the regulation is poorer than with choke input.

Fig. 108-C shows an elementary choke-input filter consisting of a single choke and condenser. The choke does not have to have very large inductance to protect the rectifier tubes from destructive peak currents. A value of 10 henrys will be ample in practically all cases. Even smaller values than this can be used, but since 10-henry chokes are not difficult to obtain or build the additional safety factor is well worth having. The bleeder resistor *R* is important from the standpoint of voltage regulation in the choke-input filter. If there is no load on the plate supply system the no-load voltage will build up to the

peak of the rectifier output voltage just as it does with condenser-input filters. For a small range of output currents the terminal voltage will drop rapidly until at about 20 to 30 milliamperes it will settle down to a steady value which changes very little with load. The bleeder resistor should be adjusted so that the minimum load on the plate supply will be enough to bring the terminal voltage down to the steady value.

The difference in output voltage between condenser-input and choke-input filters at various load currents is strikingly shown in Fig. 109. Both curves were taken with a small transformer of the type used for supplying Type 10 tubes. Curve *A* resulted when the filter was the regular brute-force arrangement shown in Fig. 108-B. Curve *B* shows the effect of putting a choke between the rectifier and the first filter condenser. Although the difference in output voltage between the two filters is only about 60 volts at a load of 200 milliamperes, at 40 ma. the voltage is over 800 with the condenser-input filter and only slightly over 500 with the choke-input filter. If Curve *B* had been continued over to the zero current line it would be found that its no load value would be the same as that of Curve *A* — in the vicinity of 900 volts. It was impossible to do this, however, because the voltmeter used in making the curves took enough current to bring the output voltage well down toward the steady value. A bleeder drawing about 20 ma. would be sufficient in this case. Its resistance would be roughly 500 volts divided by 20 milliamperes, or 25,000 ohms. It should be pointed out here that a 200-ma. load on Curve *A* probably represents an overload both on the rectifier tubes and transformer, whereas the same 200-ma. load on Curve *B* is well within the ratings of both.

With condenser-input filters it is very difficult to calculate the actual d.c. output voltage of a plate supply system. The transformer used in making the curves of Fig. 109 had an a.c. secondary voltage output of 600. Up to an output current of 130 milliamperes the terminal voltage is greater than 600, getting up over 800 at 50 ma. and less. It is easy, on the other hand, to calculate the d.c. output voltage of a choke-input filter. Simply multiply the transformer voltage by .9 and subtract the resistance drops in the transformer secondary and the filter chokes at the desired load current. This assumes that the load current will be great enough to bring the terminal voltage down on the steady part of the curve, which will practically always be the case. This formula also can be used to determine the transformer voltage necessary to give a desired d.c. output voltage. Assume, for instance, that the transmitter is to take 200 milliamperes at 1000 volts, and that the filter is to be like that at Fig. 108-D. The 10-henry input choke has a resistance of 100 ohms, the 30-henry filter choke 200 ohms and one side of the transformer secondary 300 ohms. A 40,000-ohm bleeder is to be used across the output, taking 25 milliamperes. The total load current will therefore be 225 ma. This multiplied by the total resistance in the circuit, 600 ohms, gives the total resistance drop, or 135 volts. The transformer voltage required will be

$$\frac{1000+135}{.9}=1260 \text{ volts.}$$

The filter arrangement shown at Fig. 108-D is an excellent one for all types of amateur plate supply systems, giving practically pure d.c. output and providing adequate protection for the rectifier tubes. Representative values would be, for L, 10 henrys, for L_2, 20 to 30 henrys, and for both condensers, 2 μfd. each. The resistance of R will depend upon the output voltage. Up to 1000 volts it should drain 20 to 25 milliamperes; from 1000 to 2000 volts, about 35 milliamperes, and above 2000 volts, about 50 ma.

A further improvement in regulation can be secured by using an input choke which is designed so that the core saturates as the current through it increases, thus reducing the inductance. This in effect allows the first filter condenser to take a more important part in maintaining the output voltage as the load increases, compensating somewhat for the normal voltage drop to be expected with greater current flow. A choke of this type is called a "swinging" choke. A transformer secondary with a few thousand turns usually will be found adequate for this purpose. The core need not have an air-gap, in contrast to the cores used for filter chokes. It is probable that something of this effect is obtained even with chokes designed for filter work, however, since the inductance of many such chokes drops off as the current nears the rated value. Swinging chokes are available commercially.

Filter Condensers

Aside from tubes, there is probably no other item in an amateur transmitter which requires more frequent replacement than the filter condenser. This is not always the fault of the condenser manufacturer but is more often caused by the failure of the amateur himself to take into account the conditions under which the condenser must work.

Manufacturers have generally adopted the practice of rating condensers at their maximum d.c. working voltage. This is not the a.c. effective voltage supplied by a transformer. The peak transformer voltage will be 1.41 times the rated voltage, provided the wave form is of sine shape. It often happens that the wave form is considerably distorted by the time a transformer at the end of a long line is reached, and the peak may very readily be higher than this value. A fairly good working rule to follow is that the filter condensers should be rated to stand at least 50% more voltage than the transformer secondary gives if a condenser-input filter is used. The condensers need be rated only for the same voltage as the transformer secondary if the filter has choke input and a bleeder of the right size. In the case of a full-wave rectifier working from a center-tapped transformer winding, only the voltage on each side of the center-tap is considered, because so far as the filter condensers are concerned, the two halves of the transformer are in parallel.

As an example, a condenser to work in a condenser-input filter with a transformer giving 550 volts each side of the center-tap should be rated to stand 1.5 times 550, or 825 volts. The nearest standard voltage rating is 1000, and 1000-volt condensers are therefore the size to use. Similarly a transformer giving 1500 volts each side of the center-tap would require condensers rated at 2250 volts, and a 2000-volt transformer will necessitate the use of 3000-volt condensers.

Failure to observe this rule in buying filter condensers is almost sure to result in very short condenser life. It is therefore well to invest a little more money in adequately-rated condensers in the beginning and obviate the necessity for replacement later on.

There are two types of condensers now generally available, electrolytic (d.c. only) and paper (a.c. or d.c.). For d.c. voltages of 1000 or less, the electrolytic condensers are cheaper per microfarad than the paper type. However, since electrolytic condensers are not made to stand voltages higher than 500 per unit, it is necessary to use a number of them in series for higher voltages, so that the difference in cost for voltages over 1000 is small.

The leakage current with electrolytic condensers is much higher than is the case with good paper condensers. If the voltage rating is exceeded, electrolytic condensers allow more leakage current to pass but may not break down completely. The usefulness of the condenser is not impaired, although the capacity drops off rapidly as the rated voltage is exceeded.

If electrolytic condensers are to be used with a high-voltage rectifier, or if paper condensers of lower voltage rating than that desired are available, they may be connected in series or series-parallel and made to operate safely. See Fig. 1010. For instance, two 1000-volt condensers connected in series will work satisfactorily on 2000 volts if they both have the same capacity. The *resultant* capacity, however, will be only half that of a single condenser. Condensers which do not have the same capacity rating should not be connected in series because the voltage will not divide evenly across them, the smaller condenser always taking the larger share of the voltage. To insure equal division of voltage drop across condensers in series, it is advisable to connect resistors across each section. Groups of condensers in series may be connected in parallel to increase the total capacity of the bank.

Filter Chokes

Manufacturers' ratings on filter chokes are often confusing because the inductance of the choke varies greatly with the amount of d.c. flowing in the winding, and it has not been the practice to state whether the inductance measurements were made with the rated d.c. flowing or measured with a.c. only. A choke which is rated at 30 henrys with no d.c. flowing in the windings can very easily drop to 10 henrys or less with a current which does not tax the capacity of the wire.

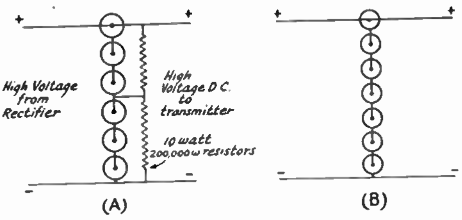


FIG. 1010. — HOW ELECTROLYTIC CONDENSERS MAY BE USED IN SERIES

for high voltage. The purpose of the resistor in (A) is to equalize the voltages across each group and thus prevent breakdown of a condenser which might take more than its share of the load. In (B) an extra condenser is used in the string so that all condensers will work at voltages well within their ratings, thus obviating the necessity for equalizing resistors.

Good chokes are made with air-gaps at some point in the core. This prevents magnetic saturation of the core and at the same time reduces the inductance of the choke, but under load conditions it is quite possible that the inductance will be higher with a choke which has an air-gap of proper size than would a choke of much higher "a.c. inductance" with no air-gap. This point should be kept in mind in selecting a manufactured choke, or in building one at home.

The design of filter chokes of different inductance values for almost any type of amateur transmitter is covered farther on in this chapter.

The Filament Supply

The second division of the power supply for the transmitter is the supply to the filaments of the tubes used. Though batteries are sometimes used for this supply, alternating current obtained from the house current through a step-down transformer usually is more practical and more satisfactory. In some cases the filament-supply winding is wound over the core of the high-voltage transformer, thus eliminating the necessity for a separate filament transformer. This practice, however, is not always to be recommended. The filament supply must be constant if the transmitter is to operate effectively, and with both filament and high voltage supplies coming from one transformer this constancy is obtained only with great difficulty, since changes in the load taken from the high-voltage winding cause serious changes in the voltage obtained from the filament winding — unless the transformer is operating well under its rating or unless special compensating apparatus is employed. Wherever possible the high-voltage and filament transformers should be separate units operating, if it can be arranged, from different power outlets, particularly with transmitters using tubes larger than the Type 10.

Examination of any of the power-supply circuits will make it obvious that the filaments of the rectifier tubes must be well insulated from the filaments of the oscillator tubes. The filaments of the rectifiers provide the positive output lead from the plate-supply system while the filaments of the transmitter tubes are connected to the negative side of the high-voltage supply. The fact that the two filament supplies must be insulated does not, however, mean that two transformers are required. The two windings can be on the same core, the necessary insulation being provided between them. Should the filament transformer be bought and should it have no windings suitable for the filaments of the rectifiers, an extra winding usually can be fitted without difficulty. For Type 66 rectifiers two No. 12 gauge wires in parallel should be used for the winding, the number of turns being determined by the "cut and try" method. With most transformers only a few turns will be necessary to give the required voltage. The rectifier-filament winding can be center-tapped or a center-tapped resistor can be used across it in the manner described for the transmitter filaments. The center-tap is not an absolute necessity, however; the positive high-voltage lead can be taken from either side of the rectifier filament winding instead.

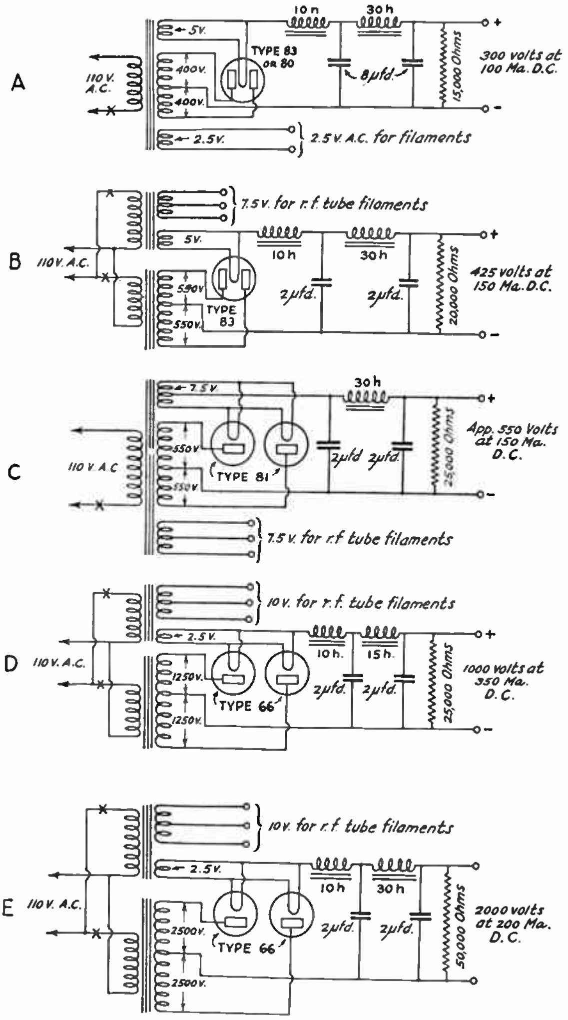


FIG. 1011. — REPRESENTATIVE POWER-SUPPLY ARRANGEMENTS FOR DIFFERENT TYPES OF TRANSMITTING TUBES

All these diagrams will give adequately-filtered d.c. output for the different classes of service. They are explained more fully in the text. Many other arrangements are possible. Control switches should be inserted in the transformer primaries at the points marked "X" to permit the filament supplies to be turned on before the plate supply.

Practical Power Supplies

The wide varieties of rectifying and filtering equipment available to amateurs, together with the different classes of service for which power supplies may be used, make it almost impossible for us to show complete constructional details of such equipment for any but the simplest of transmitters. The foregoing information should enable the amateur to choose the type of rectifier and filter best suited to his needs. As a guide in construction, however, Fig. 1011 shows a number of rectifier-filter combinations to give various output voltages and currents. All will give adequately-filtered direct current to the transmitting tubes, and in the cases where mercury-vapor rectifier tubes are shown the necessary protection is afforded them by the use of a 10-henry input choke to the filter. In all circuits except that at *C* the voltage regulation will be good so that the voltage at no load will not be very much higher than at the load currents indicated. In these cases the filter condensers need be rated to stand only the voltage delivered by one-half of the high-voltage secondary; for example, a condenser with a working-voltage rating of 1250 volts d.c. will be ample for the 1000-volt power supply shown at *D*. This assumes, of course, that the bleeder resistance is used. Without this resistor, the condensers should be rated to stand 50% more voltage than half the secondary voltage of the transformer. In the arrangement at *C* the condensers should have the higher rating whether the bleeder is used or not.

The input choke may be omitted in diagram *A* even though the small mercury-vapor rectifiers are used because the tubes are built to stand working into a condenser-input filter. Should this be done, however, the filter condensers must be rated at 600 volts working, which means that electrolytic condensers cannot be used unless two of them are put in series to replace the single condensers shown. The condensers need not have 8 μfd. capacity each, but this is a standard size with electrolytic condensers and is recommended.

The rectifier-filter system at *A* will handle any of the small transmitters using receiving-type tubes shown in Chapter Seven. Diagram *B* will take care of a pair of Type 10 tubes with ease. The rectifier-filter at *C* does not use mercury-vapor rectifiers and hence can dispense with the input choke. Its output voltage will be variable between approximately 750 and 550 volts, however, depending upon the load current. It will be suitable for a pair of Type 10 tubes if it should be thought desirable to run them at more voltage than can be obtained with Diagram *B*. At *D* is shown a power supply for one or two tubes of the 03-A, 11 or 845 type. The arrangement at *E* is suitable for use with one or two Type 52 or 60 tubes. Other combinations can be worked out without much difficulty. It is not absolutely necessary to follow the specifications in the filter section of the diagrams absolutely; for example 1-μfd. condensers or smaller chokes can be substituted in the filters of the high-power plate supplies, especially if the big tubes are amplifiers used for c.w. work in a crystal-controlled or oscillator-amplifier transmitter. For 'phone it is better to have as much filter as possible to keep the carrier free from hum.

In all these diagrams it is of course necessary to use power transformers of adequate capacity and chokes of high enough current rating to carry the load currents indicated. In *D* and *E* the plate transformers should be rated at about 500 va. to give the necessary output.

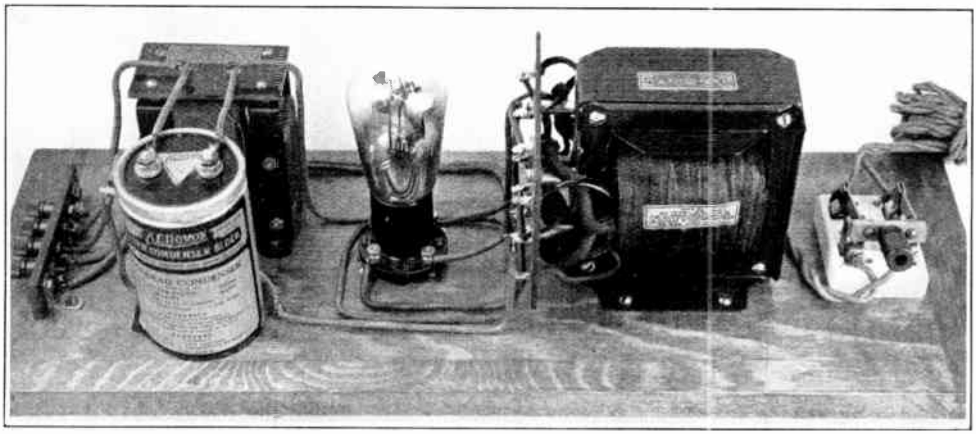


FIG. 1012.—A POWER SUPPLY, FOR USE WITH LOW-POWER TRANSMITTERS, MADE FROM BROADCAST RECEIVER PARTS

Fig. 1012 is a photograph of a power supply suitable for use with the push-pull transmitter using 45 tubes described in Chapter Seven. Its circuit diagram, Fig. 1013, will be seen to be similar to *A* in Fig. 1011 with the exception of the fact that the input choke to the filter is omitted and that no bleeder resistance is used. The filter condenser is a double-section electrolytic having a capacity of 8 μfd. in each section. It is the dry type, and is rated at 500 volts maximum. The power transformer should deliver not more than 350 volts each side of the center tap to avoid damaging the condenser.

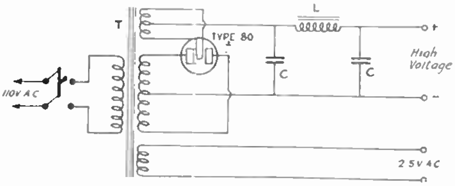


FIG. 1013.—THE LOW-VOLTAGE POWER SUPPLY CIRCUIT

T—Power transformer. Should have high-voltage winding giving not more than 350 volts each side of center tap, a 5-volt winding for the filament of the Type 80 rectifier, and a 2.5-volt winding to supply the filaments of the transmitting tubes.

L—10- to 30-henry choke with 100-milliampere or greater current-carrying capacity.

C—8-μfd. filter condensers. The one shown in the photograph is an electrolytic condenser consisting of two 8-μfd. sections.

A Type 83 rectifier may be substituted for the 80 and will improve the voltage output and regulation.

Electrolytic condensers have inherent leakage and the charge accumulated on them will dissipate itself in a short time, which is the reason why the bleeder can be dispensed with. If paper condensers are used a bleeder of about 20,000 to 30,000 ohms should be connected across the output of the filter. This power supply will deliver approximately 350 volts with a load of 100 milliamperes.

The location of parts in a power supply system is not of great importance. Make certain that the transformer and rectifier tube are placed so that the heat generated by them can be radiated into the surrounding air, and have all wires, particularly those carrying high voltage, well insulated. In other respects the layout can be made anything convenient.

When using electrolytic condensers be sure to connect the metal container to the negative side of the rectifier output and the stud terminals to the positive. Reversing these connections will short-circuit the rectifier and may ruin both the tube and the condenser.

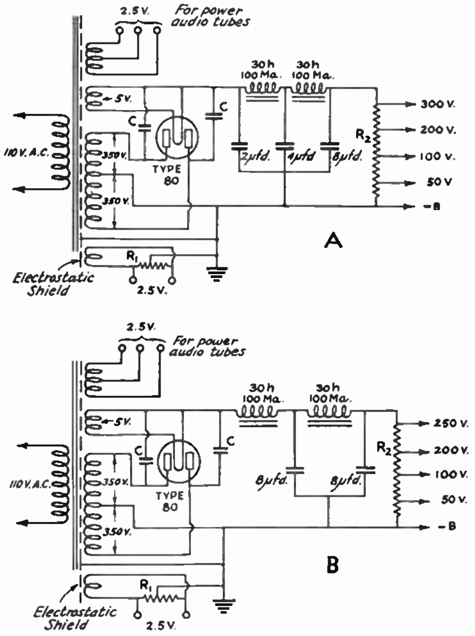


FIG. 1014. — WIRING DIAGRAMS FOR RECEIVER POWER SUPPLIES

Condenser C should be a mica condenser of about .002 µfd. capacity. Its size is not critical and it will be required only if tunable hums are present, as explained in the text. Resistor R_1 is 20 ohms total, tapped at the center. R_2 is the voltage divider for obtaining different voltages from the power supply. If the receiver itself is equipped with a divider (the preferable method) R_2 will be a simple bleeder of about 15,000 ohms. Otherwise it may be any of the regular voltage dividers sold commercially for this use, or may be a 15,000 ohm resistor tapped at every 3000 ohms. The resistance needed between taps will depend upon the currents to be drawn at each of the taps. It is not usually necessary to have the voltages nearer rated values than within 20%, with modern receiving tubes.

Voltage Dividers

In addition to the voltages shown in Fig. 1011, lower voltages may be taken from any of the power supplies diagrammed by using the bleeder resistor as a *voltage divider.* If the resistor is tapped at some point the voltage appearing between the negative side of the power supply and the tap will be proportional to the position of the tap. Thus in *D* if the 25,000-ohm resistor is tapped at 10,000 ohms from the negative side the voltage between the negative post and the tap will be

$$\frac{10{,}000}{25{,}000} \times 1000 \text{ Volts} = 400 \text{ volts.}$$

This is true, however, only when no current is taken from the tap, because when current is drawn there will be an additional voltage drop in the part of the resistor between the tap and the positive terminal which will make the voltage at the tap lower. To get the tap at the right place under load conditions it is necessary to know the current that will be drawn at the low voltage required. This current can be added to the normal bleeder current and the resistance required between the positive terminal and the tap for the desired voltage drop can be determined. For example, to get 400 volts at 50 ma. from *D*, the 50 ma. load should be added to the normal bleeder current, 40 ma., making a total of 90 ma. to flow through that part of the resistor between the positive terminal and the tap. The drop required is 600 volts, so the resistance will be

$$\frac{600}{.09} = 6700 \text{ ohms, approximately.}$$

This method of calculation is not entirely accurate because the current through the lower part of the bleeder will not remain 40 milliamperes when current is drawn from the tap, and the actual voltage will be somewhat higher than calculated. Slightly more resistance between the positive terminal and the tap can be used to compensate for this effect. If the tap voltage must be accurately set it is better to use a variable resistor or one with a large number of taps so the proper one can be chosen.

Receiver Power Supplies

Power supplies for a.c.-operated receivers do not differ materially from those used with transmitters except that the voltages are lower and all ripple must be eliminated. Nothing is more annoying than a "hummy" B supply. The ripple can be reduced to satisfactory proportions by the use of three filter condensers (a three-section electrolytic condenser with capacities of 2, 4 and 8 µfd. will be satisfactory) and two receiver-type 30-henry chokes. Fig. 1014-A is the wiring diagram of a typical receiver power supply. It uses a power transformer of the type used in broadcast receivers delivering approximately 350 volts each side of the center-tap on the high-voltage winding. This type of power supply will take care of an ordinary amateur receiver and in addition will easily handle an audio power amplifier stage using a 47 pentode or a pair of 45's in push-pull. The output voltage will be rather higher than is required for the receiver itself, however, so the filter may be rearranged somewhat to use choke input, which will reduce the voltage and give better regulation. This is shown in Fig. 1014-B.

Special care must be taken with power packs for autodyne receivers to make certain that the voltage output will be constant and that "tunable hums" do not appear. A varying output voltage will make the detector oscillation frequency change and hence make signals sound wavering and unsteady. The choke-input filter of Fig. 1014-B is recommended on this score. Tunable hums are hums which appear only at certain frequencies to which the receiver is set and only with the detector oscillating. It may be that no hum can be heard with the detector out of oscillation but a strong hum is noticed as soon as the detector is made to oscillate. This is a tunable hum and cannot be eliminated by the addition of more filter condensers or chokes since it is caused by r.f. getting into the power supply and picking up modulation. Small condensers connected across the plates and filament of the rectifier tube as shown in both diagrams usually will eliminate this type of hum. A grounded electrostatic shield between the primary and secondaries of the power transformer also will help. Not all transformers have such a shield, however. Of course the power leads coming from the receiver itself should be well by-passed to prevent r.f. from getting into the power supply.

Voltage Doubling

If for any reason a higher plate voltage is desired for the transmitter than an available transformer will furnish, special circuits may be employed that will give a d.c. output voltage approximately double that to be expected from normal rectifier circuits. Two types of voltage-doubling circuits are shown in Fig. 1015, one for a transformer with a single high-voltage winding and one for a center-tapped transformer. The load current in circuit *A* should not exceed the rated current for *one* tube. Tubes may be used in parallel to boost the current output and improve regulation. In circuit *B* the load current will be the same as with ordinary full-wave rectification; that is, twice the rated current for a single tube.

Building Small Transformers

Power transformers for both filament heating and plate supply for all the transmitting and rectifying tubes used by amateurs are available commercially at reasonable prices, but occasionally the amateur wishes to build a transformer for some special purpose or has a core from a burned out transformer on which he wishes to put new windings.

Most transformers that amateurs build are for use on 110-volt 60-cycle supply. The number of turns necessary on the 110-volt winding depends on the kind of iron used in the core and on the cross-sectional area of the core. Silicon steel is best, and a flux density of about 50,000 lines per square inch can be used. This is the basis of the table of cross-sections given.

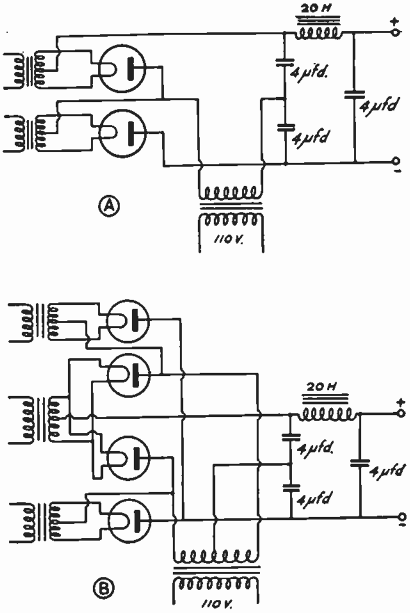


FIG. 1015. — VOLTAGE DOUBLING CIRCUITS

Diagram (A) is used with two rectifier tubes and a transformer without a center tap. In (B) four rectifiers are required, and the transformer must have a center tap. The voltage regulation will be better with (B) than (A), and in addition the rectifier will furnish twice the current obtainable from (A).

The size wire used depends on the current expected. This will vary with the load on the transformer. A circular mil is the area of the cross-section of a wire one thousandth of an inch in diameter. When a small transformer is built to handle a continuous load, the copper wire in the windings should have an area of 1500 circular mils for each ampere to be carried. (See Wire Table in Appendix.) For intermittent use, 1000 circular mils per ampere is permissible.

The transformer uses a little energy to supply losses in the core and windings. Because of the resistance of the windings and the magnetic leakage paths, the voltage of the secondary may drop materially under load. In filament-heating and plate-supply transformers we can arrange the windings compactly, make good solid joints in the core, use large low-resistance wire in the windings, and keep the length of the magnetic path fairly short and of good cross-section. This will keep the secondary voltage nearly constant under load.

A table is given showing the best size wire and core to use for particular transformers. The figures in the table refer to 60-cycle transformers. The design of 25-cycle transformers is similar but a slightly higher flux density is permissible. Because the frequency is much lower the cross-sectional area of the iron must be greater (or the number of turns per volt correspondingly larger). Otherwise the inductance of a certain number of turns will be too low to give the required "reactance" at the reduced frequency. If one builds the core so that its cross-section is 2.1 to 2.2 times the value of area worked out from the table, the same number turns of wire may be used in a primary coil for 25-cycle operation. If the same core and more turns of wire are used a larger "window" will be needed for the extra wire and insulation. Increasing both the number of turns per volt and the cross-section of the core gives the best-balanced design.

Input (Watts)	*Full-load Efficiency*	*Size of Primary Wire*	*No. of Primary Turns*	*Turns Per Volt*	*Cross-Section Through Core*
50	75%	23	528	4.80	1¼"x1¼"
75	85%	21	437	3.95	1⅜"x1⅜"
100	90%	20	367	3.33	1½"x1½"
150	90%	18	313	2.84	1⅝"x1⅝"
200	90%	17	270	2.45	1¾"x1¾"
250	90%	16	248	2.25	1⅞"x1⅞"
300	90%	15	248	2.25	1⅞"x1⅞"
400	90%	14	206	1.87	2 "x2 "
500	95%	13	183	1.66	2⅛"x2⅛"
750	95%	11	146	1.33	2⅜"x2⅜"
1000	95%	10	132	1.20	2½"x2½"
1500	95%	9	109	.99	2¾"x2¾"

Most 60-cycle transformers will behave nicely on a 25-cycle supply if the applied voltage is sufficiently reduced. Up to 52 volts at 25 cycles may be applied to a 110-volt 60-cycle winding without harm. Knowing the transformer voltage ratio, the output voltage will be known. The current-carrying capacity will be the same as at 60 cycles. The KVA (kilovolt-ampere) rating will be about half the 60-cycle value.

Before going ahead with the construction it is necessary to figure out the opening or window size that will be necessary in the core to just get the windings on without wasting any space. The best thing to do is to decide on a tentative length of winding, making a full-size drawing of the transformer on a sheet of paper. From the wire table find out how many turns of wire per layer can be put in the primary winding. Leave at least ¼" between the end of the winding and the adjacent leg of the core. Divide the total number of turns that will be needed in the winding by the number of turns per layer to find out how many layers will be needed. The depth of the winding can next be ascertained. Be sure to allow ⅛" between the core and the inside layer of wire for insulation. Allow for insulation between layers if there is to be any, too. Having finished these computations, draw in the outline of the winding, just as it will look when finished. The depth of the secondary winding can be figured in the same way, using the same length of winding as in the primary. If enameled wire is used, allow for a layer of thin paper between each layer of wire. Although enamel-insulated wire has the best space factor, single-cotton-covered enamel is best to use. Double-cotton covered wire can be used but is not so economical of space.

When the depth of both primary and secondary windings has been computed, their sum plus ¼" (for a factor of safety) will give the width of the window in the core. If the drawing begins to look like *D* instead of *E*, Fig. 1016, it will be necessary to try a different value for the length of the winding, figuring the size of the window all over again. A transformer with a large core and a relatively small amount of wire is best from the standpoint of the amateur builder because wire in smaller sizes is expensive while transformer iron is cheap. It is hard for most amateurs to wind many turns by hand unless a convenient winding jig is available.

After a little juggling with pencil and paper, the design of the transformer will be complete. The next step will be to obtain the materials and start the process of construction.

Any kind of transformer iron or silicon steel will make a good core. Sometimes an old power transformer from the local junk yard or from the electric light company can be torn down to get good and cheap core materials. It is not worth while to try to cut out core materials yourself or to use ordinary stove-pipe iron, as it will not lie flat. Laminations of about 28-gauge thickness should be used, as thicker iron pieces will give a large loss from eddy currents in the core and the heating will be objectionable. The iron must be carefully cut so that good joints can be made if the transformer is to have passably good regulation. L-shaped laminations are convenient to use in building a transformer but separate pieces for the four sides can be used if they are more readily obtained. The method of assembling a core is shown in Fig. 1017. Three sides can be built up, the windings put on, and then the fourth leg put in place, one lamination at a time. All laminations should be insulated from each other to prevent eddy currents from flowing. If there is iron rust or a scale on the core material, that will serve the purpose very well — otherwise one side of each piece can be coated with thin shellac. It is essential that the joints in the core be well made and be square and even. After the transformer is assembled, the joints can be hammered up tight using a block of wood between the hammer and the core to prevent damaging the laminations. A cigar box with two adjacent sides knocked out and the cover removed will be helpful in building up the core evenly. When three legs are completed, the whole can be tied with string, clamped in a vise, and the legs on which the windings are to be slipped wound with friction tape to hold them firmly in place and to keep the iron from damaging windings and insulation.

It is convenient to wind the coils on varnished cardboard. At any rate the coils should be wound on a wooden form and if some pliable cardboard can be put over this it will make it easy to slip the finished coils from the form to the core without mechanical injury. The wires cannot get out of place when so wound and they are well insulated from the core besides. The wooden block should be slightly larger than the leg of the core on which the winding is to be put and it should be a few inches longer than the winding. The block must be smooth and of just the right size. Several pieces fastened with small screws at the ends will make a form which can be easily taken apart when the winding is finished.

The winding itself is quite simple. The wire is wound on in layers as it takes least space when wound that way. Strips of paper between layers of small enameled wire are necessary to keep each layer even and to give added insulation. Thick paper must be avoided as it keeps in the heat generated in the winding so that the temperature may become dangerously high.

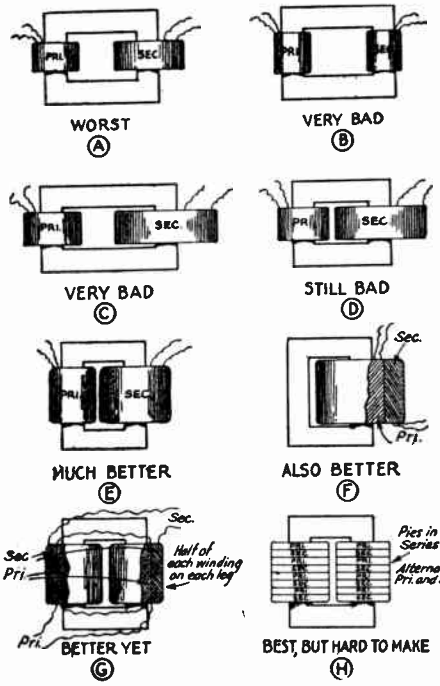
Transformers built by the amateur can be painted with insulating varnish or waxed to make them rigid and moisture proof. A mixture of melted beeswax and rosin makes a good impregnating mixture. Melted paraffin should not be used because it has too low a melting point. Double-cotton-covered wire can be coated with shellac as each layer is put on. However, enameled wire should never be treated with shellac as it may dissolve the enamel and hurt the insulation, and it will not dry because the moisture in the shellac will not be absorbed by the insulation. Small transformers can be treated with battery-compound after they are wound and assembled.

Keep watch for shorted turns and layers. If just one turn should become shorted in the entire winding, the voltage set up in it would cause a heavy current to flow which would burn it up, making the whole transformer useless.

Taps can be taken off as the windings are made if it is desired to have a transformer giving several voltages. The more taps there are, the more difficult becomes the problem of avoiding weakened insulation at the points where they are made. Taps should be arranged whenever possible so that they come at the ends of the layers. If the wire of which the winding is made is very small, the ends of the winding and any taps that are made should be of heavier wire to provide stronger leads.

High-voltage coils should be taped with varnished cambric tape. Low-voltage coils can be taped with friction tape or with untreated cotton tape and varnished later. Always lay the tape on smoothly so that each turn advances half the width of the preceding one. Pull the tape tight but not so tight as to pull the winding out of shape.

The leads should be well insulated. High-voltage leads can be run through varnished cambric tubing or "spaghetti." Pieces of flat tubular



WORST
Ⓐ

VERY BAD
Ⓑ

VERY BAD
Ⓒ

STILL BAD
Ⓓ

MUCH BETTER
Ⓔ

ALSO BETTER
Ⓕ

BETTER YET
Ⓖ

BEST, BUT HARD TO MAKE
Ⓗ

FIG. 1016. — HOW THE ARRANGEMENT OF THE CORE AND WINDINGS AFFECTS THE VOLTAGE REGULATION OF CORE-TYPE TRANSFORMERS

DESIGN DATA FOR INDUCTANCE COILS WITH IRON CORES. *Weight of Steel taken as 480 $\frac{lbs}{cu. ft.}$ = 0.28 $\frac{pounds}{cubic\ inches}$*

	CORE SIZE Cross Section	INDUCTANCE HENRYS	EQUIV GAP (G)	*ACTUAL Decimals	GAP Nearest Fraction	NO. TURNS (N)	♣ FLUX DENS. (B) Lines to inch	WINDING FORM b	WINDING FORM c	MEAN TURN inches	FEET OF WIRE	RESISTANCE (D.C)	WEIGHT OF COPPER	CORE DIMENTIONS Long Piece	CORE DIMENTIONS Short Piece	POUNDS STEEL
All wound with No. 33 enamelled wire 206.6 ohms per 1000 ft. 6591 ft. per lb. Carrying Capacity 0.05 amperes.	½x½	0.5	.040"	.017"	1/64"	1600	6500	0.42"	0.28"	3.0	400	82.5	1.0 oz	½x1.6"	½x.50"	0.30
		1.0	.041	.019		2300	9000	0.50	0.33	3.2	615	127.0	1.5 "	½x1.7	½x.55	0.31
		5.0	.043	.023		5200	20000	0.75	0.50	3.8	1670	345.0	40 "	½x1.92	½x.75	0.37
		10.0	.046	.030	1/32"	7600	27000	0.90	0.60	4.2	2640	545.0	6.5 "	½x2.1	½x.85	0.41
		15.0	.048	.035		9500	32000	1.00	0.68	4.5	3510	725.0	8.5 "	½x2.2	½x.85	0.43
	¾x¾	5.0	.043"	.023		3500	13000	0.62"	0.42"	4.5	1310	271	3.25 oz	¾x2.4	¾x.75	1.0
		10.0	.046	.030		5000	18000	0.73	0.49	4.75	2000	411	5.0 "	¾x2.5	¾x.75	1.0
		15.0	.048	.035		6300	21000	0.82	0.55	5.0	2630	544	6.5 "	¾x2.6	¾x.75	1.05
		20.0	.052	.044	3/64"	7600	24000	0.91	0.60	5.2	3280	678	8.0 "	¾x2.7	¾x.85	1.1
		50.0	.070	.100	7/64"	14000	33000	1.25	0.83	6.0	7000	1445	1LB 1 "	¾x30	¾x1.0	1.25
	1x1	10.0	.046"	.030	1/32"	3800	14000	0.64"	0.43"	5.6	1760	364	4.25 oz	1x3.0	1x.75	2.1
		15.0	.048	.035		4800	16000	0.69	0.49	5.8	2310	478	5.5 "	1x30	1x.75	2.1
		20.0	.052	.044	3/64"	5700	18000	0.78	0.52	5.9	2800	580	6.75 "	1x3.1	1x.75	2.2
		50.0	.070	.100	7/64"	11000	25000	1.10	0.75	6.7	6130	1270	15.0 "	1x3.5	1x1.0	2.5
		100.0	.100	.250	1/4"	18000	29000	1.40	0.93	7.4	11000	2280	1LB 10 "	1x3.8	1x1.1	2.75
	2x2	100.0	.100"	.250	1/4"	8900	14000	0.97"	0.65"	10.4	7700	1590	1LB 3oz	2x5.5	2x1.0	14.5
All wound with No. 30 enamelled wire, 103 ohms per 1000 ft. 3287 ft. per lb. Carrying Capacity 0.10 amps.	½x½	0.5	.040"	.017	1/64"	1600	13000	0.55"	0.38"	3.4	450	46	2.2 oz	½x1.6	½x0.63	0.31
		1.0	.041	.019		2300	18000	0.66	0.45	3.6	700	72	3.5 "	½x1.75	½x0.70	0.35
		50	.043	.023		5200	39000	1 00	0.68	4.5	1950	200	9.5 "	½x2.10	½x0.95	0.43
	¾x¾	1.0	.041"	.019		1500	12000	0.53"	0.37"	4.3	540	56	2.7 oz	¾x2.10	¾x0.63	0.87
		5.0	.043	.023		3500	26000	0.83	0.56	5.0	1470	151	7.2 "	¾x2.5	¾x0.80	1.05
		10.0	.046	.030	1/32"	5000	35000	1 00	0.67	5.4	2250	230	11.0 "	¾x2.6	¾x0.95	1.12
	1x1	5.0	.043"	.023		2600	20000	0.71"	0.49"	5.8	1250	130	6.1 oz	1x2.8	1x0.75	2.0
		10.0	.046	.030	1/32"	3800	27000	0.86	0.58	6.1	1940	200	9.5 "	1x3.0	1x0.85	2.2
		15.0	.048.	.035		4800	32000	0.96	0 65	6.4	2550	260	12.5 "	1x3.1	1x0.90	2.25
	2x2	10.0	.046"	.030	1/32"	1900	13000	0.60"	0.42"	9.5	1500	160	7.5 oz	2x4.66	2x0.60	11.5
		15.0	.048	.035		2400	16000	0.68	0.46	9.7	1900	200	9.5 "	2x4.75	2x0.66	12.3
		20.0	.052	.044	3/64"	2900	18000	0.75	0.51	9.8	2400	250	11.5 "	2x4.85	2x0.75	12.5
		50.0	.070	.100	7/64"	5300	24000	1.00	0.70	10.5	4600	480	1LB 6.5 "	2x5.50	2x0.95	14.0
		100.0	.100	.250	1/4"	8900	28000	1.33	0.90	11.2	8300	860	2LB 8 "	2x5.90	2x1.15	16.0
All wound with No. 26 enamelled wire 40.75 ohms per 1000 ft. 1300 ft. per lb Carrying Capacity 0.25 amps	½x½	0.5	.040"	.017	1/64"	1600	32000	0.90"	0.60"	4.2	550	22.5	7 oz	½x2	½x.85	0.40
		1.0	.082	.120	1/8"	3200	32000	1.30	0.85	5.1	1350	55	1LB 1 "	½x2.5	½x1.10	0.50
	¾x¾	0.5	.040"	.017	1/64"	1000	21000	0.72"	0.46"	4.7	390	16	5 oz	¾x2.3	¾x0.71	0.96
		1.0	.041	.019		1500	30000	0.90	0.58	5.1	640	26	8 "	¾x2.5	¾x0.83	1.05
	1x1	1.0	.041"	.019		1100	22000	0.75"	0.50"	5.8	530	22	6.5 oz	1x2.9	1x0.75	2.10
		5.0	.086	.170	11/64"	3700	35000	1.40	0.92	7.3	2260	92	1LB 12 "	1x3.6	1x1.20	2.7
	2x2	5.0	.043"	.023	1/4"	1300	23000	0.82"	0.53"	9.7	1050	43	13 oz	2x4.9	2x0.80	12.7
		10.0	.050	.040	1/64"	2000	32000	1.05	0.68	10.5	1750	71	1LB 6 "	2x5.2	2x1.0	13.8
		15.0	.096	.200	13/64"	3300	28000	1.35	0.86	11.1	3060	125	2 " 6 "	2x5.5	2x1.1	14.7
		20.0	.104	.280	9/32"	4000	32000	1 43	0.95	11.5	3820	156	2 " 15 "	2x5.6	2x1.2	15.2
	3x3	10.0	.046"	.030		1300	22000	0.81"	0.53"	14.0	1510	62	1LB 3oz	3x6.9	3x0.8	39
		15.0	.048	.035		1600	26000	0.90	0.60	14.2	1900	77	1 " 7 "	3x7.0	3x0.85	40
		20.0	.052	.044	3/64"	1900	30000	1.00	0.65	14.4	2300	93	1 " 12 "	3x7.1	3x0.9	41
		50.0	.140	.330	1/3"	5000	28000	1.60	1.10	15.9	6600	270	5 " 2 "	3x7.8	3x1.35	46
		100.0	.200	.600	19/32"	8400	34000	2.10	1.40	17.0	12000	485	9 " 3 "	3x8.3	3x1.65	50
All wound with No. 23 enamelled wire 20.32 ohms per 1000 ft. 648.4 ft per lb. Carrying Capacity 0.50 Amps.	½x½	0.5	0.16"	.35	11/32"	3200	32000	1.80"	1.20"	6.4	1700	35	2LB 10oz	½x3	½x1.45	0.62
	¾x¾	0.5	0.08"	.170	11/64"	1480	30000	1.25"	.83"	6.0	735	15	1LB 2oz	¾x2.9	¾x1.1	1.26
		1.0	0.16	.35	11/32"	3000	30000	1.75	1.20	7.2	1800	37	2 " 13 "	¾x3.5	¾x1.5	1.6
	1x1	0.5	0.04"	.02	1/64"	800	32000	0.90"	0.60"	6.2	410	8.5	0LB 10oz	1x3.0	1x0.85	2.2
		1.0	0.082	.17	11/64"	1600	31000	1.30	0.85	7.1	945	19	1 " 8 "	1x3.5	1x1.0	2.5
		5.0	0.387	.75	3/4"	7800	32000	2.90	1.90	11.0	7000	143	10 " 14 "	1x5.2	1x2.2	4.2
	2x2	1.0	0.041"	.019		560	22000	0.75"	0.50"	9.8	460	9.4	0LB 12oz	2x4.9	2x0.75	12.7
		5.0	0.086	.17	11/64"	1800	32000	1.35	0.90	11.3	1700	35	2 " 10 "	2x5.5	2x1.15	15.0
		10.0	0.184	.40	13/32"	3800	33000	2.00	1.30	12.8	4100	83	6 " 6 "	2x6.2	2x1.5	17.3
	3x3	5.0	0.043"	.023		860	30000	1.00"	0.60"	14.2	1000	21	1LB 10oz	3x7.1	3x0.85	40.0
		10.0	0.092	.20	13/64"	1840	31500	1.40	0.92	15.3	2350	48	3 " 10 "	3x7.5	3x1.15	43.5
		15.0	0.130	.30	19/64"	2620	32000	1.65	1.10	16.0	3500	71	5 " 7 "	3x7.8	3x1.4	46.0
		20.0	0.175	.38	3/8"	3500	32000	1.90	1.25	16.6	4850	99	7 " 8 "	3x8.1	3x1.5	48.0
		50.0	0.432	.80	13/16"	8700	32000	3.00	2.00	19.2	14000	282	21 " 8 "	3x9.3	3x2.3	58.0
		100.0	0.900	1.50	1½"	16700	31500	4.10	2.80	22.0	31000	620	47 " 5 "	3x10.5	3x3.1	68.0

* *The Actual Gap can only be an approximation owing to the many factors which may effect Fringing of flux, permeability of core, etc. It must be adjusted by trial until the proper value of inductance is obtained or better yet, until the set up operates at the best point.*

♣ *The values of (B), the flux density, are those obtained with all D.C & no A C., or the effective B if all A.C. The maximum value in the latter case will be 1.41 x B as given. In the case of rectified A C. applied to coil with no previous smoothing the maximum B may be 1.57 times the values given.*

shoe lacing are good enough to cover the low-voltage leads.

When slipping the coils on the partially-assembled core, be sure that the leads do not touch the core. If the windings fit loosely some small wooden wedges should be driven in place at each end. Last of all, the other leg of the core is put in place and driven up tight. If the coils are wedged firmly and wound tightly and the core is taped, clamped or bolted between some strips of wood or bakelite, the transformer will not hum.

After leaving the primary winding connected to the line for several hours it should be only slightly warm. If it draws much current or gets hot there is something wrong. Some short-circuited turns are probably responsible and will continue to cause overheating and possibly fireworks later.

Designing and Building Choke Coils for the Filter

The design and construction of choke coils to use in filtering the plate supply can be carried out in the same way that the building of a transformer was developed. The basic design principles are the same and the building of a choke coil is even simpler because no taps are necessary and only one coil is required on the core.

The full-page chart shows the dimensions for chokes that will meet most needs of the amateur in filter systems. Chokes of inductances between the values given in the table can be made by using less turns of wire in the winding. Inductance varies about as the square of the number of turns so that using half the number of turns specified gives one-fourth the inductance. More turns than those specified must not be used as the core will become saturated. Dimensions *b* and *c* given in the table can be understood by reference to Fig. 1018. The arrangement of core and winding is supposed to be that of the diagram, also.

The best core material is the same as that specified for building transformers — silicon steel sheet. The laminations should be .014" (or less) thick, covered with shellac or rust to reduce eddy-current losses. Fine iron wire is excellent as a core material, also. While interleaved corners are almost a necessity for a good transformer core, the core of the choke coil should be made with butt joints. An air-gap is needed in any case to prevent saturation of the core and to offer a means for adjustment of the inductance. After the gap is adjusted the core should be clamped firmly so that the magnetic pull will not change the adjustment and to insure quiet operation. Besides clamping the core, a substantial brass "air" gap can be used or a wooden or cloth wedge inserted in the gap to prevent vibration and make the adjustment permanent. The total air-gap, if there is more than one, will of course be the sum of the length of the separate air-gaps.

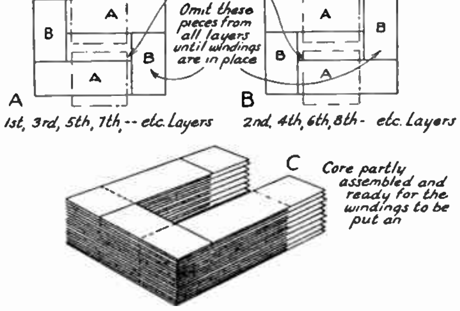


FIG. 1017. — HOW TO PUT A TRANSFORMER CORE TOGETHER

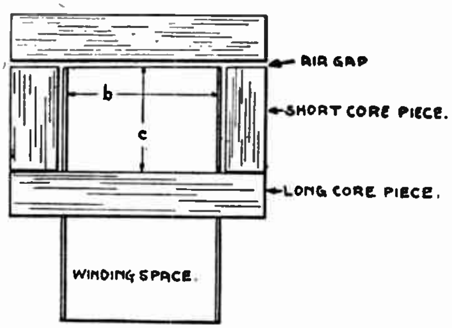


FIG. 1018. — CORE ARRANGEMENT FOR FILTER CHOKE COILS

The dimensions b and c refer to the full-page table.

Wire with thin insulation should be used to make an economical design. Large wire uses a great deal of space without giving much inductance. It is best to wind directly on the core with just a single layer of tape between. More insulation will be required for chokes that are to be placed in high-voltage plate-supply lines but this should not be any thicker than is necessary. Before starting the winding on the core, put some cotton strips along it and fasten some heavy cardboard or thin micarta end flanges in place. After winding the coil, the tape can be tied over it to keep the wire from spreading. Too much tape should not be put on or the choke will not keep cool under load conditions. The wire sizes in the table are conservative and 10% more current can be carried continuously and even more than this intermittently. If the winding is very deep, the cooling will be better if the coil is split into two sections to slip onto each long core piece. 10% more turns will then need to be added to each coil to make up for the magnetic leakage between coils which is increased by splitting the winding. Heavy flexible leads should be soldered to the ends of the coil and taped down to prevent their breaking off.

The simplest way to adjust the air-gap is to connect the filter to the load with which it is to work, changing the gap until the best filter action is observed when listening to the output of the transmitter in the monitor. A too-large air-gap will reduce the inductance and the choke will be ineffective. A too-small gap will allow the core to become saturated, and the choke will be just as ineffective.

The right value for the air-gap is one that uses up about nine-tenths of the ampere-turns of the coil to maintain flux in the gap. The rest of the magnetomotive force magnetizes the core. As the permeability of air is unity and that for sheet steel is about 3,000 (average), the ratio of air to iron can be determined approximately but the iron varies so much that the exact value must always be decided by trial. For a core of 10″ total length, an air-gap of about .05″ or a little less will meet average requirements.

Chapter Eleven

KEYING AND INTERFERENCE ELIMINATION

To UTILIZE the transmitter for telegraphic communication, it is necessary to break up its output into long and short pieces which, at the receiving end, will constitute the desired dots and dashes. There are many simple ways of so breaking up the output of the transmitter, but careful adjustment both of the transmitter and of the keying system usually is necessary to avoid the production of key-thumps, which may interfere with broadcast reception.

Methods of Keying

Keying can be accomplished by any arrangement which reduces the output of the transmitter to zero when the key is "open" and permits full output when the key is "closed." Perhaps the most obvious way of doing this is to put the key in series with one of the plate-supply leads to the tube, as shown in Fig. 111-A. When the key is open the plate power is completely cut off so that there is no output. The keying method shown at (B) is known as "center-tap" keying, because the key is connected between the filament center-tap (which may be the midpoint of a resistor or a center-tap on the filament transformer) and the point where the negative side of the power supply and the grid return circuit are connected together. This system differs from (A) because in addition to breaking the plate supply from the tube, the key also breaks the d.c. return circuit from the grid and thus also prevents the flow of grid current.

In (C) the key breaks only the d.c. grid return circuit, leaving the plate supply connected to the tube at all times. Since the plate power has not been disconnected, the explanation of this method has to be found in the operation of the tube itself, and is as follows: In all oscillators and radio-frequency power amplifiers, the excitation is such that the grid is positive during a part of the r.f. cycle so that electrons are attracted to the grid from the filament. Normally a path is provided for these electrons to flow back to the filament (this electron flow constitutes the d.c. grid current) but if the key is inserted in this return path, the resistance of the path is practically infinite when the key is open. Under these conditions the electrons cannot flow back to the filament and therefore collect on the grid. The electrons trapped on the grid give the grid a negative charge, and in the space of a few r.f. cycles enough of them accumulate to make the grid so negative that plate current cannot flow, thus preventing the tube from oscillating. The success of this method depends upon good insulation in the return path when the key is open, because if there is leakage in the key itself, in the tube socket or in the baseboard to which the parts are fastened, enough electrons can leak off the grid to allow the tube to deliver some output — greatly diminished, perhaps, but still enough to cause an objectionable "back-wave," which means that the transmitter can be heard at reduced strength when the key is open.

Keying through biasing the grid so far negative that plate current cannot flow can also be done by other methods which do not depend upon lack of leakage in the grid circuit. Fig. 111-D shows one system of this type. The grid-blocking voltage necessary to cut off plate-current flow is here supplied by a battery or "B" eliminator. When the key is open the full blocking voltage is applied to the grid through the resistor *R;* when the key is closed the blocking voltage is short-circuited, so far as the grid of the tube is concerned. Resistor *R* is in the circuit simply to prevent actual short-circuiting of the blocking-voltage source. It should be of such value as to limit the current flow to a few milliamperes when the key is closed — roughly 5000 ohms for each 50 volts of bias. The extra bias or blocking-voltage required in this keying method will depend upon the type of tube, the plate voltage, and the excitation. In normal oscillator or amplifier stages a first approximation would be a blocking voltage equal to the plate voltage divided by ⅓ the amplification factor, or μ, of the tube. The actual value of bias required may be somewhat more or less than this, and had best be determined by experiment.

The system shown at (E) is similar to that at (D), but in this method the blocking bias is obtained from the plate supply through a voltage divider. The center-tap of the filament and the grid return to the negative side of the power supply are connected to the junction of R_1 and R_2, so that when the key is open the voltage drop across R_2 is applied as bias to the grid of the tube. With the key closed, R_2 is short-circuited. R_1 may be the regular power-supply bleeder. R_2 should have about half the resistance of R_1 in practically all cases.

In any of these diagrams the center-tapped resistor across the filament supply may be omitted if the filament transformer winding is center-tapped. Simply connect the center-tap of the winding to the wire which in these diagrams goes to the midpoint of the resistor. If a storage battery is used to light the transmitting-tube filament, the center-tapped resistor may be

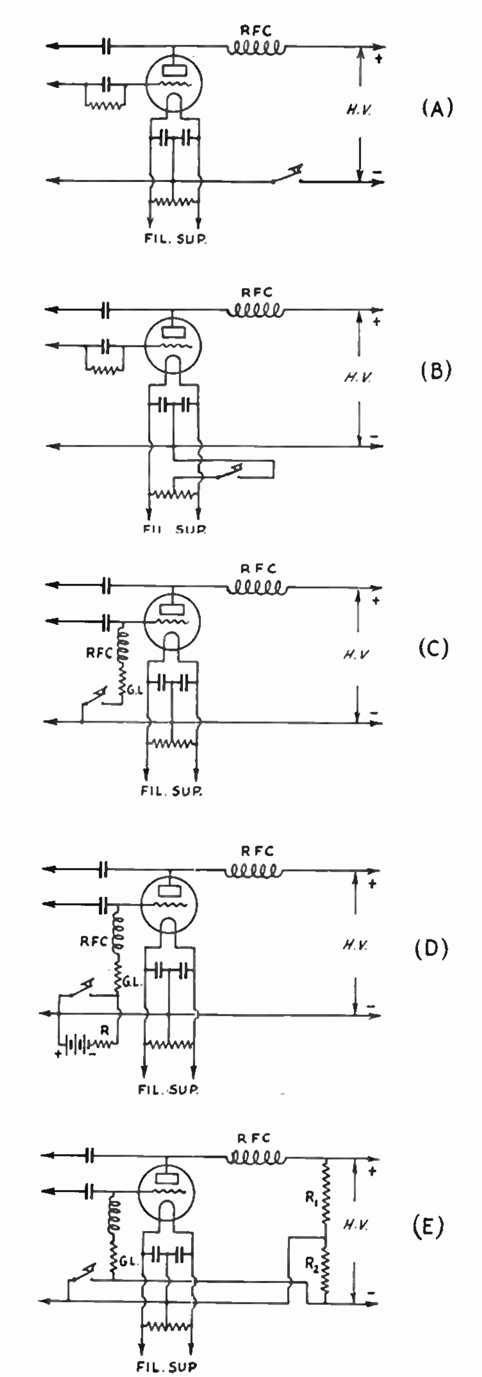


FIG. 111. — FIVE METHODS OF KEYING AN OSCILLATOR OR AMPLIFIER

(A) Plate keying; (B) Center-tap keying; (C) Grid-leak keying; (D) Blocked-grid keying with additional bias supplied by batteries; (E) Blocked-grid keying with additional bias supplied by voltage divider in plate supply.

omitted and the connection which goes to its midpoint should be connected to the negative terminal of the filament. The by-pass condensers across the filament will not be necessary.

Although the foregoing keying methods or adaptations of them are almost universally used by amateurs, other arrangements occasionally are encountered. Generally these operate on the r.f. circuits in such a way as to detune the circuit when the key is open, thus reducing the output, or by actually breaking a radio-frequency lead. Such arrangements have several disadvantages which have prevented their being adopted to any extent.

Keying Multi-Stage Transmitters

With an oscillator-amplifier transmitter it is generally preferable to allow the oscillator to run continuously and key the amplifier. If the amplifier has more than one stage, it is good practice to key in one of the low-power stages before the final amplifier is reached, since this lessens the possibility of emitting a back-wave and is not so productive of key-clicks as keying the final tube. In a multi-stage crystal-controlled transmitter with doubling amplifiers, one or more of the doubler tubes should be keyed.

The keying methods shown in Fig. 111 may be applied to any tube in a multi-stage transmitter, but in certain cases a slight rearrangement of the connections may be necessary. For instance, negative high-voltage keying, Fig. 111-A, cannot be used on a single stage if a common plate and filament supply is used for all stages, because the plate voltage would be removed from all stages simultaneously. The key should be placed in the positive lead to the tube which is to be keyed (a bad thing to do unless a keying relay is used, because of danger from shocks) or, better, a separate filament transformer can be installed for the keyed tube. A separate filament transformer or winding also is necessary with center-tap keying, *B*, and the blocked-grid arrangement at *E*. The methods shown at *C* and *D* do not require separate plate or filament supplies for the keyed stage.

Key Clicks

While for communication purposes keying methods which break up the output of the transmitter are all that is required, it is unfortunate that some highly undesirable effects can accompany the use of simple keying systems such as are shown in Fig. 111. Chief of these is the phenomenon of key clicks. Sudden starting of oscillations produces transient side-bands which theoretically will extend over the entire frequency spectrum if the oscillations rise to their full value in an infinitesimally small space of time. The amplitude of these side-bands can be quite large, but they are of very short duration — so short, in fact, that they can be heard only as a click. Because the energy is spread over an extremely wide range of frequencies, the clicks generally are not heard at appreciable distances, but in nearby receivers their effect may be quite pronounced. A somewhat similar phenomenon takes place when oscillations are stopped, as when the key is opened, but the key-click from opening the key usually is much weaker than the click at closing. Clicks not only cause interference with amateurs whose receivers are tuned near the frequency of the transmitter causing them, but also with broadcast reception in the immediate neighborhood. The clicks will be strongest near the transmitter frequency, gradually losing their amplitude at frequencies farther removed.

The problem of key-click elimination is that of preventing the undesired side-bands from being produced. To do this it is necessary to cause the oscillations to build up gradually from zero to full amplitude. This may be done by applying various types of electrical filters, the simplest of which is an inductance in series with the key. Inductance has the property of opposing the sudden rise of current. In all of the keying methods described in the foregoing paragraphs it is necessary for direct current to flow through the key circuit before oscillations can build up; an inductance of a few henrys will oppose the sudden rise of current to a sufficient extent to prevent oscillations from starting too rapidly.

Key clicks can be reduced in transmitters with several amplifier stages by keying one of the low-power tubes. The side-bands will be filtered off to a considerable extent in passing through the tuned circuits in the succeeding amplifier stages — the same effect that occurs in broadcast receivers in which freedom from interference is obtained by passing the signal through a number of tuned amplifier stages. In transmitters with large power output, however, this type of filtering may not be sufficient, and additional elimination methods must be applied to the keyed stage.

Key-Thump Filters

Arrangements which prevent the sudden building up of oscillations have become known as "lag" circuits — a term quite descriptive of their operation. The use of an inductance in series with the key has already been mentioned. It is not necessary to put it directly in the key circuit, however; it may be placed in any part of the circuit in which direct current flows, as in series with the plate supply or in series with the grid leak or bias battery, even though the key is in some other part of the circuit. Exact values for the inductance usually have to be determined by experiment. It should be large enough to prevent clicks, but should not be so large that the oscillations will build up too slowly to permit clean keying. Values between 5 and 50 henrys usually will be found satisfactory. Small transformers, such as those used for bell-ringing, often will work nicely with transmitters using one or two 10's. A variable resistor can be connected across the inductance to enable the operator to adjust the impedance to the best operating value.

Arcing at the key contacts is quite common, since the direct current flowing through the key tends to "hang on" at the instant of breaking contact, and is not only bothersome but sometimes a source of interference. Arcing is likely to be more pronounced when an inductance is used in series with the key to introduce a lag, because the sudden collapse of the magnetic field about the inductance when the current is broken generates a voltage high enough to jump the small gap between the key contacts at the instant of opening. If a condenser is connected across the key contacts, the voltage will charge the condenser instead of causing an arc between the key contacts. The condenser capacity required will depend on the amount of energy to be absorbed, values between .5 and 1.0 μfd. usually being sufficient. The charge accumulated on the condenser when the key is opened will cause an arc to form when the key is closed, unless a resistor of suitable value is connected in series with the condenser. The resistance must be low enough to allow the condenser to charge up quickly and absorb the spark when the key is opened, and yet large enough to dissipate most of the energy in the condenser when the key is closed so no spark will appear at the contacts. A 500- or 1000-ohm variable resistor will usually suffice.

Practical ways of introducing lag circuits are shown in Fig. 112. Many variations of these circuits are possible, of course.

Clicks will be much more serious if the plate supply has poor regulation — characteristic of all plate supplies with condenser input filters. The reason for this is that with no load on the plate-supply apparatus the condensers of the filter system become charged to the peak voltage of the transformer. Then, when the plate voltage is applied, the tube not only starts oscillating suddenly but starts oscillating with abnormal force because of the peak voltage which accumulated in the filter. This peak voltage is soon reduced to normal, but the result will have been a heavy key-thump.

A plate supply with good regulation will minimize this effect. A drain or "bleeder" resistor connected across the output of the plate supply and having a value such that it imposes a continuous load of about 25% of the normal transmitter load will be found helpful in cutting down the peak voltage if the regulation is poor. A more satisfactory solution is to use a choke-input filter with a suitable bleeder, a combination which results in very good regulation. This subject is covered in detail in Chapter Ten.

Another keying method which has attained a good deal of popularity is shown in Fig. 113. In this system a vacuum tube is placed with its plate-filament circuit in the center-tap of the tube to be keyed, while the key itself is in the grid circuit of the auxiliary or "keyer" tube. When the key is open, high negative bias is placed on the grid of the keyer tube so that the plate current is completely cut off; when the key is closed the grid of the keyer tube is connected to its filament and the tube acts like a resistance of low value, thus permitting plate current to flow to the oscillator or amplifier being keyed. The mechanism by which the lag is introduced in this circuit is not apparent, but tube keyers have been markedly successful, especially in low-power transmitters. The keyer tube has some resistance even though the grid is connected to the filament, so the plate voltage on the oscillator or amplifier will be lower than with other keying systems. To overcome this several tubes may be connected in parallel. Tubes of the 45 type are excellent for low-power transmitters because their plate resistance is low. One 45 should be used for each 50 ma. of plate current required by the tube being keyed. The filament transformer for the keyer tubes need not be center-tapped; in fact, the filaments may be connected in series if desired. The blocking bias is obtained by utilizing the drop in a resistor in series with the high-voltage supply.

It is impossible to cover in this *Handbook* all the methods of key-click elimination which have been proposed from time to time, but suggestions are regularly published in *QST* which often may be successfully applied to the particular conditions existing in one's own transmitter.

Interference with Broadcast Reception

The wide distribution of broadcast receivers makes it unlikely that any amateur, unless in an isolated location, can ignore the possibility that his transmitter will cause interference with broadcast reception in his vicinity. This, while serious enough not only because most of us desire to live on good terms with our neighbors but because it can cause a great many people to take an antagonistic attitude toward amateur radio, is fortunately not impossible of solution. Should interference be caused, an understanding of the several types that exist will make it easier to apply the proper corrective measures.

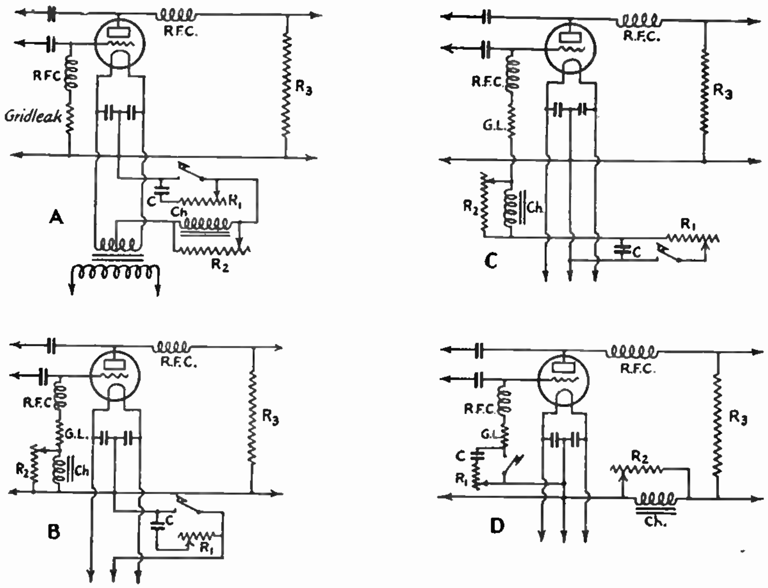


FIG. 112. — HOW LAG CIRCUITS MAY BE ADDED TO SOME REPRESENTATIVE KEYING METHODS

In all circuits the condenser-resistor is connected across the key, as shown in the other diagram. In "A" the inductance-resistor is in series with the key, which in this case (center-tap keying) breaks the full plate current. The choke must therefore be capable of carrying this current. In "B" (also center-tap keying) the choke is placed in series with the grid leak, and should be capable of carrying about 10% of the plate current. In "C" the lag circuit is applied to grid-leak keying. The choke should have the same current-carrying capacity as at "B." Grid-leak keying is also used at "D," but the choke is in the negative high-voltage lead, and therefore must carry the full plate current. The actual values of capacity, inductance and resistance must be determined by experiment, as explained in the text. These are by no means all the combinations which could be worked out, but simply illustrate the principles involved.

Interference with broadcast reception usually falls into three separate classes. The first, and most common, is that of key clicks, which already have been treated in this chapter. This type of interference is usually heard over the whole tuning range of the broadcast receiver, or if not over the whole range will be more intense at the high-frequency end of the broadcast band. Key clicks are not *tunable*, that is, they are not heard at definite frequencies with interference-free areas between. The key-thump filters described previously should eliminate this type of interference.

The second type of interference is that known as "blocking," or "blanketing." This is not so common now as it was when broadcast receivers were generally unselective, but occasionally will be encountered if the receiver is old or if the broadcast antenna is too close to the transmitting antenna. It can be readily recognized because the program disappears or is much reduced in strength when the key is closed, and is the result of overloading of the tubes in the receiver by the energy picked up from the transmitting antenna. This type of interference can be minimized by moving the broadcast antenna away from the transmitting antenna or by changing its direction. The pick-up will be least if the two antennas are at right angles to each other. In severe cases it may be necessary to install a wave-trap at the receiver to prevent blanketing.

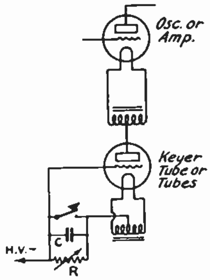


FIG. 113. — A VACUUM-TUBE KEYING METHOD TO PREVENT CLICKS

One or more keyer tubes may be used; the larger the number the greater the plate current that can be safely passed. Condenser C may be between .25 and 1.0 μfd. Resistor R should be adjusted to cause the plate current to drop to zero when the key is open. A variable resistor of about 50,000 ohms should give enough range.

A wave-trap consists simply of a coil and condenser connected as shown in Fig. 114. The condenser may be an old one with about 150 or 350 μμfd. maximum capacity and need not be especially efficient. Most amateurs have "junk boxes" with several such condensers in them. The size of the coil will depend upon the frequency on which the transmitter is working. Representative values are given in the table.

Frequency of Interfering Signal	*Coil (3" dia.)*
1,715–2,000 kc.	20 turns
3,500–4,000 kc.	8–10 "
7,000–7,300 kc.	4–5 "
14,000–14,400 kc.	3 "

Bell wire (No. 18) or a size near to it may be used. When the trap is installed the transmitter should be started up and the condenser in the trap adjusted to the point where the interference is eliminated. This trap will not affect the operation of the broadcast receiver.

Blanketing may be and generally is accompanied by key clicks. The wave trap may help to eliminate the clicks but usually a key-click filter will be needed as well. A key-click filter alone cannot eliminate or even alleviate the blanketing effect.

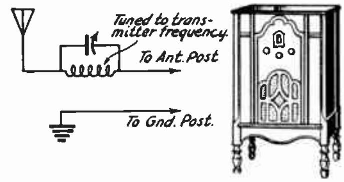


FIG. 114. — HOW A WAVE-TRAP CAN BE INSTALLED TO PREVENT CERTAIN TYPES OF INTERFERENCE

The third type of interference is peculiar to superheterodyne broadcast receivers, and is never encountered with tuned r.f. sets. A strong signal from the transmitter will be heard at three or four points on the dial, while over the rest of the tuning range there may be no sign of interference. The explanation is not difficult to follow if one understands the operation of the superheterodyne receiver as outlined in Chapter Four. The superheterodyne oscillator, the output of which is mixed with the incoming signal to form the intermediate frequency signal, generates harmonics just as does any other vacuum tube oscillator. These harmonics, at some setting of the broadcast receiver dial, will fall near the amateur bands, and if an oscillator harmonic happens to be just far enough removed from the transmitter frequency to give a beat equal to the intermediate frequency, a signal from the transmitter will be heard in just the same way as an ordinary broadcast signal. If the receiver is properly shielded and the oscillator is isolated from the antenna circuit, the signal from the transmitter cannot get into the oscillator circuit to be mixed with its harmonics and this type of interference cannot occur. When it *does* occur the fault does not lie with the transmitter but with the broadcast receiver, and nothing can be done to the transmitter to prevent such interference. It is unfortunate that the recent craze for cheap superhets of the midget variety has caused manufacturers to cut down costs to such an extent that this type of interference is quite likely to be encountered. These receivers cannot be called "modern" in the right sense of the word, and the amateur operator is entirely blameless if interference is caused. A wave-trap may help if the transmitter signal is brought into the receiver through the antenna, but in some cases the pick-up is direct because of lack of oscillator shielding, and the interference is just as strong whether the antenna is connected to the receiver or not.

One's own broadcast receiver, if of modern design, is a good "subject" for experimenting with key-click filters and other interference-prevention methods. If interference can be eliminated in a receiver in the same house, operating from the same power line and with an antenna close to the transmitting antenna, the chances are good that there will be no general interference in the neighborhood. The amateur should ascertain, however, whether or not interference is caused in nearby broadcast receivers. If your neighbors appreciate that you are as much interested in preventing interference to their enjoyment of broadcast programs as they are, much more can be accomplished than by acrimonious disputes. It is better to settle the interference problem right at the beginning than to trust to luck with the possibility of an unfavorable reaction towards amateur radio in general and yourself in particular on the part of nearby broadcast listeners.

In searching for causes of interference, it is a good idea to have someone operate your transmitter while you listen on the affected receiver. Remove the antenna from the receiver, and if the interference disappears it is certain that it is coming into the set through the antenna, which simplifies the problem. The various types of interference prevention already described should work under these conditions. If the interference persists when the antenna is removed, however, it is probably getting into the receiver through the power lines. This happens occasionally with a.c. operated broadcast receivers.

House wiring may pick up r.f. either directly from the antenna or through the power-supply system of the transmitter. If the 110-volt line is found to be picking up energy directly from the antenna it is advisable to change the location of the antenna, if possible, or run it in a different direction, not only because of interference to broadcast reception but because energy so picked up is useless for radiation and decreases the effective range of the transmitter. This is particularly important when, as often happens, electric lamps in different parts of the house are found to glow when the key is pressed. The energy used in lighting the lamps is wasted.

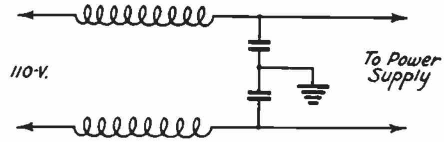


FIG. 115. — R.F. SUPPRESSORS FOR THE POWER LINE

A combination of choke coils and condensers, the construction of which is described in the text, may be connected in the power line before the plate-supply equipment is reached, to prevent r.f. from feeding back from the transmitter to the line and thus causing interference with broadcast listeners.

If the r.f. is getting back through the transmitter power-supply system radio frequency choke coils should be connected between the 110-volt outlet and the power transformer, at the transmitter. The wire of which the chokes are wound must be heavy enough to carry the current taken by the power-supply system. No. 14 or No. 16 will be sufficient in most cases. Mailing tubes make good winding forms for these chokes. Between 100 and 300 turns will be required, depending on the transmitter frequency. Tuned traps of the construction described previously may be used instead of the chokes. A pair of condensers connected in series across the line with the mid-connection grounded will often improve the results. Paper by-pass condensers such as are used in receivers (about 0.1 μfd.) rated at 200 volts or more will serve. Fig. 115 shows how the chokes and condensers should be connected.

Power transformers with electrostatic shields between the primary and secondary windings are helpful in preventing r.f. from getting into the supply lines, provided the shield is connected to a good ground, and often will make extra chokes and condensers unnecessary.

When an a.c. broadcast receiver and the transmitter are on the same 110-volt line interference may be caused when the transmitter is keyed because the load is being rapidly thrown on and off the tube, resulting in a voltage variation which appears as a noise in the broadcast receiver. Such interference can only be eliminated by reducing power or by transferring the load to a part of the line which is more lightly loaded and sufficiently removed from the receiver so that the fluctuations in load will not affect reception. If the load is heavy it may be necessary to have a separate line installed for the transmitter.

Interference usually decreases as the transmitter frequency is raised. In many cases where bad interference is caused on the 1750- and 3500-kc. bands, changing to 7000 or 14,000 kc. will cure it. If none of the usual methods is wholly effective a reduction in power often will allow the station to be worked during quiet hours without bothering the neighbors. It is a little unreasonable to expect that interference can be entirely eliminated when it is caused by a high-power transmitter whose antenna is only a few feet from broadcast receiving antennas. With the average amateur transmitter using a Type 10 or even a Type 52 tube a satisfactory solution to the interference problem can in most cases be reached by the intelligent application of one or more of the methods described above.

Rectifier Noise

Mercury-vapor rectifiers often are the source of a peculiar and easily identifiable type of interference, taking the form of a raspy buzz with a characteristic 120-cycle tone (100 cycles on 50-cycle power lines and 50 cycles on 25-cycle lines) which is usually broadly tunable in spots on the broadcast receiver dial. The cause lies in the fact that at the instant the mercury vapor ignites on each half cycle of the power frequency a small oscillation is set up, the frequency depending upon the characteristics of the power supply apparatus. Unless suitable precautions are taken the oscillations will travel back over the power line and be detected in receivers connected to the line.

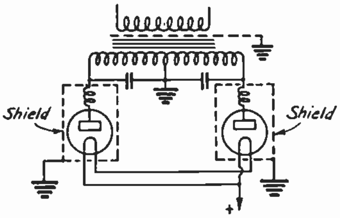


FIG. 116. — DEVICES FOR ELIMINATING NOISE FROM MERCURY-VAPOR RECTIFIER TUBES

The r.f. chokes in series with each plate should be placed inside the shields enclosing the rectifiers. The chokes should have an inductance of about 10 millihenrys each. Small honeycomb-type windings are suitable.

The line filter shown in Fig. 115 usually will suppress this type of noise without difficulty. Sometimes the condensers alone will do it, no chokes being necessary. Transformers with electrostatic shields between primary and secondary are not likely to transmit the oscillations to the line. Other ways of curing this type of interference are shown in Fig. 116. They include shielding of the rectifier tubes, connecting a radio-frequency choke between each plate and the transformer winding, and shunting fixed condensers of about .002-μfd. capacity between the outside ends of the transformer winding and the center-tap. The condensers should be rated to stand at least 50% more voltage than the r.m.s. voltage delivered by half of the secondary winding.

Radiophone Interference

Key-click filters are naturally of no value on transmitters used exclusively for 'phone transmission, since clicks do not occur. A phenomenon similar to key clicks can take place if the transmitter suffers from frequency modulation or from over-modulation because both these defects cause the radiation of side-bands often far removed from the band of frequencies normally required for the transmission of speech. These abnormal side-bands can and frequently do cause interference in the broadcast band, often just as a series of unintelligible noises when the transmitter is modulated. The obvious remedy is to use a radio frequency system in the transmitter whose frequency does not vary when modulation is taking place, and to adjust the transmitter so that over-modulation or "lop-sided" modulation does not occur. Chapter Eight covers this subject thoroughly.

Blanketing and other forms of interference caused by r.f. pickup can be treated in exactly the same way as described previously. Wave-traps in the receiving antenna lead-in and r.f. filters in the power lines will prove effective in eliminating this type of interference.

Miscellaneous Interference

Amateurs are often unjustly blamed for code interference. Foreign ships and commercial radiotelegraph services sometimes cause bad interference to radio broadcasting. This may be cured in many cases by long-wave traps similar to those already described for short-wave work. Power leaks from electrical distribution systems, disturbances from thermostats in heating pads, flatirons and oil heaters; interference from street car lines, dial telephones, loose electric lamps, ignition systems, vibrating battery chargers, mechanical rectifiers, and violet-ray apparatus are other possible sources of interference, not to mention the neighbor who operates a "blooper" (an oscillating receiver which itself is a miniature transmitter without a license). Many of the broadcast receivers sold to-day are still not properly selective. All this points to the conclusion that the broadcast listeners as well as the amateur concerned must approach the interference problem with an open mind and a coöperative attitude.

Quiet Hours

In most cases interference can be prevented by the use of key-click filters or some of the other simple devices described. If the amateur is unable to solve the problem, quiet hours must be observed from 8:00 p.m. to 10:30 p.m. (local time) and on Sunday mornings between 10:30 a.m. and 1:00 p.m. upon the frequencies which cause such interference. The regulations state that the station must "cause general interference with broadcast reception on receiving apparatus of modern design" before quiet hours are obligatory. In effect, if a good many receivers are in the vicinity and only one or two of them experience interference, the inference is that the broadcast receiver is at fault, and not the transmitter. Likewise interference with a non-selective broadcast receiver is not sufficient cause for compulsory observance of quiet hours. The amateur should coöperate with such listeners to the fullest possible extent, however, and his aim should be to eliminate interference at *all* hours of the day with reasonably good broadcast receivers.

Keying Chirps

The importance of frequency stability in transmitters — that is, the ability to hold to one frequency in spite of changes in plate voltage — has been stressed in Chapter Seven. Since most key thump filters in effect vary the voltage applied to the tube from zero to full voltage rather slowly, an unstable transmitter will exhibit a considerable change in frequency in the fraction of a second during which the voltage is increasing. This rapid change in frequency gives the signal a "yooping" sound or chirp which makes it annoying to listen to and difficult to copy. Self-controlled oscillators are especially subject to keying chirps unless carefully adjusted. High-C circuits such as those described in Chapter Seven are beneficial. Chirps are rarely present in well-designed oscillator-amplifier and crystal-controlled transmitters.

Keying Relays

When the key is so placed in the circuit that the current through it is more than 150 milliamperes or so, or in systems such as those shown in Fig. 111 at (A), (B) and (E) with plate voltages of 1000 or over, the use of a keying relay is recommended both for the sake of the key contacts and to avoid accidental shocks. When a relay is used the key is placed in a low-voltage circuit which is incapable of causing damage either to the key or to the operator.

A keying relay can be made easily from an old telegraph sounder. The magnets should be carefully insulated from the frame, and two additional binding posts should be added to the device to make it easy to connect to the contacts. Flat silver slugs measuring ¼" x ¼" x ⅙" thick make dependable contacts, and will be heavy enough to key any amateur transmitter. These can be fitted into notches filed in the armature and frame of the sounder and soldered in place. The armature and frame must be insulated from each other; if the sounder has a metal base it should be removed and a new one made of bakelite or a similar substance substituted. A piece of copper braid or a thin brass spring should be connected between the U-shaped part of the frame and the armature so that the pivots do not carry any current. In addition it will be necessary to fasten a bit of insulation between the armature and the back-stop screw to keep the armature from closing the circuit when the key is open. This can be threaded and glued to the back-stop screw itself or may be part of the armature. The relay may be operated from a storage battery or a few dry cells. It can be adjusted to work well at almost any desired speed without bad sparking or sticking.

Automobile generator cut-outs can also be transformed into keying relays for low-power transmitters. They can be obtained for a dollar or so from any automobile supply house. A connection should be brought out from each of the contacts to take the place of the key in the transmitter, care being taken to see that the windings on the cut-out do not connect to either of the contacts. There are two windings on the magnet, one of which has only a few turns of coarse wire, the other having many turns of fine wire. The latter winding will usually operate the armature satisfactorily from a 6-volt battery, but if not both windings can be removed and a new one put on, using as much No. 30 d.c.c. wire as can be put in the space. Such a relay is very fast in operation and will follow a "bug" key at high speeds.

Ready-made keying relays can be obtained from several concerns advertising in this *Handbook* and in *QST*. Several different types, designed to operate under different conditions, are available.

Break-In Operation

The ability to "listen in" in between the dots and dashes of one's own transmissions makes for speedier communication, especially when interference is bad, because the receiving operator can indicate to the transmitting operator, by holding down his key for a few seconds, that he wants to "break" or interrupt the transmissions. Break-in operation is comparatively easy if the transmitter is a simple self-controlled oscillator. A separate antenna should be used for receiving, and although in most cases it will be impossible to hear signals when the transmitter key is closed the receiver will be in operating condition within a fraction of a second after the key is up. The only objection to this method is the heavy thump in the headphones which results from listening to the transmitter. To minimize pick-up from the transmitter the receiving antenna should be short and should be run at right-angles to the transmitting antenna. If a keying relay is used, it may be equipped with an extra set of contacts which will short-circuit the receiving antenna to ground when the transmitter is keyed, although this may not prove of very great benefit unless the receiver is well shielded. A separate relay connected in the key circuit will serve the same purpose.

Oscillator-amplifier or crystal-controlled transmitters in which the oscillator is allowed to run continuously during a transmission do not permit break-in operation so easily as self-controlled sets. Satisfactory break-in can be secured, however, if a time-delay circuit is used in conjunction with the key so that the oscillator plate voltage is applied the instant the key is pressed but is

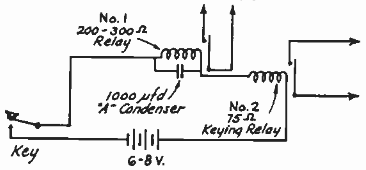


FIG. 117. — BREAK-IN SYSTEM FOR OSCILLATOR-AMPLIFIER OR CRYSTAL-CONTROLLED TRANSMITTERS

Two relays are required, one for keying and one for controlling the oscillator plate voltage. Time-delay action is secured by using a high-capacity condenser in shunt with the plate relay.

not released until after the key has been open for one or two seconds. This will keep the oscillator running during the normal pauses between dots and dashes or words and sentences, but a slightly greater than normal pause will shut off the oscillator so that signals can be heard. Fig. 117 shows a simple method of accomplishing this, using parts which are not difficult to obtain.

Two relays are used, one with low resistance for the regular keying and the other with high resistance for the time-delay circuit. The condenser across the latter relay is a 1000 μfd. electrolytic condenser of the type used in "A" eliminators. The two relays are connected in series. When the key is pressed both relays close instantaneously, and the condenser charges to a potential equal to the voltage drop across the oscillator relay. When the key is opened the keying relay opens immediately, but the other relay will stay closed for a second or so because the charge on the condenser keeps the coil magnetized. A suitable relay for this purpose can easily be made from a high-resistance telegraph relay or sounder, rewound if necessary to the desired resistance.

Remote Control

If the location is such as to allow the transmitter to be installed some distance from the receiver, the transmitter may be remotely controlled. This will make it easy to use break-in and save worrying about losses in poor dielectrics which are certain to be in the field of the lead-in or feeders if brought right down to the operating room.

In a remotely-controlled installation, relays can be used in one of several ways depending on the distance and the individual application. The problem is merely one of turning the filament-heating and plate-supply power on and off and keying the transmitter, using a minimum number of relays and as small an amount of wire as possible.

One simple method of using two relays, requiring the use of only three wires, is shown in Fig. 118. With this arrangement the filaments of the rectifier tubes can be lighted before the plate transformer is connected and can be allowed to remain lighted during an entire period of communication, which is good practice.

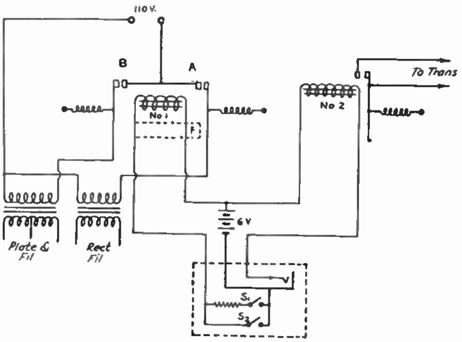


FIG. 118. — A SUCCESSFUL REMOTE-CONTROL SYSTEM

Only three wires need be used between the operating table and the transmitter. The part of the circuit enclosed in the dotted rectangle is the only part within reach of the operator. In practice, Relay No. 1, which has two sets of contacts, is adjusted so that the contacts at "A" will close when S_1 is closed, the contacts at "B" remaining open. The latter contacts close when S_2 is closed. Such a relay may be home-constructed with two separate armatures, the spacing between the armatures and the pole pieces and the tension on the springs being adjusted for proper operation. Relay No. 2 is the keying relay. This arrangement permits the filaments of the rectifier tubes to be lighted before the plate load is thrown on. S_1 may be left closed during a period of communication, thus keeping the rectifier tubes ready for instant operation.

All relay contacts should be large enough to avoid the possibility of sticking if the set is remote-controlled. The outfit also must be built substantially and adjusted to operate stably. If a motor-generator is used an automatic starting compensator operated by a suitable relay will be necessary for starting up the set.

Chapter Twelve

ANTENNAS

THE antenna equipment of the amateur station is no less deserving of consideration than the transmitter or receiver, since the finest of apparatus inside the station can easily be nullified by a poorly designed and carelessly erected aerial system. Although almost any sort of antenna usually serves well enough for receiving purposes, no degree of care in design and construction is too great where the transmitting antenna is concerned, for in almost every case the station's transmitting effectiveness will be directly proportionate to the care and effort expended in constructing the transmitting antenna. And this is true in some degree for the receiving antenna as well, because the sensitivity and selectivity — particularly the selectivity — of even the best high-frequency receiver can be improved by substituting a well designed antenna for the usual nondescript scrap of wire hung up anywhere.

One of the best ways of guaranteeing a good receiving antenna is to use the tuned transmitting antenna for receiving also; another is to use some simple modification of the more elaborate transmitting arrangements, such as the doublet shown in Fig. 121, equipped with a twisted pair (lamp-cord) as a feeder and loosely coupled to the input inductance of the receiver by a tuned or untuned coupling coil. The dimensions of the antenna and feeder components correspond with those of the transmitting antennas of a similar type which are described later.

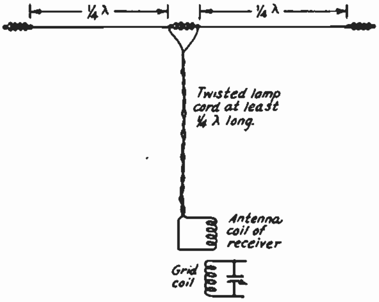


FIG. 121 — DOUBLET RECEIVING ANTENNA

Before any attempt is made to explain how the transmitting antenna systems operate, or to describe their construction, it is necessary to differentiate between the terms "antenna" and "antenna system." The treatment of short-wave antenna systems in understandable and explicit language is a difficult enough business but at least it is simplified to some extent if we can talk of the antenna — meaning that portion of an antenna system which is intended to do the radiating of energy into space — and so separate it from the feeders and other adjuncts of the antenna system which would otherwise so complicate the discussion.

Types of Antennas

Notwithstanding the great variety of antenna *systems* to be seen in operation, the antennas are, for all practical purposes, of but two distinct types. Those in which the ground is an essential part are known as Marconi antennas. In some cases antennas of this type are connected directly to a ground system but in others the connection is obtained through the capacity to ground of an extensive counterpoise. The second type of antenna is the Hertz antenna, in the operation of which the ground does not play an essential part. The Hertz antenna is not connected directly to ground and, in its purest form, consists of a single wire suspended sufficiently high above the earth or earthed objects to have an inconsequential capacity to ground. The Hertz antenna, though it was originally used by the experimenter after which it was named nearly half a century ago, is now used almost exclusively for short-wave transmission.

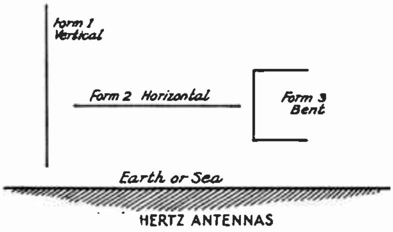


FIG. 122 — THREE FORMS OF HERTZ ANTENNAS

A single wire such as that comprising the Hertz antenna, irrespective of whether it is vertical, horizontal or bent into a V or other shape, Fig. 122, has inductance, capacity and resistance in much the same way as the tuned circuits of the transmitter have inductance, capacity and resistance. The Hertz antenna is therefore really a simple oscillatory circuit having a natural frequency in the same way that the tuned circuits of the transmitter have natural frequencies. The chief difference is that in the antenna the inductance, capacity and resistance are distributed throughout its length, whereas in the transmitter tuned circuits they are concentrated or lumped. The Hertz antenna is known as an open oscillatory circuit and has the ability to radiate effectively the energy oscillating in it. The tuning circuits in the transmitter are known as closed oscillatory circuits and have a very limited ability to radiate the energy in them.

In order to calculate the natural frequency of a closed oscillatory circuit it is necessary to use a relatively complex formula in which the capacity and inductance in the circuit are involved. In an open oscillator of the type of the Hertz antenna, however, there exists a very simple relation between the natural period and the length of the wire. The natural wavelength of the wire (the highest wavelength at which it will oscillate) will be its length in meters multiplied by a factor between 2.1 and 2.07. If the velocity of an electric wave on a wire were always 300,000,000 meters per second (the approximate velocity in free space and the velocity on which all wavelength specifications in this book are based) the natural wavelength of the wire would be exactly twice the length of the wire in meters. The velocity of a wave on a wire is always something less than the velocity in free space, however, and the natural wavelength is therefore slightly greater than twice the length of the antenna.

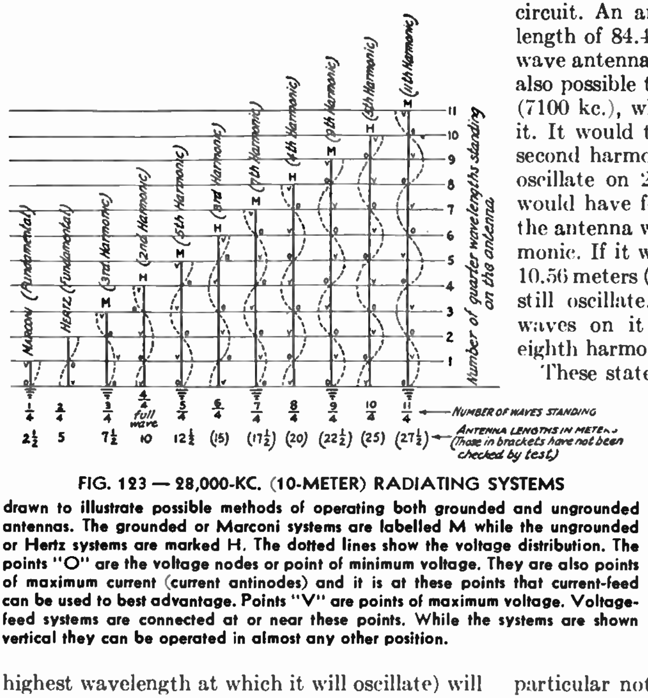


FIG. 123 — 28,000-KC. (10-METER) RADIATING SYSTEMS

drawn to illustrate possible methods of operating both grounded and ungrounded antennas. The grounded or Marconi systems are labelled M while the ungrounded or Hertz systems are marked H. The dotted lines show the voltage distribution. The points "O" are the voltage nodes or point of minimum voltage. They are also points of maximum current (current antinodes) and it is at these points that current-feed can be used to best advantage. Points "V" are points of maximum voltage. Voltage-feed systems are connected at or near these points. While the systems are shown vertical they can be operated in almost any other position.

From this it can be seen that the highest wavelength to which a Hertz antenna tunes — its natural wavelength — is approximately twice its length in meters. In other words, the length of the antenna is about half the wavelength to which it tunes. This simple relation makes it very useful to speak of wavelengths instead of frequencies when explaining the action of antennas, and this practice will be adopted in this chapter. At the same time the relationship between wavelength and frequency should be kept in mind continually.

The fact that a Hertz antenna is approximately half as long as its fundamental wavelength makes it convenient to refer to such an antenna, operated on its fundamental, as a half-wave antenna. This, however, is not the only way in which it can be operated. In the same way that the tuned circuits of the transmitter will oscillate at harmonics of their fundamental wavelengths or frequencies, so the Hertz antenna will oscillate at its harmonics and far more readily than a closed circuit. An antenna with a fundamental wavelength of 84.46 meters (3550 kc.) will be a half-wave antenna at that wavelength. However, it is also possible to make it oscillate on 42.23 meters (7100 kc.), when it will have two half-waves on it. It would then be said to be operated at the second harmonic. The same antenna would also oscillate on 21.11 meters (14,200 kc.), when it would have four half waves on it. In this case the antenna would be working on the fourth harmonic. If it was fed from a transmitter tuned to 10.56 meters (28,400 kc.) this same antenna would still oscillate. It would then have eight half waves on it and would be operating on the eighth harmonic.

These statements may seem confusing at first but it is essential that they be studied until they are understood if it is desired to appreciate just how antennas are designed and operated. It may help to examine Fig. 123, in which Hertz and Marconi antennas are shown operating at various harmonics. It will be seen that all the Hertz antennas have an even number of quarter waves on them while the Marconi types have an odd number. No particular notice need be taken of the Marconi types since they are rarely used in amateur work and will not be treated in detail in this discussion. The wavy dotted lines on this diagram indicate the distribution of voltage along the antenna. In the Hertz antenna there is always a point of maximum voltage and minimum current at both ends of the wire. This is shown more clearly in Fig. 124, in which both the voltage and current distribution are shown. It can be seen that wherever the voltage is highest the current is at a minimum and wherever the current is highest the voltage is at a minimum. The important point, however, is that in the Hertz antenna there is a point of highest voltage and no current at both ends. It is common practice to term the points of no voltage "voltage nodes" and the points of no current "current nodes." Conversely, the points of highest voltage or current are sometimes known as voltage or current "antinodes" or "loops."

It must always be kept in mind that there will be a definite number of half waves on the antenna when it is oscillating; there will be no odd quarter or eighth waves left over. This can be seen clearly in Fig. 124. When oscillating on its fundamental there is one half wave along the antenna; on its second harmonic, two half waves; on its third harmonic, three half waves; on its fourth harmonic, four half waves, and so on. If the fundamental of this antenna was 85.66 meters (3500 kc.), the next frequency at which it would oscillate would be the second harmonic. This would be twice the frequency, 7000 kc., or half the wavelength, 42.83 meters. The next frequency at which it would oscillate would be the third harmonic, which is three times the frequency — 10,500 kc. — or one-third the wavelength — 28.55 meters. And this example could be carried on to the twenty-fourth or forty-fourth harmonic if we had the space. In all of these cases, however, there would be points of highest voltage at both ends of the antenna. And since points of highest voltage are always points of lowest current, when the antenna is oscillating, these ends will be points of lowest current also. There will be other points of no current and high voltage along the antenna, as can also be seen by reference to Fig. 124. A knowledge of the location of these points is of the greatest importance in the planning of the feeding system, as we shall see.

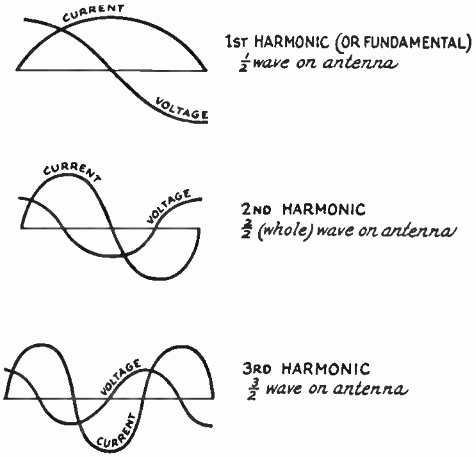


FIG. 124 — VOLTAGE AND CURRENT DISTRIBUTION OF ANTENNAS OPERATING AT HARMONICS

Determining the Length of the Antenna

It has previously been mentioned that the natural wavelength of a Hertz antenna is from 2.1 to 2.07 times its actual length instead of exactly twice its actual length. The reason for this is that the antenna has effective distributed capacity and inductance. The value of the distributed capacity and inductance will be influenced by various factors, such as the presence of nearby conductors and the size of the antenna wire, and their effect on the natural wavelength of the antenna will become greater as the frequency is higher. At frequencies of 28 mc. and above (wavelengths below 10 meters), the ratio of natural wavelength to actual antenna length may be even greater than 2.1. The length of the antenna is not an extremely critical dimension, however, because the antenna itself is a circuit having a quite broad resonance characteristic — the total of its ohmic and radiation resistance is something like 70 ohms — and deviations as great as 2% from the ideal length for a given set of conditions will not seriously affect its radiating properties. Although specific formulas are given in the following pages for calculating the proper length of the antenna for use with different types of feed systems, this formula can be generally used for calculating the length of a simple Hertz antenna:

Length in feet = 1.56 × desired natural wavelength in meters; or

Length in meters = 0.475 × desired natural wavelength in meters.

In terms of frequency:

$$\text{Length (feet)} = \frac{468{,}000}{\text{Freq. (kc.)}} = \frac{468}{\text{Freq. (mc.)}};\ \text{or}$$

$$\text{Length(meters)} = \frac{142{,}500}{\text{Freq. (kc.)}} = \frac{142.5}{\text{Freq. (mc.)}}$$

These formulas are based on a 2.1/1 ratio of natural wavelength to actual length. Expressed another way, the actual length is approximately 95% of one-half the natural wavelength. The length should be measured off accurately, of course, preferably with a good steel tape, yard stick or meter rule. Cloth measuring tapes are unreliable.

Feed Systems

We now have some idea of the manner in which a Hertz antenna can oscillate, but it is certain that the antenna cannot be strung up in the air and be expected to oscillate of its own accord. It must be supplied with power from the transmitter. The process of supplying power to the antenna is termed "feeding" or "exciting" the antenna.

It must be emphasized that the type of feed in itself does not make one antenna system more efficient than another. If the whole system is designed, erected and tuned according to specifications, the antenna itself will radiate just as effectively with one feeder arrangement as with another. The choice of a feed system is almost solely based on convenience and will be governed by local conditions. The adaptability of each of the systems described can be determined best by a study of available locations for the antenna system and the exercise of individual judgment. There is no "best" antenna system for all locations.

Primarily there are two types of feed systems in general use by amateurs — those which employ a tuned non-radiating link between the transmitter's output circuit and the antenna, and those which employ an untuned feed circuit whose characteristic (surge) impedance is matched at the antenna terminal end by a suitable coupling arrangement. The tuned feeder systems are classed as either current or voltage feed, since they couple to the antenna at either a current or voltage loop. The matched impedance systems are of two types — single-wire and two-wire. The tuned feeder arrangements are simpler and more popularly used by amateurs, and will be described first.

Current Feed Systems

It is immediately apparent that we cannot attach a current feed system to the ends of a Hertz antenna because there is no current there. But reference to the two previous diagrams will show that there are other places in the antenna where there is high current and at any of these places a current-feed system could be connected. When the antenna is operating on its fundamental there is a point of highest current at the center and the feed system could well be attached at this point. Such an arrangement provides what is probably the simplest antenna system that the amateur can use. It is shown at *A* in Fig. 125. The fundamental antenna — approximately one half-wave long — is bent so that its middle portion is within the station. At the center, the antenna coil is connected and coupled to the plate coil of the transmitter. If the antenna itself had a fundamental of the frequency on which it was desired to operate, the insertion of the antenna coil would disturb it. Hence, in actual practice, a tuning condenser is connected in series with the coil — or one on each side — so that it is possible to compensate for the loading effect of the antenna coil and tune the antenna to the required frequency. If the antenna is being operated on some harmonic there will be other places of maximum current at which the feed system could be introduced. Some of these are shown in the same diagram. It will be noticed that these points of maximum current are either one or an odd number of quarter-wave lengths from an end of the antenna.

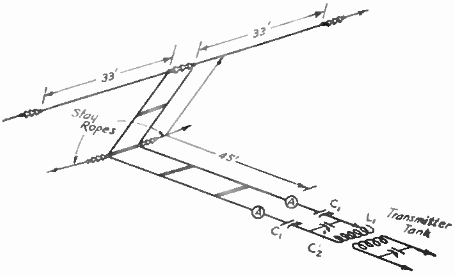
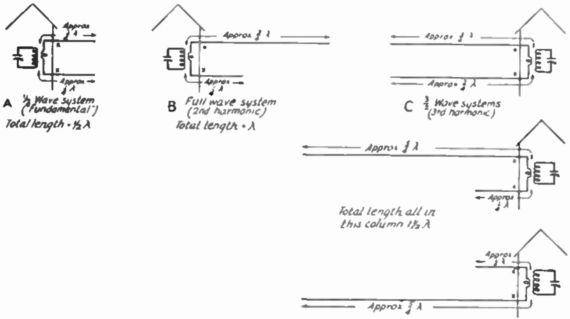


FIG. 126 — A CURRENT-FEED SYSTEM FOR SEVERAL BANDS

The antenna has a fundamental frequency of 7100 kc. and is operated on its second and fourth harmonics for 14,200 and 28,400 kc., respectively. Parallel tuning is used on 7100 kc. and series tuning for 14,200 kc., parallel tuning again being used for 28,400 kc. The system operates as two voltage-fed Hertz antennas in parallel on the two higher frequencies. The arrangement will also work quite well on the 3500-kc. band with parallel tuning of the tank circuit, the whole system being approximately a half-wave antenna with all but the two end eighth-waves "folded back on itself." With a fundamental 3500-kc. antenna (total length about 133 feet) better all-band operation could be obtained with feeders of the length given. The condensers C_1 and C_2 can be of 250- or 350-μμfd. capacity. The feeders can be pulled back as shown if the distance between the antenna and the station is less than 45 feet.



NOTE – Losses tend to be high at points X unless they are near voltage node
Antenna forms shown are general and outside parts may be slanting or vertical

FIG. 125 — CURRENT-FEED ANTENNA SYSTEMS

In the past, antennas of the type shown at A or C have been widely used by amateurs and referred to rather inappropriately as "antenna-counterpoise" systems. In reality they are just bent Hertz antennas. Their effectiveness usually is improved if the two portions are led from the station in opposite directions, so making the antenna in the form of a straight line or a wide "V". The important point is that in any such antenna system the coupling coil must be inserted at or near a point of maximum current. This will be at one or an odd number of quarter-wavelengths from the end. One or two variable condensers can be connected in series with the antenna inside the station to permit precise tuning of the system.

The antennas illustrated in this diagram, particularly at *A* and *C*, would not be very effective in practice because the antenna is doubled back on itself. The trouble is that the current at a given point on one half of the antenna is opposite in phase to the current at a similar point on the other half. The field around one of the halves will therefore tend to cancel the field around the other half and the effectiveness of the antenna as a radiator will be reduced. It is very much preferable to arrange things so that a considerable portion of the antenna is out in the open away from the influence of the remainder. Other desirable schemes would be to fold only a small portion of the antenna or to arrange it in the form of an open V. In some stations, for instance, where the transmitter is in an attic, it may be possible to make the antenna a straight wire entering the room on one side and leaving it on the other.

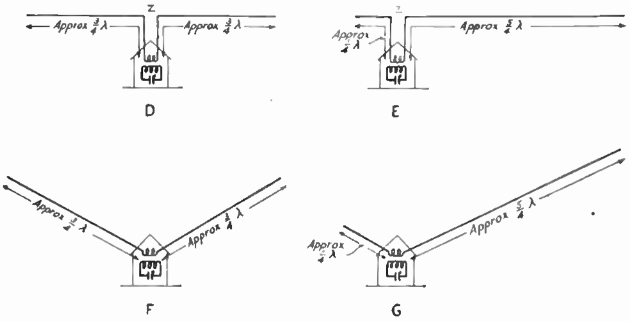


FIG. 127 — OTHER POSSIBLE CURRENT-FEED ANTENNA SYSTEMS

The schemes so far described have the disadvantage that the antenna is brought into the station where its radiation can be absorbed by the building, and where it may be unnecessarily close to the ground. It is better to leave the complete antenna strung up in a place well clear of trees or buildings, feeding it with a feeder system which is purposely arranged to play no part in the business of radiating. Arrangement *D* in Fig. 127 is preferable to the others in this respect because the vertical portion between the antenna coupling coil and *Z* has been eliminated as a part of the antenna and converted into a feeder with little radiating ability, for when the whole system is properly proportioned and tuned the fields about the two feeder wires will be opposite in phase and will cancel. To reduce radiation from the feeder to a minimum, the two wires should be not more than 10 or 12 inches apart. The construction of the feeder system is described farther on.

This type of antenna system is known as the two-wire current-feed when the feeder couples to the antenna at a current loop and the feeder is tuned to a multiple of ½ wavelength (an even multiple of ¼ wavelength). The lengths of the antenna and feeder wires can be determined from the formulas just given. The system can be operated at harmonics of its natural frequency, of course, and it is particularly adaptable to locations where it is convenient to run the feeders from the station to the middle of the antenna. The feeders need not be run in a straight line from the antenna to the transmitter but can be arranged as shown in the illustration of an antenna system designed for operation on three or more amateur bands, Fig. 126. In this system the antenna operates as a current-fed Hertz on its fundamental frequency and as two voltage-fed Hertz antennas in parallel on its even harmonic frequencies. The construction and adjustment for each band are given beneath the illustration.

Voltage Feed Systems

Some of the most practical and popular amateur antenna systems are of the voltage-feed type, which differ from the current-feed types in that the energy is fed to the antenna at one of its voltage loops (current nodes) instead of at a current loop (voltage node) as in the current-feed type. One form of voltage feed is shown in which one end of the antenna is brought into the station and attached to a tank circuit which is coupled to the output of the transmitter. This system is quite simple but has the disadvantage of making it necessary to bring the radiating portion of the antenna system into the station. The antenna length is determined by the general formula previously given and the antenna can be operated at its harmonics as well as at its fundamental frequency. Moreover, this system is readily convertible to operation as a

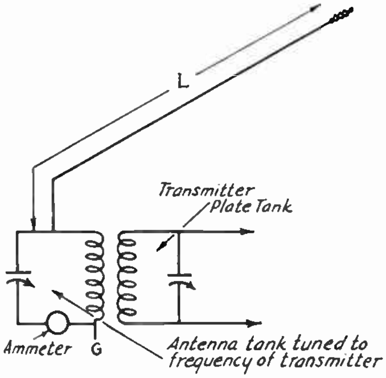


FIG. 128 — A SIMPLE VOLTAGE FEED SYSTEM

Should the length of the antenna L be 264 feet, the antenna could be operated on any of the amateur bands merely by tuning the transmitter and the antenna tank circuit to the required frequency. If the length L is 132 feet the antenna will have a fundamental of approximately 3550 kc. (84.46 meters) and it could be operated on the 3500-kc. band or any of the four higher-frequency bands. When the antenna is approximately 66 feet long its fundamental will be at 7100 kc. (42.23 meters) and operation will then be possible on the 7000 kc. band or any of the three higher-frequency bands. By connecting a good ground system at the point G the antenna system is converted to a Marconi type and operation can then be had at half the fundamental frequency of the antenna itself. Thus an antenna 132 feet long — with a fundamental of 3550 kc. — could be operated on the 1715-kc. band in conjunction with a ground connection and on all other bands by disconnecting the ground and using the voltage-feed system. The antenna need not be bent as shown in the diagram. In some locations it could be made horizontal and in others vertical. Even if one portion is sloping, another part vertical and the remainder horizontal, it will still operate. It should be as much in a straight line as well as clear of trees and buildings as possible.

Marconi (grounded) antenna for operation at half of the natural frequency (twice the natural wavelength) which it has as a Hertz antenna. This is accomplished by grounding one side of the antenna coupling tank circuit, as shown in the diagram. The antenna should never be connected directly to the output tank of the transmitter since such direct coupling of the antenna itself to the transmitter tank circuit is illegal. This system is not to be confused with the single-wire-feed antenna system which will be described later.

APPROXIMATE LENGTH OF EACH WIRE, FEET	TUNING ARRANGEMENT FOR VARIOUS BANDS				
	1750 kc (160 m.)	3500 kc. (80 m.)	7000 kc (40 m.)	14000 kc (20 m)	28000 kc (10 m)
120	SER	PAR	PAR.	PAR	SER. OR PAR.
90	PAR	SER	SER	PAR	SER OR PAR
60	PAR	SER	PAR	PAR.	SER OR PAR
40	(---)	PAR	SER	PAR	PAR.
30	(---)	(---)	SER	PAR.	SER. OR PAR
15	(---)	(---)	PAR.	SER	PAR.
8	(---)	(---)	(---)	PAR	SER.

SER - *Series Tuning* PAR - *Parallel Tuning* (---) - *Not Recommended*

FIG. 129 — SOME SUGGESTED ZEPPELIN FEEDER LENGTHS AND RECOMMENDED TUNING METHODS FOR THE VARIOUS AMATEUR BANDS

The two-wire voltage-feed system is perhaps the most generally used of all amateur antenna systems. It is popularly known as the Zeppelin or Zepp antenna and utilizes a tuned two-wire feeder attached to the Hertz antenna at one end. Since there is always a voltage loop at this feed point, the system operates as a true voltage-feed system at all harmonics as well as at its fundamental frequency. It is especially adapted to locations where it is most convenient to feed the antenna at one end. The length of the antenna should be determined from the same formula used for the preceding systems and the feeder system should be equivalent to an odd multiple of ¼-wave long; that is, each wire is approximately an odd multiple of ¼-wave in length or the tuning is so arranged that the same effect can be realized. If the feeder wires are each an odd number of ¼- or ⅜-waves long for the frequency being used, the system can be tuned to resonance by means of series condensers. If they are slightly less than a multiple of a half-wave long, parallel tuning will do the trick. Fig. 129 gives some useful feeder lengths and tuning arrangements for the operation of Zeppelin antennas of various fundamental frequencies on their fundamentals and harmonics. Figs. 1210, 1211, and 1212 show the coupling arrangements for series, parallel, and combination series and parallel tuning. A suitable Zeppelin antenna for operation on three or more bands is also illustrated in Fig. 1212.

The principal requirements for this type of antenna system are that the feeder system be symmetrical (both feeder wires of exactly the same length) and that the antenna be of the right length for the desired fundamental frequency. The actual value of the feeder current indicated by the antenna ammeter or ammeters is not the true indication of how well the system is operating. If the meters happen to be connected at or near current nodes (voltage loops) they will indicate very little current. This is particularly likely to happen when parallel tuning is used and the feeders are nearly multiples of ½-wave long for the frequency being used. The meters do indicate proper balance, however, when the current in both feeders is of the same value. If the current in one feeder is much different from that in the other it is quite probable that the feeder system is unbalanced and that there is radiation from the feeders because their respective fields are not canceling each other. The construction of the Zeppelin feeder system is like that of the other two-wire arrangements and is described in a later paragraph.

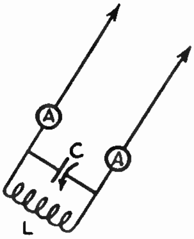


FIG. 1210 — PARALLEL FEEDER TUNING

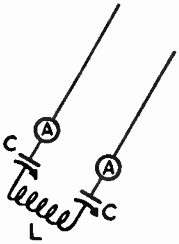


FIG. 1211 — SERIES FEEDER TUNING

Tuning

The tuning of voltage- and current-feed systems is quite similar and the tuning practices recommended in Chapter Seven should be ob-

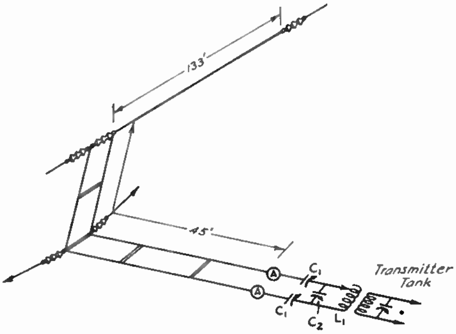


FIG. 1212 — A ZEPPELIN (VOLTAGE FEED) ANTENNA FOR SEVERAL BANDS

The antenna has a fundamental frequency of 3550 kc. but could be of any fundamental frequency between 3500 and 3600 kc. Since the feeders are less than a quarter-wave long for 3550 kc., parallel tuning should be used for this band. Series tuning will be best on the 7000- and 14,000-kc. bands and probably for the 28,000-kc. band. The condensers C_1 and C_2 may be of 250- or 350-$\mu\mu$fd. capacity.

served to obtain the maximum output compatible with good frequency stability. When series tuning is used with either of the typical antenna systems shown in the diagrams, the parallel tuning condenser should be set at minimum capacity and the series condensers at maximum. After the transmitter has been set on the desired frequency the antenna coupling coil should be coupled to the transmitter tank and the series condensers tuned simultaneously, from maximum capacity down, until the radio-frequency ammeter shows maximum feeder current and the plate milliammeter shows maximum plate current. If the transmitter should stop oscillating or the meters show two points of maximum current, the coupling should be loosened. After tuning for maximum current the capacity of the feeder series condensers should be increased until the current drops about 15%, if the transmitter is a self-excited rig. With an oscillator-amplifier set the best tuning adjustment is the one which gives maximum feeder current, of course. The procedure with parallel feeder tuning is similar except that the series condensers are set at maximum and the parallel condenser is tuned from maximum capacity down. If the feeder current should be very low in value with parallel tuning, the plate input as shown by the plate milliammeter will be a better indication of resonance. Plate current should be the greatest when the feeder circuit is tuned to resonance unless the feeder tuning has affected the transmitter tuning enough to necessitate readjustment of the transmitter circuits. Such readjustments should be made according to the directions given for the various transmitters in Chapter Seven.

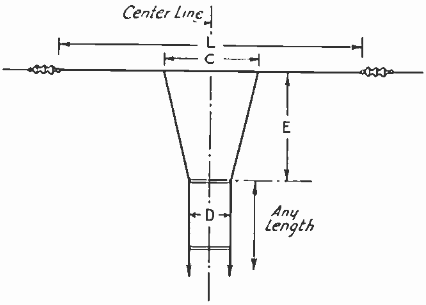


FIG. 1213 — TWO-WIRE MATCHED-IMPEDANCE ANTENNA SYSTEM

The Two-Wire Untuned Feeder System

In the tuned feeder systems just described the feeders are coupled to the antenna at points of either maximum current or maximum voltage. The feeders have voltage and current loops and nodes distributed along them just as the antenna has, and are prevented from radiating appreciably only because the field about one feeder wire cancels that of its mate. The feeders for voltage or current feed must be tuned to allow any transfer of radio-frequency energy through them because they connect to the antenna at either a point of very high impedance for voltage feed, or a point of practically zero impedance for current feed. It is well known that a radio-frequency transmission line will have standing waves on it when its terminal impedance is either infinite or zero, if the length of the line bears a suitable relation to the exciting frequency or, in other words, is tuned to the exciting frequency. The tuned voltage- and current-feed systems operate because they meet these requirements and they have standing waves on them in the same way that the antenna itself has points of current and voltage maxima and minima. Now if the feeder system could be made to transfer energy efficiently from the transmitter to the antenna without the necessity for standing waves on the feeder wires, the length of the feeder system could be anything convenient and tuning of the feeder system would be eliminated. This can be accomplished with what is known as a matched-impedance feeder system.

Any two-wire transmission line has a characteristic (surge) impedance that is dependent on the spacing between the conductors and on the diameter of the wires, and which is practically independent of the length of the wires. If the line is terminated by an impedance exactly equal to its characteristic (surge) impedance, there will be no reflection from the terminal and consequently no standing waves on the wires when they are supplied with radio-frequency power. Moreover, the line will transmit power very efficiently from its input to a suitable terminating load. This follows from the principle that the maximum transfer of power from one circuit to another is possible when the output circuit impedance is equal to the line impedance.

In the antenna system shown in Fig. 1213, the characteristic (surge) impedance of the feeder is matched by the impedance across the portion C of the antenna. The antenna length L, the feeder clearance E, the spacing between centers of the feeder wires D, and the coupling length C are the important dimensions of this system. The system must be designed for exact impedance values as well as frequency values and the dimensions are therefore more critical than those of tuned feeder systems.

The length of the antenna is figured as follows:

$$L \text{ (feet)} = \frac{492{,}000}{F} \times K; \text{ or}$$

$$L \text{ (meters)} = \frac{150{,}000}{F} \times K$$

where L is the antenna length in feet or meters for a desired fundamental frequency F, and K is a constant depending on the frequency. For frequencies below 3000 kc. (wavelengths above 100 meters) K is 0.96; for frequencies between 3000 and 28,000 kc., K is 0.95; and for frequencies above 28,000 kc. K is 0.94. F is the frequency in kc.

The value of the antenna coupling dimension C is computed by this formula:

$$C \text{ (feet)} = \frac{492{,}000}{F} \times K_1; \text{ or}$$

$$C \text{ (meters)} = \frac{150{,}000}{F} \times K_1$$

K is 0.25 for frequencies below 3000 kc., 0.24 for frequencies between 3000 and 28,000 kc., and 0.23 for frequencies above 28,000 kc. F is the fundamental frequency in kilocycles.

The feeder clearance E is worked out from this equation:

$$E \text{ (feet)} = \frac{492{,}000}{F} \times K_2; \text{ or}$$

$$E \text{ (meters)} = \frac{150{,}000}{F} \times K_2$$

K_2 is 0.30 for all bands, and F is the frequency in kilocycles.

The above equations are for feeders having a characteristic (surge) impedance of 600 ohms and will not apply to feeders of any other impedance. An impedance of 600 ohms is both convenient and standard, however, and is entirely satisfactory for amateur systems. The proper feeder spacing for a 600-ohm transmission line is computed to a sufficiently close approximation by the following formula:

$$D = 75 \times d$$

where D is the distance between the centers of the feeder wires and d is the diameter of the wire. If the wire diameter is in inches the spacing will be in inches and if the wire diameter is in millimeters the spacing will be in millimeters. These data are given in the wire table of the Appendix.

The length of the feeder system can be anything convenient, successful operation with feeders as long as 1200 feet being quite common. This type of feeder system should be constructed quite the same as the other two-wire systems with the exception of the antenna end and the transmitter coupling terminal. Since the feeder spacing is the critical dimension determining the line impedance, the wires should be kept taut and the spacing should be kept constant all the way down to the transmitter. The feeders may be run around corners if suitably insulated and rigidly supported, but sharp right-angle bends in the wires must be avoided. Particular care should be taken to run the feeder clearance portion E straight away from the antenna. Each side of E should be of exactly the same length and the feeder wires should tap the antenna an equal distance on either side of its exact center.

Three possible methods of coupling the transmission line to the transmitter output circuit are shown in Fig. 1214. This system is particularly fine for coupling the output of a push-pull oscillator or amplifier stage to a Hertz antenna, as shown in the diagram at A. The feeders should be clipped onto the tank inductance an equal number of

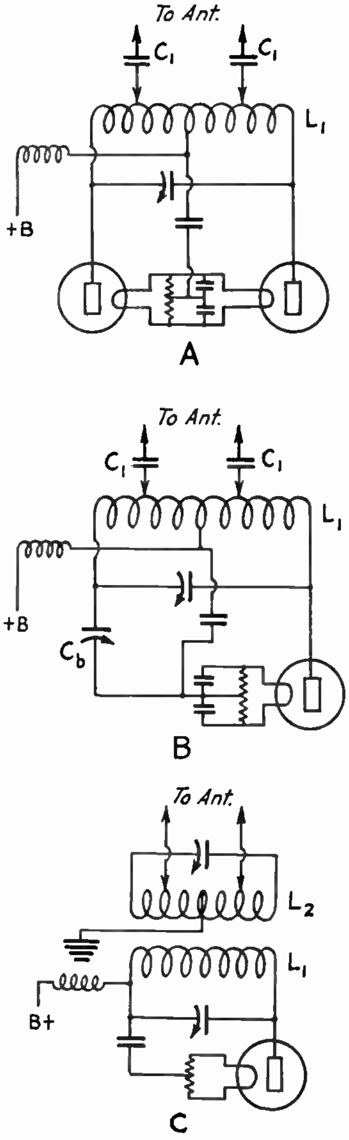


FIG. 1214 — THREE ARRANGEMENTS FOR COUPLING THE TRANSMISSION LINE TO THE TRANSMITTER

A is for coupling to a push-pull oscillator or amplifier, while B and C are two methods for coupling to single-ended stages. The condensers C_1 are blocking condensers of about .002µfd. capacity which prevent shorting the d.c. plate supply if the feeder system should become grounded. They are not necessary with the inductive coupling method shown in C.

turns on either side of its center because it is essential that the load on each tube be the same. The correct places for the taps can be found by starting at the center and moving the taps farther along the coil until the tubes are drawing their proper input power. The fixed condensers C are used as a precaution to prevent short-circuit of the plate supply in case the feeders should become grounded. Since the feeder current is very small in value, the usual antenna ammeter will be unsatisfactory for indicating maximum power input to the antenna. The plate current milliammeter reading will serve, however.

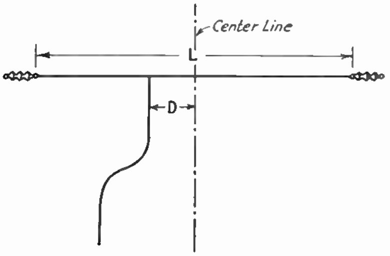


FIG. 1215 — SINGLE-WIRE FEED SYSTEM
The length L and coupling D are determined from the chart

Diagram *B* illustrates the plate tank arrangement satisfactory for coupling the two-wire feeder system to the output of a single-ended stage. The condenser C_b is connected from the "free" end of the tank circuit to the filament circuit and should be equal in capacity to the tube plate-filament capacity. Its purpose is to make the tank circuit electrically symmetrical about the center. Diagram *C* illustrates the method of connecting this type of feeder to the output of a transmitter when it is impossible to arrange the plate tank to give the required balance. The feeder tank circuit will be similar in construction to the usual transmitter tank circuit. As with the other arrangements the clips are adjusted on either side of the inductance's center until the maximum power is being transmitted to the antenna. This will occur, of course, when the impedance across the feeder input is equal to the surge impedance of the transmission line.

Single-Wire Feed

The single-wire matched-impedance feed system operates on the same principle as the two-wire feed: there will be no standing waves on the feeder and consequently no radiation from it when its characteristic impedance is matched by the impedance at its terminal. The principal dimensions are the length of the antenna *L*, Fig. 1215, and the distance *D* from the exact center of the antenna to the point at which the feeder is attached. These dimensions can be obtained from Fig. 1216 for an antenna system having a fundamental frequency in any of the amateur bands. The antenna should be designed for the lowest frequency band which is to be used, and operated on its harmonics in the higher-frequency bands. Although the dimensions shown in the chart are for the 3500-kc. band, the dimensions for the 7000-kc. band can be obtained by multiplying the frequency by 2 and dividing the lengths by 2; and for the 14,000-kc. band by multiplying the frequency by 4 and dividing the lengths by 4. When the antenna is to be operated on harmonic frequencies the length must be such that the harmonics of the antenna's fundamental frequency fall inside the higher frequency bands. Suppose that the antenna is to be used for the 3500-, 7000- and 14,000-kc. bands. Since the limits of the 14,000-kc. band are 14,000 and 14,400 kc., the fundamental frequency of the antenna must lie between 3500 and 3600 kc. The antenna length should be, therefore, somewhere between 132 and 135.5 feet. The feeder should be tapped onto the antenna at a distance from the antenna center of 18′ 11″ for operation with an antenna of 135.5′ length, or at 18′ 5″ for an antenna of 132′ length.

In constructing an antenna system of this type the feeder must run straight away from the antenna (at a right angle) for a distance of at least ⅓ the length of the antenna. Otherwise the field of the antenna will affect the feeder and cause faulty operation of the system. There should be no sharp bends in the feeder wire at any point.

Directional Antennas

Directional antennas for both transmitting and receiving are particularly advantageous at the higher amateur frequencies, especially in the 28- and 56-mc. bands because at these frequencies the dimensions of practicable directional systems are small enough to make them adaptable to the space most amateurs have available. Directional antennas are not only useful for concentrating the radiated energy in a desired compass direction but also for concentrating the radiated energy on

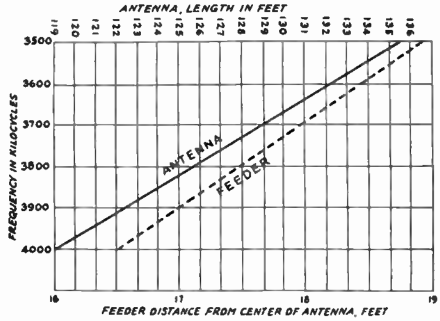


FIG. 1216 — SINGLE-WIRE FEED DATA CHART FOR NO. 14 WIRE FEEDER

a favorable angle of radiation. Experiments on the 28,000-kc. band, for instance, show that radiation at high angles to the earth's surface is futile for communicating with other stations of the world and the useful part of the total radiation is that transmitted at low angles.

Two simple arrangements for directive transmission are illustrated in Figs. 1217 and 1219, both designed to concentrate the radiated energy in low angles to the surface.

The directional properties of systems of the types shown depend on the phase relations of the currents in the wires. When two parallel antennas a half-wave apart are excited in phase their radiation is concentrated along a line at right angles (broadside) to their plane. Also, a half-wave antenna spaced a quarter-wave from the fed antenna and parallel to it (but not connected to it) will act as a reflector with the result that the radiation is concentrated in the direction away from the reflector. Both of these principles are utilized in the directive antenna shown in Fig. 1219. The feeder system is arranged to supply four half-wave antennas so that the currents in all four are in phase. This is accomplished by voltage-feeding all the antennas from one pair of feeders and transposing the feeders between the lower and upper antennas. A typical transposition insulator is illustrated in Fig. 1218. The four antennas alone would make an excellent bilateral directive system, of course, but the addition of the four reflectors increases the concentration of the radiation in the direction of the arrow and makes the system unilateral. The dimensions given on the diagram are for a frequency of 29,000 kc. Antenna lengths for other frequencies can be worked out from the formulas given for Hertz antennas in the first part of this chapter. The half- and quarter-wave spacings between the antennas should be actually one-half and one-quarter of the wave length.

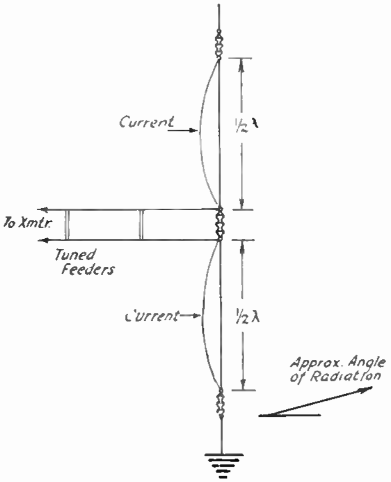


FIG. 1217 — A SIMPLE VERTICAL ANTENNA SYSTEM FOR LOW-ANGLE RADIATION

The current in the two antennas is in phase and radiation is in all directions of the compass at a low angle to the earth's surface.

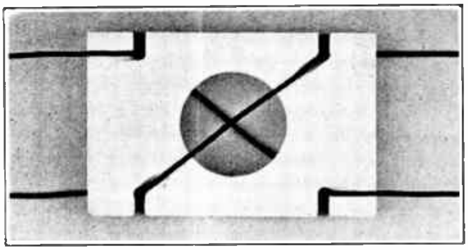


FIG. 1218 — AN ISOLANTITE FEEDER TRANSPOSITION INSULATOR

The separation between the wires is 1⅝".

Antenna Construction

For the purpose of this discussion let us divide the antenna system into two parts — the conductors and the insulators. If the system is to operate most effectively the conductors must be of low resistance. On the other hand the insulators must be of the highest possible resistance. For low- or medium-powered transmitters an entirely satisfactory conductor is No. 14 gauge hard-drawn enamelled copper wire. For higher-powered transmitters No. 12 gauge is preferable. Every effort should be made to make the wires in one piece so that the only joints are at the output terminals of the transmitter. Where joints cannot be

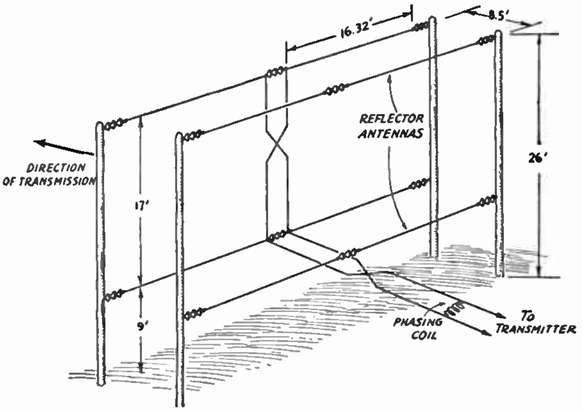


FIG. 1219 — A 28-MC. DIRECTIVE ANTENNA SYSTEM

Four-in-phase antennas backed up by four reflectors concentrate the radiation in the direction indicated by the arrow.

avoided they should be thoroughly soldered. It should always be possible to make the Hertz antenna-portion in one piece.

If the feeder system is of the tuned type the currents in it will be of the same order as those in the antenna and the same care in avoiding joints is necessary. In the untuned feeder system, however, the currents are relatively low and this consideration is therefore not as important. In these cases smaller wire can be used if necessary.

In building a two-wire feeder the wires should be separated by wooden dowels which have been boiled in paraffine. In this way the feeder is given a tendency to swing in windy weather as a unit.

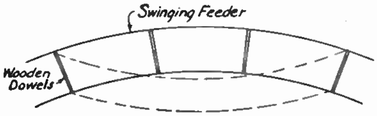


FIG. 1220 — THE USE OF LIGHT WOODEN DOWELS IN THE FEEDER

permits the system as a whole to swing. In this case the effect of movement of the feeder would not be as noticeable.

When heavy glass or porcelain spacers are used the tendency is for each wire to vibrate with respect to the other, so causing changes in the capacity between the wires and consequent changes in the emitted frequency. The wooden dowels can be attached to the feeder wires by drilling a small hole in the dowels, then binding them to the feeders with wire.

A good insulation to use throughout the antenna system is Pyrex glass. Glazed porcelain also is very good. It should be kept in mind that the ends of tuned feeders or the ends of the antenna are points of maximum voltage. It is at these points that the insulation is most important. A 12″ Pyrex insulator is quite satisfactory for amateur transmitters of any power. For the low-powered transmitters one of the smaller sizes, or two in series, would be satisfactory.

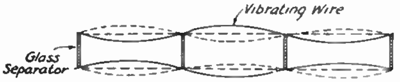


FIG. 1221 — WHEN HEAVY GLASS SPACERS ARE USED

in the feeder construction there is a tendency for the wires to vibrate as shown, so causing a wobbly frequency from the transmitter.

Probably the most satisfactory method of leading the antenna or feeders into the station is through holes drilled in the centers of the window panes. The drilling can be accomplished by using an ordinary steel twist drill if plenty of turpentine is provided at the point of the drill. It is best to remove the panes before drilling is attempted, since it will be difficult to avoid breaking them if the work is done when they are in the window. Large Pyrex bowls are also satisfactory as lead-in insulators, the bowls being mounted over large holes cut in a board of such a size that it fits snugly under the lower or above the upper sash when it is partially opened.

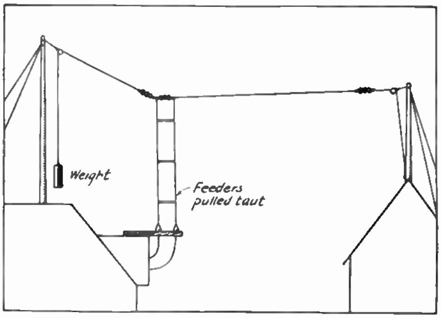


FIG. 1222 — A TYPICAL EXAMPLE OF GOOD ANTENNA CONSTRUCTION

One halyard is tied fast while the other has a heavy weight on its lower end. The weight keeps the tension on the antenna constant and compensates for stretching and shrinkage of the rope.

It is hardly possible to give practical instructions for the suspension of the antenna since the methods used will vary so widely in individual instances. In most cases poles are desirable to lift the antenna clear of surrounding buildings but in some locations the antenna is in the clear when strung from one chimney to another or from a chimney to a tree. Small trees are not usually satisfactory as points of suspension for the antenna on account of their movements in windy weather. If the antenna is strung from a point near the center of the trunk of a large tree this difficulty is not as serious.

In most locations a variety of possible arrangements will present themselves. It will be well for the amateur to try the antenna in different positions or to try different types of antennas. Time expended in such experiment undoubtedly will be well worth while.

Chapter Thirteen

ASSEMBLING THE AMATEUR STATION

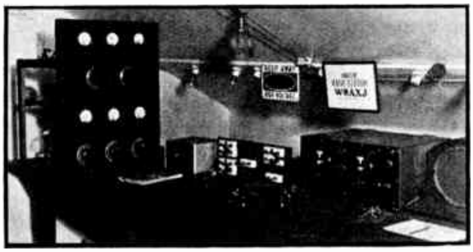
IN THE preceding chapters we have seen how all the component parts of an amateur station may be designed and built, and we have come to know that a complete station consists of a receiver, a transmitter with power supply, a monitor or frequency meter or both, and suitable antennas for transmission and reception. Many amateurs, on completion of the necessary units for their station, are so anxious to put the outfit into operation that they merely toss the apparatus on a table, connect it up in some haphazard fashion and begin operating. This procedure frequently results in danger to the operator and his family from exposed wiring. Also it invariably leads to unreliable and unsatisfactory operation of the equipment. The sincere amateur not only takes pride in the quality of signal his transmitter emits but also in the appearance of his station. One does not need a powerful transmitter or an elaborate receiver to have a fine amateur station.

AN IDEAL ARRANGEMENT FOR THE LOW-POWERED STATION

The transmitter and power supply are placed on a shelf supported above the operating table. The key is at the right, well back on the table so that the operator's elbow will be supported. Ample space is available on the front of the table for writing. The small switch at the left is the antenna change-over switch. It is unnecessary if a separate antenna is used for reception.

Finding a Location

The first problem encountered in building a station is usually the selection of a suitable space in the house. Some fortunate amateurs are able to provide a special "shack" away from the house. Others are able to monopolize an entire room for their station. Most amateurs, however, are obliged to content themselves with a corner of the basement, their bedroom or the attic. Some fellows, living in apartments, have even been restricted to the space under the kitchen stove, or in a small closet. Still others, for the sake of convenience and comfort, have built their transmitter and receiver into a small cabinet located in the living room, the heavier power supply apparatus being arranged in the basement.



A LAY-OUT SUITABLE FOR THE STATION HAVING A LOW-POWERED CRYSTAL-CONTROLLED TRANSMITTER

In this instance, the transmitter is located at one end of the long operating table. A self-controlled transmitter should not be located on the operating table because the vibration resulting from manipulation of the key is very prone to result in an unstable signal from the transmitter. This neat attic station is W8AXJ.

Further schemes for the amateur limited in space are made available by remote control methods — some typical examples of which are given in Chapter Eleven. With remote control, the transmitter and its power supply may be located in the attic, in the basement or in a specially built "dog-house" in the back yard. The receiver and control switches may then be located in a small cabinet in the living room or on a small table in any other room available.

There is certainly room for an amateur station in any house or apartment.

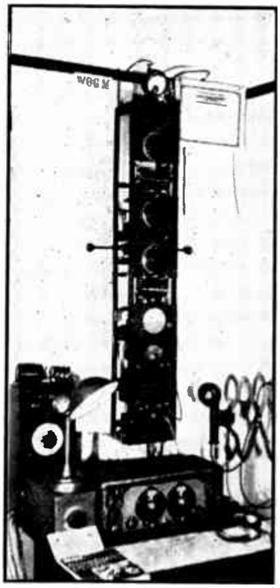
The Operating Position

Convenient operation of a station calls for ample space around the receiver and key. There must be room for the log book, call book, message blanks and miscellaneous papers. For this reason, it is almost universal practice to use a table or desk as the operating position.

The items which are handled most frequently are the receiver, power switches, key, frequency meter and monitor. It is well, therefore, to group all of these on the table or desk selected. Perhaps the most popular practice is to place the receiver towards the left of the table. The monitor is then located alongside the receiver on the right (where it is near enough to give a good signal in the receiver) and the key is screwed to the table slightly to the right of this and far enough back to give a good support for the operator's arm.

Since the filaments of the transmitting tubes should be lighted before the high voltage is applied, two switches should also be fitted on the table — one for the primary of the filament transformer and one in the supply circuit to the plate supply apparatus. These switches can be mounted under the front edge of the table in a position convenient for right-hand operation. With low-power transmitters, the filament and plate power are often supplied by one transformer; in such a case only one power-line switch will be necessary.

It is usually inadvisable to mount the transmitter or power supply on the operating table. In the case of the self-controlled transmitter, indeed, it is extremely bad practice. All such transmitters are susceptible to vibration and to the effects of "body capacity." Consequently, they cannot be expected to deliver an output of constant frequency when subject to the vibration of keying and the movements of the operator. It is very much better, even in the case of a crystal-controlled set, to mount the transmitter itself on a shelf supported from the wall, on a separate table, or in a special frame. In any case, the transmitter should be conveniently placed with respect to the feeder or antenna leads.

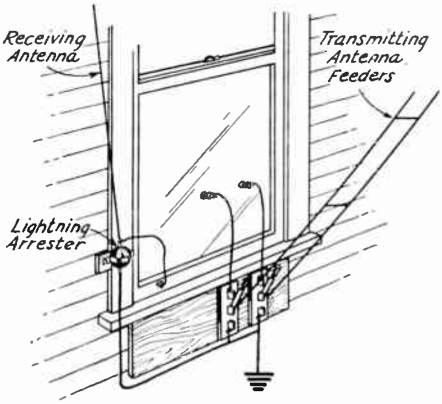


W6GM — AN UNUSUAL STATION ARRANGEMENT

Because space is limited, the transmitter has been built into an elongated frame which is suspended from the picture molding around the room, thereby eliminating the need for floor or table space. The transmitter is an m.o.p.a., with a pair of 45's in push-pull exciting a pair of 10's, also in push-pull.

The power supply equipment of even a low powered transmitter requires careful placement because of the danger involved. It should not be on the operating table nor should it be under the table in a position where the operator's feet could come in contact with it. Often it is placed on a shelf under the transmitter table or frame. Alternatively, it could be in a large and well ventilated box under the operating table and off to one side.

It is futile, of course, to attempt to outline every possible arrangement of the components of the station. It is better that the amateur should make a study of the stations he visits (and of those illustrated in this chapter and in *QST*) with the idea of improving on them or at least adapting them to his particular needs.

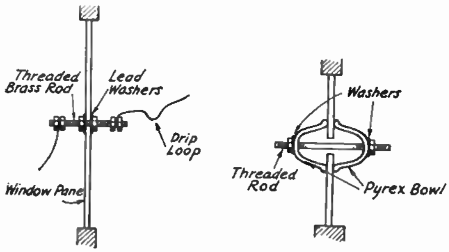


ANTENNA AND FEEDER GROUNDING METHODS FOR LIGHTNING PROTECTION

Lightning switches are used on the transmitting antenna lead-in or feeders. A lightning arrester is satisfactory for the receiving antenna.

Underwriters' Rules

Before actually starting on the installation and wiring of the complete station, the amateur should certainly make a study of the Underwriters' requirements.



TWO GOOD METHODS OF BRINGING THE TRANSMITTING ANTENNA LEAD-IN THROUGH A WINDOW

The specific rules covering radio equipment are given in Article 37 of the National Electric Code, under the heading of "Radio Equipment." Some states have adopted this code or a more strict version of it. Certain cities have adopted it, too, and they enforce their regulations through municipal inspectors. Before making an installation it is well to find out if the apparatus and wiring are subject to a state and city inspection as well as to inspection by insurance interests.

"Approved" refers to devices designed for the purpose used in accordance with recognized practice. The device must be acceptable to the inspection department having jurisdiction (there may be a city or state inspector in addition to the insurance rating or inspection bureau). When there is no inspector for the city or state, insurance interests inspect through their rating organizations, one of which covers each part of the United States. Your local insurance agent can advise you in whose territory you are located so you can get in touch with the proper authority.

AN ELABORATE 'PHONE AND C.W. STATION

The amateur fortunate enough to have a whole room at his disposal may arrange his equipment (and his furniture) in some such manner as this. The station is W1DTJ.

A conference with the inspection department *before* making an installation or change will save inconvenience and expense later. Your own interests and those of fellow citizens will be best protected from an insurance and fire-hazard standpoint by having such a conference.

ONE WAY OF UTILIZING AN ODD CORNER OF THE HOUSE

This is an example of the manner in which special cabinet work may be used to improve the appearance of the station. Two transmitters, receiver, monitor and power control panel are visible. All batteries, power supply equipment and other accessories are concealed in the bottom of the desk. W9UM is the station illustrated.

The wiring must follow the requirements observed in your particular community. In some instances a separate power line must be run directly to the watt-hour meter. A few feet of "BX" from the nearest outlet to a "Square-D" switch box, properly fused at the switch, will usually be satisfactory. The installation of high-voltage apparatus and wiring must be done in approved fashion. High-tension cable, supported on porcelain pillar insulators, keeping the high voltage away from all woodwork and neighboring conductors, is a safe type of construction.

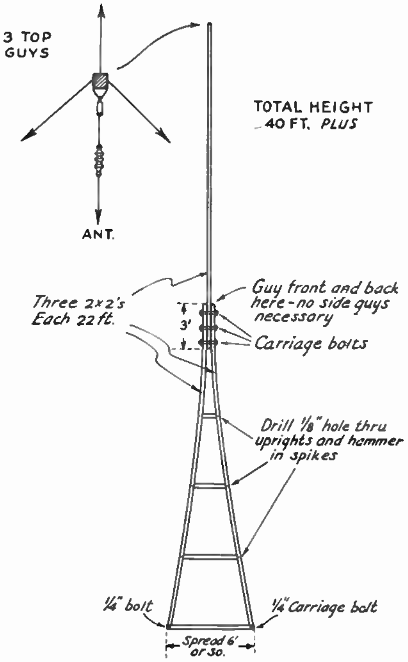
A receiving antenna can be connected to ground before it gets to the set through either the in-door or out-door type of lightning arrester. Several approved types are sold by local dealers with complete instructions for installation. These arresters usually are simply spark-gaps sealed in a vacuum to lower the voltage break-down. The ground can be made by scraping a water pipe or ground rod clean and bright with a file. A 10-cent ground-clamp will make a good connection to the pipe. A yearly inspection will insure a good ground. An approved lightning arrestor operating at a potential of 500 volts or less is required for each lead-in conductor of a receiving station. There are no requirements for indoor antennas, however.

Transmitting antennas or feeders must be grounded by means of lightning switches. The switch should be of the single-pole double-throw type having a minimum break distance of 4 inches and a blade of at least .0625 square inch cross-section. The switch should be in the most direct line between lead-in and ground but can be located either outside or inside the station. Live parts of the switch must clear the wall (or other conductors) by 3 inches. The switch must be connected to the ground wire whenever the station is not in operation.

Antennas for receiving and low-power transmitting stations should be supported and insulated similarly to public service communication lines, while for medium- and high-power stations the requirements for constructing supply lines for transmitting electrical energy in like situations must be met. Antennas should not cross over or under supply lines or telephone and telegraph wires nor should they run above and parallel to them in such a way that a falling antenna might come in contact with a live wire. Antennas should not cross railroad tracks or public thoroughfares. They should not be attached to poles owned and maintained by local public utilities for supporting power lines or communication cables or wires. In most cases local ordinances forbid such construction as a menace to the public welfare. When antennas are put up in such hazardous locations special precautions should be taken to have ample strength in the antenna wire and its supports, as well as ample clearances. Antennas should not be supported on chimneys. When a tree is used there should be some provision for keeping the antenna from snapping when the tree sways in the wind.

A FULL-GROWN AMATEUR STATION IN THE LIVING ROOM

Receiver and transmitter are built into a small cabinet fitted with folding doors. The front of the upper space (which contains the receiver) drops down to form the operating position. The power supply equipment is immediately underneath in the cellar.



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

Any size of wire can be used for a receiving antenna. Probably No. 14 B. & S. (American Wire Gauge) hard-drawn copper wire, enameled to prevent corrosion, will have the best balance of electrical conductivity and mechanical strength for that purpose. Transmitting antenna wires for medium or high power amateur stations should have a strength not less than that of No. 10 hard-drawn copper wire and should be insulated with insulators having a minimum creepage distance of 10 inches.

The lead-in wires must be brought into the station through approved lead-in bushings. A good but cheap way to bring in the antenna lead is to drill a hole in the center of a large window pane. A brass machine screw with rubber gaskets will go through this and make an excellent lead-in. The lead-in insulator must have a 3-inch clearance beyond the wall of the structure. Antenna leads must never come within 5 inches of supply wires. A wooden board at the top or bottom of a window will make a good support for lead-in bushings under most circumstances. Pyrex bowls make good bushings. Lead-in bushings or tubes must be rigid, noncombustible, nonabsorptive, and have good insulating properties.

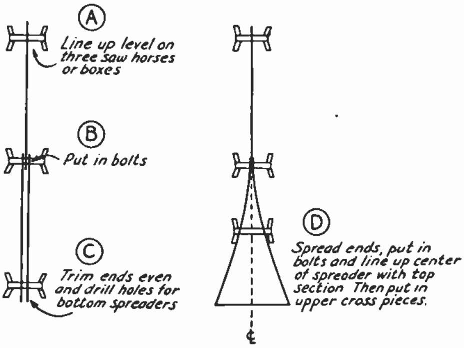
ANOTHER EXAMPLE OF A CORNER STATION

The transmitter, located on a shelf on the wall, may be tuned without any inconvenience yet is immune to the vibration resulting from keying. The coil rack on the far wall is an item of value. The station is W1AGW.

Everyone who owns an amateur station or who plans to have one should send ten cents (not in stamps) to the Superintendent of Documents, Government Printing Office, Washington, D. C., for the booklet *Safety Rules for Radio Installations*, Handbook of the Bureau of Standards No. 9.

The Antenna

In addition to the problems of installing the apparatus inside the house, the amateur must also concern himself with the problems of the outdoor equipment — the antenna and its support. In this connection it is very difficult to offer suggestions because of the widely different requirements in different locations. It is certain that any amateur having the patience and application necessary for the completion of the transmitter, receiver and accessories is not to be stumped by the selection and provision of suitable supports for the antenna. In some cases the lack of yard space presents a *real* problem. Usually the owner of the adjoining property will consent to the antenna being extended into his domain. Failing that, about the only alternative is to restrict one's activity to one of the higher frequency bands on which a sufficiently short antenna can be used.



ILLUSTRATING THE METHOD OF ASSEMBLY

Building a Mast

It is very rarely that an effective antenna can be erected without putting up some form of mast. And in many cases the mast must be erected and guyed in a restricted space. With the idea of providing some suggestions for the prospective mast-builder, we will present the description of a typical mast. The example selected is a 40-foot mast of simple construction and low cost. The only lumber used is 2-by-2 straight-grained pine (which many lumber yards know as hemlock) or even fir stock. The uprights can be each as long as 22 feet (for a mast slightly over 40 feet high) and the cross-pieces are cut to fit. Four pieces of 2-by-2 22 feet long will provide enough and to spare. The only other materials required are five ¼-inch carriage bolts 5½ inches long, a few spikes, about 300 feet of No. 12 galvanized iron wire for the guys or stays, enough No. 500 ("egg") glazed porcelain strain insulators to break up the guys into sections and the usual pulley and halyard rope. If the strain insulators are put in every 5 feet approximately 30 of them will be enough.

After selecting and purchasing the lumber — which should be straight-grained and knot-free — three sawhorses or boxes should be set up and the mast assembled in the manner indicated in the diagrams. At this stage it is a good plan to give the mast two coats of "outside white" house paint.

After the second coat of paint is dry, attach the guys and rig the pulley for the antenna halyard. The pulley anchorage should be at the point where the top stays are attached so that the back stay will assume the greater part of the load tension. It is better to use wire wrapping around the stick, with a small through-bolt to prevent sliding down, than to use eye bolts. The latter weaken the mast.

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

Once the base has been placed on its spot and made level right-and-left, the front and back guys from the mid-section are anchored so that the mast stands vertical fore-and-aft. The last step is to anchor the top guys so that the upper section lines up vertical. This can be done quite accurately by sighting up from the bottom, while a helper tightens and loosens guys as commanded.

Chapter Fourteen

THE A.R.R.L. COMMUNICATIONS DEPARTMENT

THE Communications Department is concerned with the practical operation of the stations of League members. Its work includes arranging amateur operating activities, establishing standard operating procedure, encouraging good operation, improving message relaying, and concluding tests to these ends.

The aim of the Communications Department is to keep in existence an active organization of League stations made entirely of privately-owned radio stations covering the entire continent of North America. One of its objectives is to create a body of skilled operators whose services and abilities will further the general knowledge of the art of radio communication. The relaying of friendly messages between different parts of the country without charge is one of the most important phases of the work coming under the supervision of the Communications Department. Amateur operators have also always been of great assistance to our country in times of emergency in which quick communication has been a factor, especially when other methods of communication have failed.

These objects of our organization must be kept in mind at the same time we, as individuals, are getting enjoyment from our chosen hobby. Only by operating our stations with some useful end in view can we improve the service which we give others and increase the pleasure we get, at the same time justifying our existence.

The activities of the Communications Department are arranged and recorded through *QST* and by special correspondence. Tests and relays are arranged from time to time to develop new routes for traffic handling, to prepare ourselves to render emergency service in time of need, and to bring to light additional general radio information. In this way all members of the League benefit from the experience of certain individuals who excel along specified lines of work.

The policies of the Communications Department are those urging members to adopt uniform operating procedure and to use system in their station operating. The Communications Department constantly works to make our communication system as efficient as a non-commercial message-handling organization can be. Compliance with government regulations, orderly operating, and coöperation with each other and with outside interests for the advancement of the art, are a part of its policies. The first duty of the department to member-stations is to supervise operating work so well that the amateur will continue to justify his existence in the eyes of his Government. Then he will be allowed a continuance of the privileges which he has received as his due in the past.

Records of worth-while traffic handling, of message routing, and of specific tests conducted between the different stations are kept in the files of the Communications Department and recorded in the Official Organ of the League, *QST*.

It is obviously impossible to distribute up-to-the-minute information in a monthly periodical. Therefore mimeographed circular letters are used on special occasions. The active stations are thus kept informed of the developments in such a rapidly progressing system. Through such letters, through *QST* and through a large volume of routine correspondence with individual members, the contact is kept good and the activities we have outlined are effectively carried out by the interested member-stations.

Official Broadcasting Stations have been appointed to improve on even the arrangement we have just outlined. These stations regularly transmit addressed information to all amateurs by voice and in telegraphic code. This service of sending addressed messages to A.R.R.L. members on current matters of general interest is supplemented by official and special transmissions on timely subjects from Headquarters Station W1MK (schedule given on page 17).

In these pages we are going to explain the organization of the Communications Department, the proper message forms to use, and some special practices which experience has proved best. We urge that you help strengthen amateur radio by studying the operating practice suggested and by adopting uniform operating procedure.

Everyone at League Headquarters welcomes criticism that is accompanied by constructive suggestions. The fullest benefits of organization are realized only when every member participates freely in his organization and gives brother amateurs and his organization the benefit of his advice, suggestions, criticism, participation and coöperation in the common cause, amateur radio. In individual operating work as well, advancement comes as we learn to exchange constructive suggestions in the true amateur spirit.

In some department of the A.R.R.L.'s field organization there is a place for every active amateur who has a station. It makes no particular difference whether your interest lies in getting started and learning the code, traffic handling, DX, friendly contacts by 'phone, or other aspects of amateur radio. Whatever your qualifications, we suggest that you get into the game and coöperate with your Section Manager by sending him a monthly report of the particular work you are doing. As you become experienced in amateur work of different kinds it is likely that you will qualify for appointment as Official Relay Station, or that you can accept other important responsibilities in connection with the conduct of A.R.R.L. work in the different sections. Operating work and the different official appointments will be explained in detail in this and the following chapter. We want to make it clear right at the start that the Communications Department organization exists to increase individual enjoyment in amateur radio work, and we extend a cordial invitation to every amateur and reader of this book to participate fully in the different enterprises undertaken by and for amateur operators.

Organization

The affairs of the Communications Department in each Division are supervised by one or more Section Communications Managers, each of whom has jurisdiction over his section of a Division.

For the purpose of organization the A.R.R.L. divides the United States and Possessions (plus Cuba and the Isle of Pines) and Canada (plus Newfoundland and Labrador) into divisions as follows:

Atlantic Division: Delaware, District of Columbia, Maryland, Pennsylvania, that section of New Jersey within the Third Federal Inspection District, and that section of New York within the Eighth Federal Inspection District.

Central Division: Illinois, Indiana, Kentucky, Michigan, Ohio and Wisconsin.

Dakota Division: Minnesota, North Dakota and South Dakota.

Delta Division: Arkansas, Louisiana, Mississippi and Tennessee.

Hudson Division: The entire Second Federal Inspection District, consisting of certain counties of New Jersey and New York States.

Midwest Division: Iowa, Kansas, Missouri and Nebraska.

New England Division: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont.

Northwestern Division: Idaho, Montana, Oregon, Washington and the Territory of Alaska.

Pacific Division: Arizona, California, Nevada, the Territory of Hawaii and the Philippine Islands.

Roanoke Division: North Carolina, Virginia and West Virginia.

Rocky Mountain Division: Colorado, Utah and Wyoming.

Southeastern Division: Alabama, Florida, Georgia, South Carolina and the Island of Porto Rico. (*The Republic of Cuba and the Isle of Pines are attached to this Division for Communications Department activities.*)

West Gulf Division: New Mexico, Oklahoma and Texas.

Maritime Division: The provinces of New Brunswick, Nova Scotia and Prince Edward Island. (*Newfoundland and Labrador are attached to this Division for Communications Department activities.*)

Ontario Division: Province of Ontario.

Quebec Division: Province of Quebec.

Vanalta Division: Provinces of Alberta and British Columbia and Yukon Territory.

Prairie Division: Provinces of Manitoba and Saskatchewan and the Northwest Territories.

Each United States Division elects a Director to represent it on the A.R.R.L. Board of Directors and the Canadian Divisions elect a Canadian General Manager who is also a Director. The Board determines the policies of the League which are carried out by paid officers at League Headquarters. When the Board is not in session, the officers of the League, constituting an Executive Committee, can act for the Board, subject to certain limitations.

The Communications Department has a field organization made up of officials selected by the membership in a way similar to the Directors. Each Director and the Communications Manager at League Headquarters decide the proper sectionalizing of each Division. A.R.R.L. operating territory is further subdivided into Sections to facilitate the collection of reports, and more important, the efficient supervision of activities and appointments in the field organization.

These field officials (S.C.M.s) are listed on page 5, while the names and addresses of the Directors are printed on page 6, of each *QST*.

In each Section there is a Section Communications Manager who, under the direction of the Communications Manager, has authority over the Communications Department within his Section. He is responsible to, and reports to the Communications Manager, except in Canada, where he reports to the Canadian General Manager.

Whenever a vacancy occurs in the position of Section Communications Manager in any section of the United States, its island possessions or territories, or the Republic of Cuba, the Communications Manager announces such vacancy through *QST* or by mail notice to all members of the Section, and calls for nominating petitions signed by five or more members of the Section in which the vacancy exists, naming a member of the Section as candidate for Section Communications Manager. The closing date for receipt of such petitions is announced.

After the closing date, the Communications Manager arranges for an election by mail or declares any eligible candidate elected if but one candidate has been nominated. Ballots are sent to every member of the League residing in the Section concerned, listing candidates in the order of the number of nominations received. The closing date for receiving ballots is announced. Immediately after this date, the Communications Manager counts the votes. The candidate receiving a plurality of votes becomes Section Communications Manager. The Canadian General Manager similarly manages such an election for a Section Communications Manager whenever a vacancy occurs in any section of the Dominion of Canada, Newfoundland or Labrador.

Section Communications Managers are elected for a two-year term of office.

The office of any Section Communications Manager may be declared vacant by the Executive Committee upon recommendation of the Communications Manager, with the advice and consent of the Director, whenever it appears to them to be in the best interests of the membership so to act, and they may thereupon cause the election of a new Section Communications Manager.

Communications Department Officials and Appointments

The following portions, relating to Section Communications Managers, to their appointment of different qualified and responsible officials to cover specific phases of A.R.R.L. communication work, to the duties of each in reporting, etc., are reprinted from the "Rules and Regulations of the Communications Department" and set forth the regulations which govern these matters within the department.

Section Communications Manager

1. The Section Communications Manager is responsible to the Communications Manager at League Headquarters for the efficiency and coöperation of his personnel. His policies are the democratic policies of the League itself.

2. His territorial limitations are determined by the Division Director (or C.G.M.) and the Communications Manager.

3. He recommends the appointment or cancellation of Official Relay Stations in accordance with the rules pertaining to the Official Relay Station Appointment.

The Section Communications Manager examines application and question forms, signing the prescribed certificate of appointment and forwarding it to the station owner when the appointment can be properly made. Form 4 appointment card bearing the certificate number is forwarded to League Headquarters with the questionnaire forms properly filled out by the applicant. Cancellations (Form 4C) are made for inactivity or for violations of any provisions of the Rules and Regulations (including F.R.C. amateur regulations) pertaining to the O.R.S. appointment.

An applicant who fails to qualify may again apply for appointment after three months have elapsed. Annual endorsement of O.R.S. certificates is required to keep these appointments in effect, and S.C.M.s must send new Form 4 cards to Headquarters annually to keep stations appointed on A.R.R.L. records and mailing lists.

The American Radio Relay League, Inc.
Hartford, Conn., U. S. A.
Communications Department Appointment
SECTION COMMUNICATIONS MANAGER

This certifies that [illegible] has been elected to the office of Section Communications Manager for two years from this date for the [illegible] Section of the [illegible] Division. Until further notice he is invested with all authorities of that office and is subject to the rules and regulations of The American Radio Relay League in the performance of the duties of the Office which he holds.

It is his duty to coöperate with all radio amateurs in his territory in such a manner as will best further the work of The American Radio Relay League.

Dated this 21st day of September 1931

4. He shall be responsible for the maintenance of the Official Broadcasting Station System within his section, recommending such appointments (Form 4) or cancellations (Form 4C) as may be necessary. Due consideration shall be given the distribution of stations on the different frequency bands and the qualifications of stations and operators for this service.

5. He is responsible for the traffic activities of his section. He shall appoint Route Managers, Official Observers and any other such assistants for specific work as may be deemed necessary by the Communications Manager. These officials will have full authority within the section over the activities indicated by their titles. They will report and be responsible to the Section Communications Manager for their work. With the consent of the Communications Manager the Section Manager may, if necessary, designate a competent Official Relay Station appointee or League member to act for him in a particular matter in any part of his territory. He shall be careful to instruct such an appointee properly in the duties he is to execute while acting for the S.C.M.

6. He shall conduct investigations of radio organizations and interference cases whenever such cases are referred to him by the Communications Manager or the Division Director.

7. He shall appoint Vigilance Committees in the centers of activity where amateur interference conditions appear to make such committees desirable in helping to lighten the load of complaints received by the Supervisors of Radio. Amateur club organizations are to be encouraged to organize interference committees to keep closely in touch with this situation

everywhere, coöperate with the press, and coördinate amateur work.

8. He shall have referred to him by his various appointees any correspondence that may relate to matters of general policy, or suggestions for improvements in conducting the affairs of the League.

9. He may requisition necessary Communications Department supplies provided for making appointments and supervising the work in his section. He may render an itemized postage expense account monthly. Section Managers are entitled to wear the distinctive A.R.R.L. pin with red background, similar in other respects to the regular black-and-gold A.R.R.L. membership pin.

10. He shall render a monthly report to Headquarters, consolidating all the reports by subjects into a comprehensive summary. This report shall reach Headquarters on or before the 26th of each calendar month. It shall be made up from all reports from O.R.S. and other active stations, together with the reports from special appointees (5) and as mentioned under the subject of reporting. Reports shall be mailed to Headquarters by S.C.M.s on or before the 20th for the reporting month (16th to the 15th inclusive) in the mainland U. S. A. and Canada. Reports from non-members may also be accepted and included.

Official Observers

Each S.C.M. recommends for appointment a suitable number of Observers who report regularly to the S.C.M. on off-frequency operation noticed, sending out notification forms (provided from Headquarters) to help amateurs in keeping within the assigned bands. Official Observers also make general observations on operating conditions, taking the proper action to bring about improvement, always reporting the action taken to the Section Communications Manager.

Each Official Observer shall have an accurately calibrated monitor or frequency meter or shall be equipped to carry on his work in checking stations beyond the limits of the amateur bands against calibrations from the Standard Frequency Station transmissions and checks from government or commercial "marker" stations of known frequency operating adjacent to our own amateur channels. Observers shall be supplied with notification postal card forms and with report blanks on which the stations logged off-frequency and notified shall be reported to A.R.R.L. Headquarters (through the office of the S.C.M.) just as rapidly as the blanks are filled out. While observers work directly under their Section Managers, their observations shall include all amateur stations in the U. S. or Canada or wherever there are representatives of the A.R.R.L. field organization.

On logging a station the notification form shall be completed and mailed in each case when the station logged is found to be operating with an amateur call signal outside the confines of the amateur bands. A duplicate of the reporting form may be kept by observers to enable them to check on stations continuing off-frequency after having received friendly notification. Observers shall also get in touch with stations by radio when this seems necessary and practical.

From time to time the attention of appointees in the A.R.R.L. observing system will be called to particular situations and particular bands requiring their special attention and at other times their work may be distributed on different frequencies as time permits and conditions seem to warrant.

Observers when possible shall report harmonic or parasitic radiations and other operation of commercial or government telegraph services or broadcasting stations causing interference in the amateur bands, these being reported direct to the S.C.M. or Headquarters as promptly as possible so that suitable remedial action may be taken.

The notification service to amateurs is designed as a friendly move to protect amateur privileges from official government restrictions which may be endangered by careless or intentional disregard of regulations by individuals who might thus jeopardize the enjoyment of all amateurs.

While primarily confining their duties to frequency checking as just outlined, observers also embrace the opportunity to report flagrant violations of good amateur practice, including improper procedure, poor spacing, "a.c." notes, etc.; all to the end that these things may be brought before the operators concerned, the effectiveness of stations improved, and high standards of amateur operating maintained. Observers also make station-distribution surveys showing actual density of stations and operating conditions in our different amateur bands.

Route Managers

While the Section Communications Manager is the traffic executive of the section, the Route Manager is the authority on schedules and routes and his station is always active in traffic and organization work. Section Managers generally appoint one Route Manager to every twenty or twenty-five Official Relay Stations, depending on the radio population of the Section concerned and the amount of organized activity. Route Managers maintain good local radio contacts regularly so that stations can be lined up and routes developed and operated by radio.

Route Managers coöperate actively with all active stations in their districts so that each Route Manager is the nucleus of a communication net which he organizes himself, and for which he is responsible at all times to his Section Communications Manager. Route Managers arrange schedules for local traffic handling between the different towns and cities in their territory as well as keep many schedules at their own station and keep track of between-section schedules, reporting monthly to the S.C.M., who in turn reports to A.R.R.L. Headquarters. The Route Manager also keeps posted on schedules already in operation within the Section, on the between-Section schedules and those kept with foreign points by stations within his jurisdiction (which is determined by the S.C.M.). The R.M. reports to the S.C.M. monthly (at the same time the O.R.S. report) including in his report a complete list of all routes and schedules known to him brought just as up-to-date as possible and covering the specific activity of routes and schedules.

Route Managers often may be distinguished at conventions and hamfests by their League emblem with the distinctive deep-green background, but otherwise similar in size to the black-and-gold emblem worn by every League member.

Official Broadcasting Station

Each Official Broadcasting Station appointee shall receive information on timely subjects from Headquarters each week or at other intervals to be put on the air at various scheduled times during the week following receipt of the information. Section Managers shall give preference to stations having available considerable amounts of power, or stations whose operators are especially qualified to give good service in view of the geographical location, the frequency bands in use, or the timely choice of schedules or frequency with which schedules can be kept. Consideration shall also be given to the ability of such stations, especially at great distances from Headquarters, to copy the information in advance of its receipt by mail as sent by Headquarters station W1MK.


The American Radio Relay League, Inc.
Hartford, Conn., U. S. A.
Communications Department Appointment
ROUTE MANAGER

This certifies that [illegible] owner and operator of station [illegible] has been appointed to the office of Route Manager for the San Francisco Section of the Pacific Division.

Until further notice he is invested with all authorities of that office and is subject to the rules and regulations of The American Radio Relay League in the performance of the duties of the Office which he holds.

It is his duty to coöperate with all radio amateurs in his territory in organizing and maintaining traffic routes and schedules in such a manner as will best further the work of The American Radio Relay League.

Dated this 20th day of October 1936

Applicants for this appointment must submit their qualifications to the Section Manager with the proposed dates, times and frequencies for transmission of the broadcasts. In deciding on the times of transmission schedules, preference should be given to those times when the largest number of amateurs are listening, that is, the hours between 6:00 p.m. and midnight. Section Managers are instructed to cancel the appointments of stations not adhering to the schedules agreed upon, and the appointments of stations not returning information on current or revised schedules when periodic surveys of the broadcasting system are made.


The American Radio Relay League, Inc.
Hartford, Conn., U. S. A.
COMMUNICATIONS DEPARTMENT APPOINTMENT
OFFICIAL BROADCASTING STATION

This Certifies that station [illegible] owned by [illegible] is appointed an Official Broadcasting Station of The American Radio Relay League, Inc. Until further notice this station is invested with the authority to broadcast all official messages in the performance of which it is subject to the rules and regulations of The American Radio Relay League, Inc.

Dated this Twenty-fourth day of February 19[illegible]

F. E. Handy

The Official Relay Station

The Section Communications Manager shall recommend for appointment as Official Relay Stations such stations of League members as apply for and merit such appointment. The recommendation shall be based on the ability of the applicants to come up to a specified set of qualifications. The applicant shall have a loyal, coöperative attitude; he shall follow standard A.R.R.L. operating practices (understanding and using the proper message form, finish signals, service message, cable-count check on important messages, and so on); he shall have a transmitter and receiver capable of operation at any time, and he must be able to send and receive Continental code at a rate of at least 15 words per minute.

1. It shall be the duty of each Official Relay Station appointee to report monthly to his Section Communications Manager, to keep the station in readiness to operate, to use A.R.R.L. operating practices exclusively, and to take in the activities of the League whenever possible. The message file must be held for three months ready for call by the S.C.M. at any time. *Reports are due on the 16th* of each month if the station is located on the mainland of the United States.

2. Each Official Relay Station shall receive an appointment certificate to be displayed prominently in the station, a quarterly bulletin newsletter from Headquarters, and Form 1 reporting cards on which to turn in the regular monthly reports to the Section Communications Manager.

3. When a station is of necessity inoperative for six months or less, the appointment may be

held on an inactive list by the Section Communications Manager, providing the station owner has reported the facts of the case and requested that he be excused from active operating and reporting during this time. Inactive lists shall be turned in to Headquarters by the Section Communications Manager with his monthly report. O.R.S. appointments shall be transferable from one Section to another, with the consent of the Section Communications Managers concerned, who must alter their records and notify Headquarters of such changes. Such appointments shall not be transferable from one station-owner to another.

The American Radio Relay League, Inc.
Hartford, Conn., U. S. A.
Communications Department Appointment
OFFICIAL RELAY STATION APPOINTMENT

4. The violation of the provisions made above for operating and reporting shall be sufficient reason for the Section Communications Manager to recommend cancellation of the appointment. The Section Communications Manager shall notify the Official Relay Stations that this action is pending when the first and the second reports have been missed. The appointment shall be cancelled automatically when the third consecutive report fails to come through on time. Such cancellations shall be classed as "complete." New application and question forms must be filled out and evidence of better performance submitted before reappointment can be considered. If an O.R.S. resigns his post after consistent work, an "honorable" cancellation shall be issued; and reinstatements within one year may be made on application without filing new papers.

5. O.R.S. certificates must be returned to Section Managers annually for proper endorsement to keep appointments in effect.

Reports

Each Official Relay Station report shall include the number of messages originated, delivered, relayed, and the total. The Form one reporting card furnished by the A.R.R.L. shall be used when it is available but the non-arrival of this form shall not constitute an excuse for not reporting.

The Section Communications Manager shall condense all reports received, leaving out any "negative" information. His report shall not mention inactivity or non-reporting. Traffic figures shall be separately listed at the end of the report and shall not be included in the body of the report, where all general amateur activity, experimenting, 'phone, DX, traffic, and other station work will be chronicled. When possible, the Section Communications Manager shall send in his report typewritten and double-spaced. Section Communications Managers shall not transmit the reports received by them to Headquarters except on request but shall prepare and forward for *QST* use a condensed report of the month's activities and the status of amateur affairs in the territory under their jurisdiction.

More About the O.R.S. Appointment

The Official Relay Station appointment of the Communications Department deserves some further explanation. Telegraphing members who hold amateur licenses are most interested in this work.

Our League was once a much smaller organization than it is to-day. What traffic handling was done was performed in a very easygoing manner. Messages were not taken seriously by those who sent them or by those who handled them. Because there were fewer stations operating, it was harder to relay messages to their destinations. Deliveries were the exception rather than the rule.

As the League expanded more stations came on the air. It became increasingly possible to land messages right at the city of destination.

New developments followed the reopening of amateur stations in Oct. 1919. Tube transmission and the change to higher frequencies, made a complete revamping of our communication system necessary. The granting of appointments right and left, the increase in numbers of inexperienced operators, the new conditions under which we were operating (on several frequency bands), each left its mark on our communication system. In earlier times newcomers automatically got operating experience by listening to commercial and government long wave stations. By the time their stations were in workable shape to handle relay traffic, the necessary operating experience had been gained. After 1919 newcomers threw sets together from the information then made available. Stations capable of communicating over thousands of miles on high frequencies were established by operators whose tuners no longer reached frequencies where good commercial traffic was being efficiently handled. Lack of this preliminary training was responsible for poor operators. Unreliable stations and operators, out for "DX" records only, slowed up traffic. Complaints were received on the unreliability of operators and on the poor delivery of messages everywhere.

Finally, it was decided to abandon the old system and to start afresh. The need of placing a greater responsibility on the traffic handling of stations was felt keenly. A class of stations that could be depended upon should be created! An iron-bound set of qualifications and a set of Rules and Regulations for Official Relay Stations were drawn up as a standard and a foundation for the present traffic-handling organization was built. Appointments under the new system of things are no longer given without investigation.

New applicants must communicate *by radio* with a Section official and receive his approval, and application forms indicating knowledge of recommended procedure must be filed with the S.C.M. The present system of Official Relay Stations, which has been in successful operation for many years, is the result.

An Invitation

Any A.R.R.L. member who has a station and operator's license and wants to "do things" with his equipment will find it easy and very much worthwhile to earn an appointment in the Communications Department organization. As has been explained, knowledge and use of certain fundamentals of operating procedure are prerequisite to appointment to the important basic post of Official Relay Station in our field organization. Study procedure. Put into practice the things that you read. Originate and relay some traffic regularly. Keep a few schedules with other amateurs. Report all your activities on time (the 16th) each month to your S.C.M. whose address is given on page 5, any *QST*, to prove your qualifications and interest. Regardless of whether you have yet applied for appointment, a postal to the S.C.M. will give him information to use in his report for *QST* and boost the standing of your station and Section.

O.R.S. are the "minute men" of amateur radio — always organized, reporting, active, and holding their equipment in tip-top condition ready for instant service on any communicating problem, large or small. Official Relay Stations are, as the name implies, stations that can be depended on absolutely to see a hard job through. They are ready for every opportunity of service to the public or amateur radio that may come their way, whether a special emergency, test, experiment, or just in the line of ordinary operation. They deliver and relay promptly all traffic that comes their way irrespective of whether radiotelephone or telegraph operation is employed. O.R.S. appointment is highly significant since it puts the station owner in a special position as respects the opportunities of service. The appointment certificate also has come to be known as the badge that shows an amateur station has "arrived" in the dependable class.

O.R.S. appointees are entitled to wear the distinctive blue A.R.R.L. pin which is similar to the regular membership pin except that it has a blue instead of a black background. Vacancies in the ranks of the Communications Department officials usually are filled from the ranks of the Official Relay Stations. Every owner of an Official Relay Station receives a bulletin letter from A.R.R.L. Headquarters quarterly with the latest schedules, news, and procedure hints and helps. Special reporting cards for the convenience of the Official Relay Station operators in reporting their traffic-handling work and records are sent out with the bulletin.

To secure an appointment as Official Relay Station is quite a simple matter if you have the qualifications and a little experience. After building the station, gaining some code speed, and reporting your activities to the S.C.M. as suggested, ask the S.C.M. to furnish you with an application for appointment as Official Relay Station (or use the one printed for your convenience in the rear of this book). The S.C.M. will be glad to send you the necessary forms to be filled out and returned to him, and to give you advice on the application as may be necessary. But you must be willing to accept a certain amount of "personal responsibility" in regard to regular reporting each month, and absolute reliability in forwarding and delivering a number of messages regularly through your station.

The appointment is one made with mutual advantage to yourself and to our Communications Department. Fill out the application form as soon as you can qualify!

Chapter Fifteen

OPERATING A STATION

THE enjoyment of our hobby comes from the operation of our station once we have finished its construction. Upon the *station* and its *operation* depend the traffic reports and the communication records that are made. We have taken every bit of care that was possible in constructing our transmitter, our receiver, frequency measuring and monitoring equipment and in erecting a suitable antenna system. Unless we make ourselves familiar with uniform standard operating procedure, unless we use good judgment and care in operating our stations, we shall fall far short of realizing the utmost in results achieved. More than this, we may make ourselves notorious unless we do the right thing, because we may interfere with other stations or delay their work.

After some listening-in experience you will hear both kinds of operators and realize the contrast that exists between the operation of the good men and that of "lids" and "punks" who have never taken the trouble to familiarize themselves with good practice. Occasionally you will pick up an amateur whose operating is so clean-cut, so devoid of useless efforts, so snappy and systematic, that your respect is gained. It is a pleasure to listen and work with him. On the other hand the operator who sends forty or more CQ's and signs two or three times in a slipshod manner gains the respect of no one. His call may be impossible to identify. His lack of operating judgment seriously impairs and handicaps *his own success and enjoyment* in addition to causing other amateurs to form an unfavorable opinion of his work and the uncalled-for interference he creates. By *proper* procedure the number of two-way contacts (QSO's) and the enjoyment and profit in each will be a maximum.

For efficient traffic handling, the transmitter should be adjusted for stable, satisfactory operation on one or two known but different frequencies in the amateur band. Known condenser settings for definite frequencies will enable the operator quickly to change frequency (QSV) at any time. Whenever such a change is made, be sure to check the frequency accurately. There is *no excuse* for operating off frequency. Any frequency calibrations should be checked often to guard against variations.

Making a practice of checking frequency each time you open the station for operation. Take no chances. Do not try to work on the edge of an amateur band but *keep well within the known accuracy of your frequency measuring equipment and methods.*

The operator and his methods have much to do with limiting the range of the station. The operator must have a good "fist." He must have patience and judgment. Some of these qualities in operating will make more station records than many kilowatts of power. Engineering or applied common sense are as essential to the radio operator as to the experimenter. Do not make several changes in the set hoping for better results. Make one change at a time until the basic trouble or the best adjustment is found.

An operator with a clean-cut, slow, steady method of sending has a big advantage over the poor operator. Good sending is partly a matter of practice but patience and judgment are just as important qualities of an operator as a good "fist."

The good operator sends signals which are not of the "ten words per minute" variety, but they are slow enough so that there is no mistaking what he says. The *good* operator does not sit down and send a long call when he wants to work someone. He puts on the 'phones and *listens in.* He goes over the dial thoroughly for some time. The fellow that is admired for his good operating is the one who is always calling some particular station instead of using the "inquiry signal." Because he *listens* until he hears someone to work and *then* goes after him, our good operator gets his man nearly every time. A good operator chooses the proper time to call, he makes plain signals, and he does not call too long. A short call is sufficient because if a station does not get the call it is likely that he is listening to another station. A long call makes the receiving operator lose patience and look for someone else.

The adjustment of the receiver has much to do with successful operation, too. The good receiving operator notes the dial setting and when he has completed calling in proper fashion, he waits a moment and then tunes above or below the logged dial setting just in case something has shifted slightly in the receiver or transmitter. The best operator has patience and waits a few minutes in case of delay at the transmitter or in case fading signals make a second answer necessary.

Communication

After all, communication has as its object the exchange of thought between two minds. Sometimes those minds are near each other and it is possible for the individuals concerned to converse at length and exchange their thoughts freely. At other times, and this when radio communication is involved, the individuals are miles apart and the thoughts to be transmitted must be condensed to just a few words. Then these words must be relayed or passed on from operator to operator. When they reach their ultimate destination someone can interpret them fully if they have been properly and carefully handled by the intermediate operators.

Time is involved in making any exchange of thought. Because every man's life and experience is measured by time, this factor becomes important in everything we do or say. The number of messages handled, the number of distant stations worked, the number of records made at our station, all depend in some degree on the time available for our hobby. The more time we spend at the set, the more well known our station becomes and the more extensive will be the sum total of our results in amateur radio.

As time is a factor, uniform practices in operating have become necessary to insure a ready understanding of what is going on in the minds of each operator. "Q" signals and abbreviations of various sorts have been devised and are in general use to-day just because of the time element involved, to enable every operator to exchange intelligible thoughts with as little waste effort as possible. So proficiency in the commonly-used abbreviations and in knowledge of uniform operating practices is to be desired. Proficiency comes with practice. In the Appendix are the "Q signals" and some abbreviations used by amateur operators.

Accuracy is of first importance. Then *speed* in transmission and handling of radiograms must be considered. Very often, transmission at moderate speeds moves traffic more quickly than fast sending. A great deal depends on the proficiency and good judgment of the two operators concerned. Fast sending is helpful only when two fast operators work together.

Procedure

The Official Relay Stations follow some general requirements for law-abiding operation which are mentioned on the appointment certificate. Some specific rules and regulations have been made to raise the standard of amateur operating. Official Relay Stations observe these rules carefully. They may be regarded as "standard practice."

Any actively-operating stations will do well to copy these rules, to post them conspicuously in the station, and to follow them when operating.

1. The calling station shall make the call by transmitting not more than three times the call signal of the station called and the word DE, followed by its own call signal sent not more than three times, thus: VE9AL VE9AL VE9AL DE W1MK W1MK W1MK. In amateur practice this procedure may be expanded somewhat as may be necessary to establish communication. The call signal of the calling station *must* be inserted at frequent intervals for identification purposes. Repeating the call signal of the called station five times and signing not more than twice (this repeated not more than five times) has proved excellent practice in connection with break-in operation (the receiver being kept tuned to the frequency of the called station). The use of a break-in system is highly recommended to save time and reduce unnecessary interference.

Stations desiring communication, without, however, knowing the calls of the operating stations within range, may use the signal of inquiry, CQ, in place of the call signal of the station called in the calling formula. The A.R.R.L. method of using the general inquiry call (CQ) is that of calling three times, signing three times, and repeating three times. CQ is not to be used when testing or when the sender is not expected or looking for an answer. After a CQ, the dial should be covered thoroughly for two or three minutes looking for replies.

The directional CQ: To reduce the number of useless answers and lessen needless QRM, every CQ call shall be made informative when possible. Stations desiring communication shall follow each three-times-sent CQ by an indication of direction, district, state, continent, country or the like. Stations desiring communication with amateur stations in a particular country shall include the official prefix letters designating that country after each CQ. To differentiate domestic from foreign calls in which the directional CQ is used, the city, state, point of the compass, etc., is mentioned only after the third CQ just before the word DE and the thrice-repeated station call. Examples follow. A United States station looking for any Canadian amateur calls: CQ VE CQ VE CQ VE DE W1MK W1MK W1MK K. A western station with traffic for the east coast when looking for an intermediate relay station calls: CQ CQ CQ EAST DE W6CIS W6CIS W6CIS K. A station with messages for points in Massachusetts calls: CQ CQ CQ MASS DE W3QP W3QP W3QP K. In each example indicated it is understood that the combination used is repeated three times.

2. Answering a call: Call three times (or less); send DE; sign three times (or less); and after contact is established decrease the use of the call signals of both stations to once or twice. Example: W1BIG DE W1MK GE OM GA K (meaning, "Good evening, old man, I am ready to take your message, go ahead").

3. Ending signals and sign off: The proper use of AR, K and SK ending signals is required of all Official Relay Stations. AR (end of transmission) shall be used at the end of messages during communication and also at the end of a call, *indicating when so used that communication is not yet established.* K (invitation to transmit) shall be used at the end of each transmission when answering or working another station, almost carrying the significance of "go ahead." SK (or VA) shall be used by each station only when signing off, this followed by your own call sent once for identification purposes. SK (end of work)

indicates to others that you are through with the station which you have been working and will listen now for whomever wishes to call. Never CQ after signing off until you have covered the dial thoroughly looking for stations calling you. Examples:

(AR) G2OD DE W1AQD AR (showing that W1AQD has not yet gotten in touch with G2OD but has called and is now listening for his reply). Used after the signature between messages, it indicates the end of one message. There may be a slight pause before starting the second of the series of messages. The courteous and thoughtful operator allows time for the receiving operator to enter the time on the message and put another blank in readiness for the traffic to come. If K is added it means that the operator wishes his first message acknowledged before going on with the second message. If no K is heard, preparations should be made to continue copying.

(K) ZL2AC DE W6AJM R K. (This arrangement is very often used for the acknowledgment of a transmission. When anyone overhears this he at once knows that the two stations are in touch, communicating with each other, that ZL2AC's transmission was all understood by W6AJM, and that W6AJM is telling ZL2AC to go ahead with more of what he has to say.) W9APY DE W3ZF NR 23 R K. (Evidently W9APY is sending messages to W3ZF. The contact is good. The message was all received correctly. W3ZF tells W9APY to "go ahead" with more.)

(SK) R NM NW CUL VY 73 AR SK W7NT. (W7NT says "I understand OK, no more now, see you later, very best regards, I am through with you for now and will listen for whomever wishes to call. W7NT signing off.")

4. If a station sends test signals to adjust the transmitter or at the request of another station to permit the latter to adjust its receiving apparatus, the signals must be composed of a series of V's in which the call signal of the transmitting station shall appear at frequent intervals.

5. When a station receives a call without being certain that the call is intended for it, it shall not reply until the call has been repeated and is understood. If it receives the call but is uncertain of the call signal of the sending station, it shall answer using the signal - - — — - - (?) instead of the call signal of this latter station.

6. Several radiograms may be transmitted in series (QSG . . . . .) with the consent of the station which is to receive them. As a general rule, long radiograms shall be transmitted in sections of approximately fifty words each, ending with - - — — - -(?) meaning, "Have you received the message correctly thus far?"

7. A file of messages handled shall be kept, this file subject to call by the Section Manager at any time at his discretion. Only messages which can be produced shall be counted in the monthly reports, and these under the A.R.R.L. provisions for message-counting.

Above all, the operator will *never make changes or alterations in the texts or other portions of messages passing through his hands.* However slight or however desirable such changes may seem, the changing of a message without proper authority or without the knowledge of the originator of the message may be considered the "unpardonable sin." The proper thing to do of course is to notify the party filing the message or the originating station of your observations, secure permission from the proper source for making the change by sending a "service message" or other means. If the case seems urgent, the traffic should not be delayed but should be delivered or forwarded with appropriate notation or service accompanying it.

In acknowledging messages or conversation: Never send a single acknowledgment until the transmission has been successfully received. "R" means "All right, OK, I understand *completely.*" When a poor operator, commonly called a "lid," has only received part of a message, he answers, "R R R R R R R R R R, sorry, missed address and text, pse repeat" and every good operator who hears, raves inwardly. The string of acknowledgments leads one to believe that the message has been correctly received and that it can be duly filed away. By the time this much is clear it is discovered that most of the message did not get through after all, but must be repeated. Perhaps something happens that the part after the string of R's is lost due to fading or interference, and it is assumed that the message was correctly received. The message is then filed and never arrives at its destination.

Here is the proper procedure to follow when a message has been sent and an acknowledgment is requested. When all the message has been received correctly a short call followed by "NR 155 R K" or simply "155 K" is sufficient. When most of the message was lost the call should be followed by the correct abbreviations (see Appendix) from the international list, asking for a repetition of the address, text, etc. (RPT ADR AND TXT K). When but a few words were lost the last word received correctly is given after ?AA, meaning that "all after" this should be repeated. ?AB for "all before" a stated word should be used if most of the first part of the copy is missing. ?BN . . . . . AND . . . . . (two stated words) asks for a fill "between" certain sections. If only a word or two is lost this is the quickest method to get it repeated.

Do not send words twice (QSZ) unless it is requested. Send single unless otherwise instructed by the receiving operator. When reception is very poor, a QSZ can be requested to help make better copy. When conditions are even moderately fair, a QSZ is unnecessary. Few things are as aggravating as perfect transmission with every word coming twice. Develop self-confidence by not asking others to "QSZ" unless conditions are rather impossible. Do not fall into the bad habit of sending double without a request from fellows you work.

Do not accept or start incomplete messages. Omission of the fundamental parts of a message often keeps a message from getting through to its destination. Official Relay Station appointments are subject to cancellation for failure to make messages complete enough.

Operating Notes

A sensitive receiver is often more important than the power input in working foreigners. There is not much difference in results with the different powers used, though a 250-watter will probably give 10% better signal strength at the distant point than a Type 52 or 10's, other factors being the same. It will not do much better than this because the field strength drops so rapidly as we get away from the antenna. In working foreign countries and DX stations you should be able to hear ten or a dozen stations before expecting that one of them will hear your call.

A common fault among amateurs who do not get in touch with DX stations readily is that their calls are too short. Often they do not send enough *short* CQ's indicating the country or place desired even when the receiver is sensitive enough to bring in several stations located at the desired spot. Of course the type of radiator can always be blamed or the antenna location but usually the operator has only himself to blame.

The signal "V" is sometimes sent for two to five minutes for the purpose of testing. When one station has trouble in receiving, the operator asks the transmitting station to "QRV" while he tries to adjust his receiving set for better reception. A decimal point is often sent by the letter "R." Example: 2:30 PM is sent "2R30 PM." A long dash for "zero" and the Morse C (.. .) for "clear" are in common use. An operator who misses directions for a repeat will send "4," meaning, "Please start me, where?" These latter abbreviations, like others in our present day practice, are hybrids, originating in wire practices and Morse usages.

Improper calling is a hindrance to the rapid dispatch of traffic. Long calls after communication has been established are unnecessary and inexcusable. Some stations are slow to reply to a call. However, the day of the station with dozens of switches to throw is past. Controls for both receivers and transmitters are simpler, fewer in number, and more effective. The up-to-date amateur station uses a "break-in" system of operation and just one switch controlling the power supply to the transmitter.

Poor sending takes the joy out of operating. There are stations whose operators are not able to send better and those who can send better but do not. The latter class believe that their "swing" is pretty. Some of them use a key with which they are not familiar.

Beginners deserve help and sympathetic understanding. Practice will develop them into good operators. The best sending speed is a medium speed with the letters quickly formed and sent evenly with proper spacing. The standard type telegraph key is best for all-round use. Before any freak keys are used a few months should be spent in practicing with a buzzer.

No excuse can be made for a "garbled" text. Operators should copy what is sent and refuse to acknowledge messages until every word has been received correctly. Good operators never guess at anything. When not sure of part of a message they ask for a repeat. The "lid" operator can be told very quickly when he makes a mistake. He does not use a definite "error" signal and go on with his message but he usually betrays himself by sending a long string of dots and nervously increasing his rate of sending. The good operator sends "?" after his mistakes and starts sending again with the last word sent correctly. Unusual words are sent twice. "?" is sent and then the word repeated for verification.

The law concerning superfluous signals should be noted carefully by every amateur. Some operators hold the key down for long periods of time when testing or thinking of something to send. Whenever this is done during operating hours, someone is bothered. Unnecessary interference prevents someone from getting in contact with (QSO) someone else, and if messages are being handled the copy is ruined. If you must test, disconnect the antenna system and use an equivalent "dummy" antenna (made of lumped resistance, capacity and inductance). Always send your call occasionally when operating with the antenna. Pick a time for adjusting the station apparatus when few stations will be bothered.

Using a Break-in System

A break-in system of operation makes it possible for us to interrupt the other fellow if we miss a word or do not understand him. With a telephone we stop talking as soon as the distant party speaks and interrupts us. In a telegraph office the operator who misses a word opens his key so that the sending is interrupted and cannot go on until the receiving operator has had his say and again closed the circuit. In a radio system using a break-in the receiving operator presses the key and makes some long dashes for the transmitting operator to hear. As soon as he gets the signal he stops transmitting and listens to what the receiving operator says, before resuming sending.

A separate receiving antenna put up at right angles to the transmitting antenna makes it possible to listen to most stations while the transmitting tubes are lighted. It is usually necessary to pause just a moment occasionally when the key is up to listen for the other station.

Much useless calling and unnecessary transmission is prevented if break-in is used. Two stations can use the system to mutual advantage. When messages are being handled, if some interference comes in or if a word is missed due to swinging signals, a few taps of the key will set things straight in a jiffy. "BK BK GA ROANOKE" (or whatever was the last word received correctly) will save time and unnecessary sending. If the trouble continues, the sending station can "stand by" (QRX) or it can take traffic until the reception conditions at the distant point are again good.

For example, suppose W8SF has a message for New York City. He calls, "CQ CQ CQ NY DE W8SF W8SF W8SF," repeating the call three times and concluding with "K." W2PF hears him, and answers, "W8SF DE W2PF BK ME BK ME." When W8SF hears W2PF, W8SF immediately holds his key down and makes some long dashes. W2PF, who is of course receiving "break-in" while he calls, stops sending when he hears the dash. W8SF then calls in the regular manner, saying "W2PF DE W8SF GE HR MSG AR." Then W2PF gives him a "GA OM" and the message is sent without further preliminaries. Since both stations are using break-in, they can interrupt each other at any time when something goes wrong or a letter is dropped, and traffic can be handled in half the usual time. There is a real "kick" from working a break-in arrangement.

In calling, the transmitting operator sends the letters "BK," "BK IN," or "BK ME" at frequent intervals during his call so that stations hearing the call may know that a break-in is in use and take advantage of the fact. He pauses at intervals during his call, to listen for a moment for a reply from the station being called. If the station being called does not answer, the call can be continued. If the station called answers someone else, he will be heard and the calling can be broken off until he has finished his business and is again listening for more stations to work.

Keeping a Log

Every operator of an amateur station must keep a log of the operating work that is done; it should cover, as well, the tests of an experimental nature that are carried out with the transmitter or receiver.

The well-kept log is invaluable in checking up reports of any nature concerning amateur station operation. It contains positive evidence of every transmission. It is a permanent record of the achievements of the station. The Federal Radio Commission obliges every amateur station to maintain an accurate log of the time of *each* transmission, the station called, the input power to the last stage of the transmitter, the frequency band used and the operator's personal "sine" for each session of operating. So, in addition to other excellent reasons for log-keeping, the regulations make a complete record of transmitting activity compulsory.

Amateurs keep a log because of the ready-reference value in proving records and because of the pleasant recollections and associations that come from reviewing the history of friendly radio contacts and from displaying the record of the accomplishments of the station to interested visitors and friends.

A loose-leaf notebook can be used. The sheets can be renewed each month and those used can be taken out and filed away with the cards and station records. A stenographer's ordinary notebook costing from ten to thirty cents and about 4½" by 8½", takes little space on the operating table and also makes a good log book. If simplicity and low cost are the only considerations, such a modified notebook-log is recommended.

A dozen pages may be ruled in advance with vertical lines. In the first column the date and times are noted. In the second column the calls of stations worked, heard, and called are put down. A circle, parentheses, or a line drawn under the call can indicate whether a station was worked, heard and called, or simply heard. A special designating sign or abbreviations before or after the call letters can show this information. Provision must be made for entering the power and the frequency band used.

Figure 1 shows a very detailed log which really gives a lot of information but which is somewhat harder to keep in good shape. *W*, *H*, and *C* are used for "worked," "heard" and "called." A bar under the "R" in "RAC" may show that the note is well-rectified and fairly smooth. A line under the "AC" can indicate that the ripple is pronounced. Plenty of information will be available for stations wanting information when such a log is kept, no matter how late the request for information is received.

Some amateurs' logs use an *X* to indicate when they call a station. If communication is established a circle is placed around the X. Power and frequency can be written across the page, new entries being made only when these are changed. The dial settings of receiver or frequency meter may be entered in logging stations so that we can come back to these same stations without difficulty when desired. *A*, *B*, *C*, and *D* are sometimes used to indicate the 1750-, 3500-, 7000- or 14,000-kc. bands.

Figure 2 shows the official A.R.R.L. log. The first entry for each watch is that for the date and time. Greenwich Civil Time is the logical reference standard but local standard time is easiest to use to avoid confusion and so this is used by most amateurs, *PST*, *MST*, *CST*, *EST*, *GCT*, etc., is entered in the heading of the first column in the A.R.R.L. log and then the date which corresponds to that brand of time is put in the first space below the heading, and time entries on the first vacant line below that, those to be entered progressively until a change in date.

CW and *F* can be used in the second column to distinguish between your use of c.w. telegraphy and radiophone operation; or *A1*, *A2*, or *A3* standing for c.w. telegraphy, c.w. telegraphy modulated at audible frequencies, and speech or music, respectively. The frequency band you use may be indicated in the next column but it is better to record the exact frequency. The next column is for the plate input power to the last stage of your amplifier.

If you hear G5BY calling W1UE, log W1UE in the fifth column and G5BY in the sixth column. If G5BY were calling CQ, then CQ should be entered in the fifth column. A letter in the C-W-H column shows by a single appropriate letter whether a station was called, worked, or heard *by you*. *H* would indicate here that you heard G5BY. *C-W* might indicate that you called a station and completed the contact immediately afterward. Reports on the characteristics of G5BY's signal would be entered in the space provided for "station heard" or data on received signals. The signal strength, the tone (*P.D.C.*, *R.A.C.*, *Chirpy D.C.*, *Xtal*, *Voice*, quality or frequency of modulation, etc.) and the frequency or dial setting can be logged here, making it easy to retune to this station, offer evidence on its frequency, or to fill out a report card.

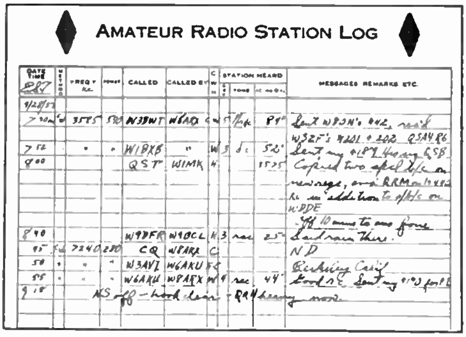
Log users will quickly adopt certain convenient practises which simplify the keeping of a log such as use of ditto marks to record frequency and power as long as these remain unchanged, and the use of an *X* for one's own call signal, to save time in making the entries in the fifth and sixth columns. When several stations answer a CQ, each should be listed in the sixth column following your own call signal in the fifth column. Any unusual data requiring explanation, such as an interrupted or incomplete contact due to power line failure, local interference, etc., should go in the "remarks" column. Also a detailed record of messages exchanged should be entered. This last column should show everything from the "sine" of a new operator taking the key to reports on your own signals from other operators.

Date	*Time*	*Call*	*W H*	*My Power*	*My Freq.*	*His Freq.*	*His Note*	*My QSA*	*His QSA*	*Remarks*
May 9	0310	G5BY	H	....	....	3820	Xtal	..	3	Clg CQ and W8AWJ
" 11	0120	W8DYH	W	275 w	3700	3525	Phone	5	4	Fast fading and poor mod.
" 11	0130	W6CZR	H	....	....	3780	RAC	..	5	Working KA1AF.
" 11	0137	W9FLG	W	275 w	3700	3900	Gud d.c.	5	5	QRM lighter now
" 11	0200	K6EWB	W	180 w	7200	7030	Xtal	3	3	On sked. Rec'd 2, sent 3

FIG. 1

Left-hand pages in the log may be left blank to use for extensive remarks on emergencies or expeditions, for diagrams, records of tuning adjustments and ranges, or changes in equipment.

A log is of great value in a number of additional ways through use of these left-hand pages. A comparison of the operating results obtained with different apparatus in use at different times is valuable. The "DX" or traffic-handling value of the various frequencies over varying distances may be readily found from the log. The effect of weather or time of day may be also quickly found. Every change made in either the transmitter or antenna system should be noted down in the log so that results may be compared for dates before and after the date when a change was made. No matter how trivial the change, put it down in the log. Remember that only one change at a time should be made if the changed results are to be attributed to one definite cause.



AMATEUR RADIO STATION LOG

FIG. 2

KEEP AN ACCURATE AND COMPLETE STATION LOG AT ALL TIMES! THE F.R.C. REQUIRES IT

The official A.R.R.L. log is shown above, answering every government requirement in respect to station records. Bound logs made up in accord with the above form can be obtained from Headquarters for a nominal sum or you can prepare your own, in which case we offer this form as a suggestion, hoping that you find it worthy of adoption. Every station must keep some sort of a log.

Word List for Accurate Transmission

When sending messages containing radio calls or initials likely to be confused and where errors must be avoided, the calls or initials should be thrown into short code words:

A — ABLE
B — BOY
C — CAST
D — DOG
E — EASY
F — FOX
G — GEORGE
H — HAVE
I — ITEM
J — JIG
K — KING
L — LOVE
M — MIKE
N — NAN
O — OBOE
P — PUP
Q — QUACK
R — ROT
S — SAIL
T — TARE
U — UNIT
V — VICE
W — WATCH
X — X-RAY
Y — YOKE
Z — ZED

Example: *W1BCG* is sent as *WATCH ONE BOY CAST GEORGE.*

A somewhat different list can be obtained from the local Western Union telegraph office and posted beside the telephone to use when telephoning messages containing initials and difficult words. Such code words prevent errors due to phonetic similarity. Here is the Western Union word-list:

A — ADAMS
B — BOSTON
C — CHICAGO
D — DENVER
E — EDWARD
F — FRANK
G — GEORGE
H — HENRY
I — IDA
J — JOHN
K — KING
L — LINCOLN
M — MARY
N — NEW YORK
O — OCEAN
P — PETER
Q — QUEEN
R — ROBERT
S — SUGAR
T — THOMAS
U — UNION
V — VICTOR
W — WILLIAM
X — X-RAY
Y — YOUNG
Z — ZERO

'Phone Procedure

Amateur radiophone stations should use the international radiotelephone procedure which is part of the supplementary regulations to the International Radiotelegraph Convention.

For spelling call signals, service abbreviations and words, such lists as just given should be used.

At the start of communication the calling formula is spoken twice by both the station called and the calling station. After contact is established it is spoken once only. Examples of 'phone procedure in accordance with the International Radiotelegraph Convention:

W5QL calls: "Hello W3JZ Philadelphia, hello W3JZ Philadelphia, W5QL Oklahoma City calling, W5QL Oklahoma City calling, message for you, message for you, come in please."

W3JZ replies: "Hello W5QL Oklahoma City, hello W5QL Oklahoma City, W3JZ Philadelphia answering, W3JZ Philadelphia answering, send your message, send your message, come in please."

W5QL replies, "Hello W3JZ Philadelphia, W5QL Oklahoma City answering, the message begins, from Oklahoma City Oklahoma W5QL number........ [usual preamble, address, text, signature, etc.], message ends; I repeat, the message begins, from Oklahoma City Oklahoma W5QL number...... [repetition of preamble, address, text, signature, etc.], message ends, come in please."

W3JZ replies: "Hello W5QL Oklahoma City, W3JZ Philadelphia answering, your message begins, from Oklahoma City Oklahoma W5QL number..... [repetition of complete message], end of your message, come in please."

W5QL replies: "Hello W3JZ Philadelphia, W5QL Oklahoma City answering, you have the message correctly, you have the message correctly, W5QL Oklahoma City signing off."

Note that in handling traffic by voice, messages are repeated *twice* for accuracy, using the word list to spell names and prevent misunderstandings. The receiving station must repeat the message back *in addition*. Only when the sender *confirms* the repetition as correct can the message be regarded as handled.

Amateur Status

It is most important that individually and as an organization we be most careful to preserve our standing as amateurs by doing nothing to harm that most precious possession, our amateur status.

No brief can be held for the amateur who accepts direct or indirect compensation for handling specific messages. This is in direct violation of the terms of the amateur station license and the regulations of the Federal Radio Commission.

It is the purpose of these paragraphs to warn amateurs to avoid being "used" by commercial interests in unethical ways. An amateur asked our advice recently on accepting a whole set of fine station equipment from a business house — the only string being that he should consistently try to handle some traffic with a certain foreign point. A hotel on the Pacific Coast offered an amateur radio club a fine meeting place with free light, power and heat — provided the amateurs would establish an amateur station and relay messages for guests of the hotel. A certain newspaper planned to "organize an amateur radio club" and establish a "net" for the collecting of amateur news for the paper. It offered the amateurs a club room and the facilities of a powerful station that it would install as "net control station" in return for the things it could gain by making amateurs violate their amateur status!

There are plenty of legitimate activities in which amateurs may participate. The League approves amateur coöperation with worthy enterprises, sponsors tests to show the utility of short-wave communication, encourages worth-while service to expeditions in getting their messages from the far parts of the earth. Be assured that there is nothing wrong in accepting trophies and prizes of any sort for legitimate amateur competition in communication contests. Watch carefully and refuse to enter into any agreements or alliances through which you accept anything in the nature of a consideration for services rendered in connection with your amateur radio station. There is no question of the good intentions of the amateurs involved in the several cases cited. Very great damage can be done unless there is strict observance of both the spirit and letter of the regulations involving amateur status. Avoid sugar-coated promises and opportunities which might be construed as direct or indirect compensation and a violation of amateur status. Seek competent advice before you jump at chances to get something for nothing. Preserve your most valued possession, your status as an amateur.

Our right to handle friendly communications of worth-while character and to engage in valuable work of all kinds in emergencies and with expeditions remains unquestioned. A "consideration" of any nature whatsoever absolutely establishes the "commercial" nature of any traffic.

Emergency Work—QRR

Amateurs have always given an excellent account of themselves in many emergencies of local and national character. In every instance, the amateurs who have considered the possibilities of an emergency arising *before* the trouble actually came to pass were the ones who must be credited with doing the most important work. They were ready, prepared for the crisis when it came. It behooves all of us to think upon these matters, to likewise prepare ourselves for doing a creditable job in each future opportunity. The very least we can do is to study the history of such cases so that we may proceed correctly and systematically about our business without losing our heads and passing up glorious opportunities for service in a crisis.

Priority must be given messages from a stricken point asking for relief measures such as food, antitoxin, blankets, doctors, nurses and necessities of life. Next in order of importance (and also in order of transmission) are the press messages informing the outside world of all that has taken place, the extent of the disaster, perhaps containing public appeals for assistance if the authorities in the affected area believe this necessary. A third class of messages is between friends and relatives, messages of inquiry or messages of assurance to and from the stricken territory.

During emergencies it is often possible to send press addressed to U.P., A.P., N.A. N.A., etc. between the transmissions of relief priority traffic. Invariably such messages are correctly delivered to local member-newspapers in such associations, the public kept informed, and amateur radio credited. Such broadcasts should be sent at regular intervals if possible. They have sometimes been overlooked in the rush.

Considerations of an emergency power supply are of first importance in many cases where radio is destined to play a part. If local electric service mains are crippled one may have recourse to B batteries, dynamotors driven from storage batteries, and the like. By consulting with other amateurs and putting all the available facilities together in the most favorable location a station can be made operative in short order. An order from some competent authority will make supplies of batteries or temporary service from a public utilities company available for emergency stations. It is sometimes as easy to move the amateur station to a power supply as to collect a power supply together and bring it to the amateur station. This is especially true if the transmitter and receiver are built as independent units. In some emergencies B batteries have been provided from local electrical supply stores.

Be ready for the emergency call, QRR, when it comes. Jump into the breach with your station if feasible or stand by and avoid interference to those handling emergency traffic if this seems to be the right thing to do. "Standing by" is sometimes the harder but wise course if the important communications are being handled satisfactorily by others and your traffic is "public correspondence" for individuals.

If you live along the line of a railroad you should get in touch with the local representative of the railroad so he will communicate with you in case amateur radio can help in an emergency. You should likewise make note of the address of Red Cross headquarters, of local military units, police departments, representatives of press associations and the like, if possible putting your station on record with such organizations and other competent authorities so that you will be called upon to assist when emergency communication is necessary. When storms approach or disaster threatens it is best to keep in touch with the situation by radio and again to offer service to these agencies well in advance of the actual emergency. Emergency work reaps big returns in public esteem and personal satisfaction.

Perhaps the last duty of the emergency station but a duty nevertheless is a full report of the work that was done so that the whole achievement can be credited to amateur radio. *Stations outside an "emergency zone" and in communication with relief stations in that zone are requested to inform A.R.R.L. Headquarters of this situation by telegram to facilitate traffic movement and for the information of the press.*

After emergency communications are completed, report in detail direct to A.R.R.L. just what part you and fellow amateurs played in the situation. On such reports *QST* articles are written. *From analysis of all reports an Award Committee of A.R.R.L. Headquarters officials, base their recommendations for awards granted for notable "public service" work.* Certificates are given individual amateur operators from time to time in recognition of meritorious work contributing substantially to the service record of the amateur through noteworthy achievement in *emergencies*, and regular work with *expeditions*. Report your work!

Interference Committees

The subject of public relations is important to us amateurs both individually and as an organization. No amateur can long afford to operate when he knowingly interferes widely with broadcast reception in his neighborhood and when there are simple remedies to be applied. Even the observance of prescribed quiet hours, while covering the situation legally, does not entirely suffice. Broadcast listeners do not look on interference with greater tolerance just because it is caused outside certain hours, and of course we want the good will which only a full understanding of the problem and contact with next-door residents can bring. Since all amateur operators are well qualified technically and most b.c.l.'s are not, the burden of responsibility falls on us in individually contacting any listeners who may be troubled. Patience in explaining, frankness, tolerance in listening to other viewpoints and other qualities of diplomacy are needed to give the full technical explanations required, to win confidence and permission to conduct necessary tests, install wave-traps, etc.

Most of our troubles are due to "proximity," choice of frequency, and the like, and sometimes simple adjustments or changes will cure the difficulty altogether.

You will find methods for key thump elimination and wave trap installation elsewhere in this book. A.R.R.L. Headquarters will be pleased to send suggestions on request, if you explain your problem fully and carefully. Amateurs are sometimes wrongfully blamed for causing interference. Actually most interference is traceable to faulty electrical equipment, inadequate shielding or poor design of receivers, and less than one percent of the interference reported is traceable to amateur sources.

We recommend and request that each A.R.R.L. affiliated club organization maintain an interference committee, to keep order, make investigations and recommendations locally, coöperate with the press, the public, and listeners who wish to file complaints of amateur interference. These committees can be composed of representative broadcast listeners, amateurs and with one member from a local newspaper to assist in collecting and referring complaints. A few leading questions will disclose the amateur cases and other difficulties can be referred to local power and communications companies.

The club interference committees investigate reports of *amateur* interference, put the interested parties in touch with each other and suggest ways of reducing or getting rid of the interference. When quiet hours are necessary, they are recommended.

It is necessary for both parties to an interference problem to understand that *both the transmitter and the receiver* are part of the problem — improved adjustment of the former — improved design of the latter to increase its selectivity, may be necessary. Where "proximity" is part of the problem special measures should be considered to isolate circuits and equipment by installation of suitable "traps," to aid selectivity, or by chokes and condensers to prevent "coupling" through common supply line wires. Each individual must accept responsibility for his equipment. Coöperation is the only policy that will help either party — a full measure of coöperation and understanding must be brought about in every interference case.

Call Books

One useful addition to every station is a good call book. When stations are heard or worked, the first thing that interests us is the location. If we have messages to be handled, it is necessary that we know the location of stations so that we may route our messages correctly.

No call books are ever quite up-to-date because new stations are continually coming on the air and old stations occasionally drop out of existence and some changes have taken place in just the short time while an up-to-date list of calls is being set in type by the printer.

A complete list of Canadian amateur station calls can be obtained for 25 cents from the Department of Marine and Fisheries, Ottawa, Canada.

The "Radio Amateur Call Book Magazine," listing amateur and many high-frequency commercial stations of the entire world, may be obtained from A.R.R.L. Headquarters, 38 La Salle Road, West Hartford, Conn., single copies, $1.00 (foreign $1.10). This call book now appears in March, June, September and December, with new calls added up to the date of issue. Yearly subscription, $3.25 (foreign $3.50). This publication is the most up to date of all such books, since it is issued and revised quarterly. An up-to-date call book is a practical necessity and convenience in just about every ham station.

Operating Hints

Listen carefully for several minutes before you use the transmitter to get an idea of what stations are working. This will help in placing messages where they belong.

Use abbreviations in operating conversations. This saves time and cuts down unnecessary interference.

Stand by (QRX) when asked to by another station who is having difficulty working through your interference. It is equally courteous to shift frequency (QSV) to a point where no interference will be caused. Sometimes a change in frequency will help the station you are working to get your message through interference. Accurate frequency meters at both stations will make this change speedy and the contact sure.

Report your messages to the local traffic official every month on time. Otherwise you cannot expect your report to reach *QST*. Reports sent to Headquarters are routed back to the local officials who make up the monthly report.

Don't tell a fellow his signals are QSA5 when you can just hear him.

Don't say "QRM" or "QRN" when you mean "QRS."

Don't acknowledge any message until you have received it completely.

Don't CQ unless there is definite reason for so doing. When sending CQ, use judgment. Sign your call frequently, interspersed with calls, and at the end of all transmissions.

Abbreviated standard procedure deserves a word in the interest of brevity on the air. If you hear some old timers using it you will understand what is meant by reading the following paragraph. In handling lots of messages with a number of scheduled stations, most traffic can be cleared by holding all stations to 15-minute schedules. Several schedules should be arranged in consecutive order. To get several messages through in 15 minutes isn't an easy job but abbreviated practices help to cut down unnecessary transmission. However, make it a rule not to abbreviate unnecessarily when working an altogether unknown station.

W1AUF DE W1BMS P, meaning paid, personal, or private message (adopted from commercial procedure) is much quicker than *HR MSG* added to a call. *N QSK* is shorter than *QRU CU NEXT SKED*. Instead of using the completely spelled out preamble *HR MSG FM AUGUSTA MAINE W1BIG NR 156 OCTOBER 13 CK 14 TO*, etc., transmission can be saved by using *RDO AUGUSTA ME W1BIG 156 OCT 13 14 TO*, etc. One more thing that conserves operating time is the cultivation of the operating practice of writing down "156 W1UE 615P 11 13 28" with the free hand during the sending of the next message.

Be courteous over the air. Offer suggestions for improving the other fellow's note or operating methods. Expect and ask for similar suggestions without expecting any praise. Constructive things can be said without being disagreeable or setting one's self up as a paragon. *Be truthful but tactful.*

Readability and Audibility

The International Radiotelegraph Convention has agreed upon a Q Code of abbreviations for all services. Readability is indicated by sending a figure (1 to 5) after the appropriate Q signal, to show progressive signal strength. QSA means, "The strength of your signals is . . . . ."

Thus one might say "QSA 3," the exact and literal meaning of which is "The strength of your signals is fairly good; readable, but with difficulty." The scale:

1 — Hardly perceptible; unreadable.
2 — Weak; readable now and then.
3 — Fairly good; readable; but with difficulty.
4 — Good; readable.
5 — Very good; perfectly readable.

The R-system of indicating *audibility* is widely used by amateurs to supplement a report on the more important consideration of *readability*. The readability, indicated by the above scale, may be handicapped by local interference (QRM), atmospherics (QRN), receiver background, or a noisy operating room to such an extent that signals are uncopiable, even though strong. The report on audibility is one concerned entirely with the *strength of the signal* without regard to other sounds in the 'phones or room. Introduced in May, 1925, *QST*, the R-system of audibility came into use in a very short time. The meanings of the several R signals are as follows:

R1 — Faint signals, just audible.
R2 — Weak signals, barely audible.
R3 — Weak signals, copiable (in absence of any difficulty).
R4 — Fair signals, readable.
R5 — Moderately strong signals.
R6 — Strong signals.
R7 — Good strong signals (such as copiable through interference).
R8 — Very strong signals; can be heard several feet from phones.
R9 — Extremely strong signals.

Chapter Sixteen

MESSAGE HANDLING

ONE activity of the League that is quite important is the accepting and relaying of messages. Station owners may originate traffic *of any kind* going to any part of the United States, Hawaii, Porto Rico, Alaska, or the Philippines. Canadian messages may be handled under certain restrictions. Important traffic in emergencies or messages from expeditions for delivery in Canada must be put on a land wire by the U. S. amateur station handling. The international law prohibiting the handling of important messages to most foreign countries must be observed.

Messages may be accepted from friends or acquaintances for sending by amateur radio. Such messages should be put in as complete form as possible before transmitting them. *Incomplete messages should not be accepted.* As messages are often relayed through several stations before arriving at their destination, *no abbreviations should be used in the text* as mistakes are bound to happen when the text is shortened in this manner. To people not acquainted with radio abbreviations, messages written in shortened form are meaningless. Delivering stations must be careful to see that messages are written out fully.

In handling messages we are doing something really worth-while. We want to start only good worth-while messages from our stations. Our efforts should be directed to making the quality of our message service high. The number of messages we handle is of secondary importance. The *kind of messages* we originate or start from our stations and the *speed* with which the messages pass through our station and the *reliability or accuracy* with which the messages are handled are the things of paramount importance.

Message Form

Each message originated and handled should contain the following component parts in the order given:

(a) City of origin
(b) Station of origin
(c) Number
(d) Date
(e) Check (optional)
(f) Address
(g) Text
(h) Signature

(a) The "city of origin" refers to the name of the city from which the message was started. If a message is filed at League Headquarters by someone in Hartford, Conn., the preamble reads *Hr msg fm Hartford Conn W1MK Nr 457 April 9*, etc.

If a message is sent to your radio station by mail the preamble reads a little differently to show where the message came from and from what city and station it originated as well. If a message was filed at A.R.R.L. Headquarters and if it came by mail from Wiscasset, Maine, the preamble would run like this to avoid confusion: *Hr msg fm Wiscasset Maine via Hartford Conn W1MK Nr 457 April 9*, etc.

(b) The "station of origin" refers to the call of the station at which the message was filed and this should always be included so that a "service" message may be sent back to the originating station if something interferes with the prompt handling or delivery of a message. In the example of preambles just given W1MK is the station of origin, that call being the one assigned the League Headquarters Station.

(c) Every message transmitted should bear a "number." Beginning on the first day of each calendar year, each transmitting station establishes a new series of numbers, beginning at Nr. 1. Keep a sheet with a consecutive list of numbers handy; file all messages without numbers; and when you send the messages, assign numbers to them from the "number sheet," scratching off the numbers on that list as you do so, making a notation on the number sheet of the station to which the message was sent and the date. Such a system is convenient for reference to the number of messages originated each month.

(d) Every message shall bear a "date" and this date is transmitted by each station handling the message. The date is the "day filed" at the originating station unless otherwise specified by the sender.

(e) Every word in the address text and signature of a message counts in the check using radio cable-count. Words and abbreviations in the preamble are not counted.

(f) The "address" refers to the name, street and number, city, state, and telephone number of the party to whom the message is being sent. A sufficiently complete address should always be given to insure delivery. When accepting messages this point should be stressed. In transmitting the message the address is followed by a double dash or break sign (— . . . —) and it always precedes the text.

(g) The "text" consists of the words in the body of the message. No abbreviations should ever be substituted for the words in the text of the message. The text follows the address and is set off from the signature by another break (— . . . —).

(h) The "signature" is usually the name of the person sending the message. When no signature is given it is customary to include the words "no sig" at the end of the message to avoid confusion and misunderstanding. When there *is* a signature, it follows the break; *the abbreviation "sig" is not transmitted.*

The presence of unnecessary capital letters, periods, commas or other marks of punctuation may alter the meaning of a text. For this reason commercial communication companies use a shiftless typewriter (capitals only). The texts of messages are typed in block letters (all capitals) *devoid of punctuation*, underlining and paragraphing *except where expressed in words.* In all communication work, accuracy is of first importance.

Numbering Messages

Use of a "number sheet" or consecutive list of numbers enables any operator to tell quickly just what number is "next." Such a record may be kept in the log, or with the message file, or posted on the wall of the station. Numbers may be crossed off as the messages are filed for origination. Another method of use consists of filing messages in complete form *except for the number.* Then the list of numbers is consulted and numbers assigned as each message is sent. As the operator you work acknowledges (QSLs) each message cross off the number used and note the call of the station and the date opposite this number.

A "number sheet" is quite essential to help in keeping records straight, and to avoid possible duplication of numbers on messages. It is of assistance in checking the count of originated messages in a given month. With each amateur station log book A.R.R.L. provides C.D. Form 3, a *number sheet of originated messages* — or you can start a consecutive list of numbers in January of each year on a blank sheet, adding numbers as needed.

The original number supplied each message by the operator at the originating station is transmitted by each station handling the message. No new numbers are given the message by intermediate stations. If a message is filed at W1MK on April 9 and when sent is given the number "nr 458," this same call, date and number are used by all stations handling this message. The number and date become a part of the city-and-station-of-origin identification used for the purpose of tracing. Only at stations where a message originates or is filed can a number be assigned to a message. Intermediate relaying stations neither change numbers nor supply new ones to messages.

Checking Messages — Cable Count

In the address the names of cities, states, countries or other divisions of territory each count as one word regardless of the number of letters they contain. Proper names in the address and signature are counted at the rate of one word for each 15 letters or fraction thereof. The words "street," "avenue," "square" or "road" are always to be counted each as one word separately from the name of the street, etc., whether written with it or separately. Names of ships are counted as one word irrespective of the number of letters they contain. When there are two ships of the same name, the name and the call letters of the ship are together counted as one word. The name of the state is always counted as one word in addition to the name of the city. Initials in the address are counted each as one word. Each group of house or street numbers is allowed to pass as one word, however.

It is customary to omit the count of the name of a state in the check when it is written and sent in parentheses in the address.

If a telephone number is included in the address, the word "telephone" or "phone" counts as one word. The name of the exchange is an additional word in the check. Each group of five figures or fraction thereof counts as one word. A hyphen indicating the word "ring" may be substituted for one figure in a telephone number without increasing the check. *Phone Charter 328-5* counts as 3 in the check. *26039* counts as 1 in the check. *2603-9* is a six-character group and accordingly counts as 2 in the check. Mixed letter and figure combinations are counted as a word to each character. A house number followed by a letter counts as but one word, however.

Radio calls are often included in the address to make proper routing easy. *W5XAY* counts as one word in the address but as five words in the body or signature of the message.

In the text, words are counted for every fifteen characters or fraction thereof if the message is a plain language message. A word containing from 16 to 30 letters counts 2 in the check.

Names of cities in the address count always as one word while in the text they may count as more than one word depending on how written and transmitted. *New York City* counts as one word in the address but three words wherever it appears in the body of the message. *New York City* is counted as one word when written and sent without spacing between the parts.

Isolated characters each count as one word. Five figures or less in a group count as one word. Words joined by a hyphen or apostrophe count as separate words. A hyphen or apostrophe each counts as one word. However, they are seldom transmitted. Two quotation marks or parenthesis signs count as one word. Punctuation is never sent in radio messages except at the express command of the sender. Even then it is spelled out. In the text of messages, the names of ships are counted at the rate of 15 letters to a word if the names are written out separately. If all parts are joined to form one word, each 10 letters or fractional part counts as one word.

Messages may be classed as plain language messages, coded messages or cipher messages. A plain-language message bears the same thought indicated by the dictionary meaning of the words used in the text. All ordinary messages are plain-language messages. Every 15 characters or fraction thereof counts as one word. Numerals are counted in groups of five or less. A fraction bar or decimal point counts as one character or figure. An underline counts as an extra word wherever it appears.

Examples (plain language):

CSS	1 word	91¾	1 word
ARRANGEMENT	1 word	396¾	2 words
UNCONSTITUTIONAL	2 words	2961	1 word
X-RAY	2 words	85772	1 word
(the hyphen is not transmitted)		171186	2 words

In coded messages the words are all pronounceable but their arrangement is not necessarily in sentences to express the thought. Several selected words or word groups express more extensive thoughts. Every ten characters or less count as one word. Either dictionary or artificial words may be used but all words must be pronounceable. Words containing 11 to 20 letters count "2" in the check. When one has a copy of the simple and commonly used codes the business of coding and decoding is easy.

Examples (coded):

CAUSTIC	1 word	AVIABLOSKI	1 word
COMBINZUBIOUS	2 words	HOOTBAFF	1 word

In cipher messages the letters or figures in each uninterrupted series are counted at the rate of 5 (or fraction thereof) per word. Groups of letters are checked at the same rate as groups of figures. Mixed letters and figure combinations count a word to each character. *R4TG* counts as four words unless it is an established trade mark or trade name. Radio calls are always counted as cipher. *W1MK* counts as four words in the text or signature of a message (though but one word if sent "en groupe" in the address). For accuracy it should be written *watch one mike king.* Abbreviated or misspelled words are counted at the 5-letter rate in any message where they accidentally appear. A misspelled word with missing letters takes the same count as though it were correctly spelled.

Examples (cipher count):

XYPPQ	1 word
D6W	3 words
CXQPWL	2 words

If a message is written partly in plain language, partly in cipher, and partly coded, the words in plain language and code are counted at the 10-letter rate while the other parts of the messages are checked at the 5-letter rate.

When messages are written in plain language and cipher, the passages in plain language take the 15-letter count and the passages in cipher take the 5-letter count.

Messages in plain language and code take the 10-letter count.

When the letters "ch" come together in the make-up of a dictionary word, they are counted as one letter.

Either whole or fractional numbers spelled out so each group forms a continuous word may be checked at the 15-letter rate. *FOB, COD, SS, ARRL, QST*, and such expressions in current use, are counted five letters to a word wherever they appear. Each group must of course be sent and counted separately to indicate separate words. Groups of letters are not acceptable in the address but must be separated and checked as one word each.

Here is an example of a plain-language message in correct A.R.R.L. form and carrying the "cable-count" check:

(HR MSG FM HARTFORD CONN W1MK NR 83 — 217p MAY 3 CK 50 TO)
H B ALLEN
416 MOUNTAINVIEW AVE
MOUNTHOLLY NEW JERSEY
PLEASE COMMENT ON PROPOSED OLD TIMERS WEEK USING 3500 KILOCYCLES STOP BACK NUMBER OF QST WAS FORWARDED MONDAY STOP WHAT FREQUENCY IS MOST IN USE AT W3ATJ QUESTION 73 TO YOU AND NEW JERSEY GANG
(sig.) *ARRL COMMUNICATIONS MANAGER*

The count on each part of the message is added to give the "check" shown. Address, 8; text, 39; signature 3. The check is the sum of these three or 50 words. The first parts of the message in parentheses are always transmitted but do not count in the check. "Sig" is not transmitted.

The following words that give most trouble in counting this message add into the "check" as follows:

H	1	QST	1
B	1	W3ATJ	5
416	1	73	1
AVE	1	NEW JERSEY	1
NEW JERSEY	1	ARRL	1
3500	1		

The use of a check on amateur messages is optional. Where employed, however, it is a matter of courtesy to see that the check is correct and is handed on along with the rest of the message. Very important messages should be checked carefully to insure accuracy, and if an important message is received with no check, a check should be added.

Foreign Traffic Restrictions

Any and all kinds of traffic may be handled between amateur stations in different parts of the United States, Hawaii, Alaska, Porto Rico and the Philippine Islands. There is no qualification or restriction except that amateur status must be observed and no material considerations become involved in the communications. Contrasting sharply with this comparatively broad right to handle amateur communications domestically in these United States are certain prohibitions and restrictions which concern the exchange of amateur dispatches *internationally*.

Internationally, unless contacts between amateur stations of different countries have been prohibited, as by any particular country giving notice of its opposition to this exchange, "experimental" amateur communication may go forward. In the years that have elapsed since the Washington Convention no prohibition on amateur communication has been filed by any country with the Berne Bureau.

The general regulations attached to the Convention cover the limitations to which work between amateur stations in different foreign countries is subject. Any country ratifying the Washington Convention is at liberty to make arrangements with specific other governments for amateur communication *more liberal* than the quoted terms of the Convention. If no specific negotiations are made the amateurs of any country may work internationally as long as they observe the following regulation (Article 6):

"When this exchange is permitted the communications must, unless the interested countries have entered into other agreements among themselves, be carried on in plain language and be limited to messages bearing upon the experiments and to remarks of a private nature for which, by reason of their unimportance, recourse to the public telegraph service might not be warranted."

A government may give its amateurs the full rights of exchange permitted in the above, or on the other hand it may restrict its amateurs by local regulation or by terms of licenses so that they enjoy just part or none at all of the privileges made available by international agreement. In some countries (particularly European countries) the width of the frequency bands and power is severely restricted, the use of some bands withheld, traffic for third parties expressly forbidden, absurd time regulations restricting operating are in effect, and the like. For this reason practically all European amateurs will not accept messages for third parties, for relay, or even unimportant communications for themselves unless the remarks relate to technical or experimental work.

In England, France, Austria, Czechoslovakia, Germany, Netherlands, Belgium, South Africa, Spain, Ireland, Denmark, Madeira, S. India, Indo-China, Hongkong, and Uruguay practically no "third party" communications are handled by amateurs due to the severe restrictions of these governments.

We are advised that in Norway greeting and unimportant messages for third parties may be handled. In Peru there are "no restrictions on friendly correspondence" but stations must not handle such "in a commercial manner" where this would affect companies handling commercial traffic. In Australia and New Zealand restrictions somewhat similar to those in Europe obtain, but the amateur societies in these countries seldom have difficulty securing special permission to handle "approved" greeting messages from radio exhibitions.

Messages have been handled freely with Brazil, China, Peru and Chile in the past, and it is understood that the Chinese government is expected to license its amateurs soon, with the right to handle personal, although not commercial traffic internationally.

The Madrid Convention (1932) may grant increased recognition through definition of amateur stations, in the past confused with experimental stations. The Article quoted will probably be amended and clarified, prohibiting exchange of information or correspondence *internationally* "on behalf of third parties" . . . and as before subject to modification by negotiation between countries. No new international treaty will be effective before 1934, and there appears no threat of major change in our domestic amateur work from this source.

As always, the major opportunity for outstanding message-handling work exists right at home. There are chances to render a real service to local communities everywhere that an amateur puts up a station and gets on the air, and especially in time of emergencies. Excellent work in traffic handling is so very common that it takes almost exceptional emergency and expedition work, or work with unusual characteristics, to "rate" special mention. Many expeditions and exploring parties go to the far parts of the earth — and now they always take high-frequency equipment along for contact work.

The Canadian Agreement

The special reciprocal agreement concluded between our country and the Dominion of Canada at the behest of the A.R.R.L. permits Canadian and U. S. amateurs to exchange messages of importance under certain restrictions. Article 6 of the General Regulations annexed to the International Radio Telegraph Convention contemplates the exchange of plain language messages and private remarks of such relative unimportance that recourse to public telegraph services is unwarranted. So this agreement is an expansion of the international regulations to permit the handling of more important traffic.

The authorized traffic is described as follows:

"1. Messages that would not normally be sent by any existing means of electrical communication and on which no tolls must be charged.

"2. Messages from other radio stations in isolated points not connected by any regular means of electrical communication; such messages to be handed to the local office of the telegraph company by the amateur receiving station for transmission to final destination, e.g., messages from expeditions in remote points such as the Arctic, etc.

"3. Messages handled by amateur stations in cases of emergency, e.g., floods, etc., where the regular electrical communication systems become interrupted; such messages to be handed to the nearest point on the established commercial telegraph system remaining in operation."

The arrangement applies to the United States and its territories and possessions including Alaska, the Hawaiian Islands, Porto Rico, the Virgin Islands, the Panama Canal Zone and the Philippine Islands.

Originating Traffic

Every message has to start from some place and unless some of us solicit some good traffic from friends and acquaintances there will be no messages to relay. Of course the simplest way to get messages is to offer to send a few for friends, reminding them that the message service is free and no one can be held responsible for delay or non-delivery. A number of the amateur fraternity have distributed pads of message blanks to local stores and business houses to assist in getting good traffic to originate regularly. A neatly typed card is displayed near-by explaining the workings of our A.R.R.L. traffic organization, and *listing the points to which the best possible service can be given.*

The time of collecting messages and the list of schedules kept may also be posted for the benefit of those interested. Wide-awake amateurs have distributed message blanks to the nearest tourist camps during the summer seasons of recent years and lots of good traffic has been collected through a system of message-collection boxes placed in public buildings and hospitals. A sign prominently displayed outside the radio station has in some instances proved a good source of obtaining worth-while messages. Messages from broadcast listeners to the stations where programs originate have helped in the search of the traffic-minded amateur to be of service to the public at the same time he enjoys his hobby.

Messages that are not complete in every respect *should not be accepted* for relaying. The city of origin, station of origin, number, date, address, text, and signature constitute a complete message. All these parts are necessary to make a message of value to the recipient, to make it possible to deliver the message and to route an answer back to the sender.

To properly represent amateur radio, placards when used should avoid any possible confusion with telegraph and cable services. Any posters should refer to AMATEUR RADIOGRAMS, and explain that messages are sent through AMATEUR RADIO STATIONS, as a HOBBY, FREE, without cost (since amateurs can't and will not accept compensation). The exact conditions of the service should be stated or explained as completely as possible, including the fact that there is NO GUARANTEE OF DELIVERY. The individual in charge of the station has full powers to refuse any traffic unsuitable for radio transmission, or addressed to points where deliveries cannot be made. Relaying is subject to radio conditions and favorable opportunity for contacting. Also, it is desirable to word messages as telegrams would be worded instead of writing letters. Better service can be expected on 15-word texts of apparent importance than on extremely long messages. Traffic should not be accepted for "all over the world" since there are not active amateurs in all countries, and since the Washington Convention prohibits relaying important messages to some countries where there are amateurs.

Careful planning and organized schedules are necessary if a *real* job of handling traffic is to be done. Advance schedules are essential to assist in the distribution of messages. It may be possible to schedule stations in cities to which you know quantities of messages will be filed. Distribute messages, in the proper directions, widely enough so that a few outside stations do not become seriously overburdened. Have the latest copies of *QST* at hand and study the traffic summaries at the end of sectional activity reports. Nearly all these stations are reliable Official Relay Stations interested in traffic handling. The list of calls will help you to identify or distinguish reliable consistent operators to whom to entrust valuable messages.

Operators must route traffic properly — not merely aim to "clear the hook." New stations worked should be informed of the amount of traffic you wish to clear and agree to handle the messages, *before* they are sent. Delays and non-deliveries result from giving an operator more than he can handle efficiently. Operators should *not* accept traffic when not in a position to continue operating their stations to give it proper handling.

It is better to handle a small or moderate volume of traffic *well*, than to attempt to break records in a manner that results in delayed messages, non-deliveries, and the like which certainly cannot help in creating any public good-will for amateur radio.

Tracing Messages

Tracing messages is sometimes necessary when it is desired to follow the route of a message or to find where it was held up or delayed. Tracing is usually accomplished by sending a copy of the message and a letter requesting that the time, date, and station calls of the stations from whom the message was received and to whom the message was given, be noted in the proper place on an enclosed sheet. The letter asks that the sheet and message be forwarded in rotation to all the stations handling the message until it has overtaken the message, when the tracer is mailed back to its starting point with the information collected from all the logs along the route.

Amateur Stations at Exhibits and Fairs

Where installation of an amateur radio station in a booth is planned make application at an early date for the necessary station license from the Federal Radio Commission for the location. When a license for a *portable* amateur station is already available of course this station can be installed at different locations, providing only that the proper F. R. C. office is notified of the location from which the equipment will be operated, as provided in the regulations. No license for station equipment is required if the exhibit will not include a transmitter in actual operation. Whatever type of exhibit is planned, write A.R.R.L. in advance, in order to receive sample material to make your amateur-booth more complete.

If the time is short and there is no opportunity for special organization of schedules to insure reliable routing and delivery, quite likely exhibit work, to be most productive of good-will results had best *not* include message handling plans — at least not from the booth-station itself where subject to noise, electrical interference, and other handicaps. To handle such traffic as offered with *real efficiency*, it should be distributed for origination via existing schedules of the *several most reliable local amateur stations. By dividing the traffic filed with other stations it may be sent more speedily on its way.* The full coöperation of all local stations should be requested. However, be sure that the operators undertaking to help are qualified and have good schedules for distributing messages.

"Show stations" must avoid origination of "poor traffic" by rigid supervision and elimination of meaningless messages with guessed-at inaccurate and incomplete addresses right at the source. Misaddressed and rubber-stamp-type traffic will always be subject to serious delays and non-delivery, and especially so when the traffic load is so great that handling such messages becomes irksome and work instead of fun. What good any message if it cannot be delivered?

The "Apparent Importance"

The "apparent importance" of a dispatch has been proved to have a very direct bearing on the speed of relaying a message and the likelihood of its delivery, especially if the relaying is to be attempted through several unknown stations instead of between one or two known reliable stations keeping regular schedules. It may seem a strange commentary on amateur relaying that such is the case, but examination of delivery results proves the statement; and the very fact that amateur radio is a hobby, and that it is "human nature" to devote most time and effort to doing what seems most worthwhile, will afford sufficient explanation. In successful relaying work *all* factors must be taken into account.

Troubles to Avoid in Originating Traffic

Incomplete preambles seem to be the most common fault in message handling. The city of origin, the station of origin, the number, the date, and the check are all a part of the preamble which goes at the beginning of every message. The *city* and *station of origin* are most essential. Without them it is impossible to notify the sender that his message could not be delivered and without this information it is not possible to route the reply speedily. The number and date are essential in servicing and tracing radiograms. All Official Relay Stations are instructed to refuse to accept messages without this necessary information. Every station should demand an "office of origin" from stations who have messages, and traffic may be rightly cancelled (QTA) on failure to include it. Thus messages will never get on the air without a starting place.

Many messages carry an insufficient address and cannot be delivered. Originating stations should refuse to accept messages to transmit when it is apparent that the address is too meagre.

Some stations lose track of the messages which they accept for delivery or transmission. They use scratch pads to copy signals on and they never clean up the operating table or have a place for things. The remedy is to adopt a few of the principles of neatness and to spend about two minutes each time you are through operating to put things in order. Write messages on message blanks of a uniform size when they arrive at the station. Keep together the messages to be sent. A good system to use is to mark the state of destination in the upper right hand corner of each message, arranging the messages in a heavy clip so that the names of the states are in easy view. A file box may be similarly arranged. A simple log book, a good filing system, an accurate frequency meter and an equally accurate clock, are sure signs of a well-operated station. The apparatus on the operating table will tell a story without words.

Volume vs. Deliveries

In passing we should add that starting traffic in volume always results in lowering percentage deliveries simply because "operating enjoyment" becomes "work" and amateur operators with limited time are able to cope with only definite quantities of messages. While in emergencies traffic could and would be willingly moved at any sacrifice of time, thus giving great credit to the amateur, the transmission of less important material, especially in volume, meets resistance, due to the characteristics of human nature and the fundamental aspects of amateur radio as a hobby (not a job). This of course does not excuse any amateur from accepting messages he knows he cannot handle. *It is best to refuse traffic when not in a position to handle it, and especially if unwilling to accept proper responsibility for doing your best to see it on its way — or delivered — speedily.*

Relay Procedure

Messages shall be relayed to the station nearest the location of the addressee and over the greatest distance permitting reliable communication.

No abbreviations shall be substituted for the words in the text of a message with the exception of "service messages," to be explained. Delivering stations must be careful that no confusing abbreviations are written into delivered messages.

Sending "words twice" is a practice to avoid. Use it only when expressly called for by the receiving operator when receiving conditions are poor.

Messages shall be transmitted as many as three times at the request of the receiving operator. Failing to make a complete copy after three attempts, the receiving operator shall cancel the message (QTA).

Let us assume that a station in Hartford, Conn., receives a message whose destination is Dallas, Texas. The message is at once written out on a message blank, filling in the city and station of origin, leaving only the "number," "rec'd," and "sent" spaces vacant.

The operator does not hear any western stations so he decides to give a directional "CQ" as per A.R.R.L. practice. He calls, *CQ, CQ, CQ TEXAS DE W1MK W1MK W1MK*, repeating the combination three times.

He listens and hears W9CXX in Cedar Rapids calling him, *W1MK W1MK W1MK DE W9CXX W9CXX W9CXX AR*.

Then he answers W9CXX indicating that he wishes him to take the message for Dallas. W1MK says *W9CXX W9CXX DE W1MK R QSP DALLAS? K*.

After W9CXX has given him the signal to go ahead, the message is transmitted, inserting the "number" in its proper place, and assigning the next number indicated on the "number sheet." The message is sent in A.R.R.L. sequence.

"HR MSG FM HARTFORD CONN W1MK NR247 NOV 11 CK31 TO FRANK M CORLETT W5ZS 2515 CATHERINE STREET DALLAS TEXAS —...— COMMUNICATIONS DEPARTMENT SUPPLIES AND MEMBERSHIP LIST ARE GOING FORWARD TODAY PLEASE SEND YOUR REACTION TO GENERAL NUMBER 372 OUR ARMY FILE —...— SIG HOUGHTON AR W1MK K.

W9CXX acknowledges the message like this: *W1MK DE W9CXX NR 247 R K*. Not a single *R* should be sent unless the whole message has been correctly received.

The operator at W1MK writes in the number of the message, scratches off number 247 on the "number sheet," putting *W9CXX* after the number. In the "sent" space at the bottom of the message blank he notes *the call of the Cedar Rapids station, the date, time, and his own personal "sine."* At the same time he concludes with W9CXX something like this: *R QRU 73 GB SK W1MK*, meaning, "All received OK, I have nothing more for you, see you again, no more now, best regards, good-bye, I am through with you and shall at once listen for other stations who may wish to call me. W1MK is now signing off."

W9CXX will come back with *I R GB AR SK W9CXX*, meaning "I understand, received you OK, good-bye, I am through." Then he will listen a few minutes to see if anyone is calling him. He will listen particularly for Texas stations and try to put the message through W5ZC or a neighboring station. If he does not hear someone calling him, he will listen for Texas stations and call them.

Getting Fills

Sometimes parts of a message are not received correctly or perhaps due to fading or interference there are gaps in the copy. The problem is to ask for "fills" or repeats in such a way as to complete the message quickly and with the minimum of transmission.

If the first part of a message is received but substantially all of the latter portions lost, the request for the missing parts is simply *RPT TXT AND SIG*, meaning "Repeat text and signature." *PBL* and *ADR* may be used similarly for the preamble and address of a message. *RPT AL* or *RPT MSG* should not be sent unless nearly all of the message is lost.

Each abbreviation used after a question mark (. . — — . .) asks for a repetition of that particular part of a message.

When a few word-groups in conversation or message handling have been missed, a selection of one or more of the following abbreviations will enable you to ask for a repeat on the parts in doubt. 'Phone stations of course request fills by using the full wording specified, without attempt at abbreviation.

Abbreviation	*Meaning*
?AA	Repeat all after
?AB	Repeat all before
?AL	Repeat all that has been sent
?BN...AND	Repeat all between...and
?WA	Repeat the word after
?WB	Repeat the word before

The good operator will ask for only what fills are needed, separating different requests for repetition by using the break sign or double dash (—...—) between these parts. There is seldom any excuse for repeating a whole message just to get a few lost words.

Another interrogation method is sometimes used, the question signal (··—— ——··) being sent between the last word received correctly and the first word (or first few words) received after the interruption. *RPT FROM* ..... *TO* ..... is a long, clumsy way of asking for fills which we have heard used by beginners. These have the one redeeming virtue of being understandable.

The figure four (....—) is a time-saving abbreviation which deserves popularity with traffic men. It is another of those hybrid abbreviations whose original meaning, "Please start me, where?" has come to us from Morse practice. Of course *?AL* or *RPT AL* will serve the same purpose, where a request for a repetition of parts of a message have been missed. While these latter usages are approved, the earlier practice is still followed by some operators.

Delivering Messages

The only service that we can render anyone by handling a message comes through "delivery." Every action of ours in sending and relaying messages leads up to this most important duty. Unless a message is delivered, it might as well never have been sent.

There is no reason for anyone to accept a message if he has no intention of relaying it or delivering it promptly. It is not at all discourteous to refuse politely to handle a message when it will be impossible for you to forward it to its destination.

Occasionally message delivery can be made through a third party not able to acknowledge the radiogram he overhears. When a third party happens to be in direct contact with the person addressed in the message he is able to hand him an unofficial confirmation copy and thus to make a delivery much sooner than a delivery could be made otherwise. It is *not* good radio etiquette to deliver such messages without explaining the circumstances under which they were copied, as a direct delivery discredits the operator who acknowledged the message but who through no fault of his own was not able to deliver so promptly. With a suitable note of explanation, such deliveries can often improve A.R.R.L. service and win public commendation.

Provisions of the Radio Act of 1927 make it a misdemeanor to give out information of any sort to any person except the addressee of a message. It is in no manner unethical to deliver an unofficial copy of a radiogram, if you do it to improve the speed of handling a message or to insure certain and prompt delivery. Do not forget that there are heavy fines prescribed by Federal laws for divulging the contents of messages to anyone *except* the person addressed in a message.

When it is possible to deliver messages in person, that is usually the most effective way. When the telephone does not prove instrumental in locating the party addressed in the message it is usually quickest to mail the message.

To help in securing deliveries, here are some good rules to follow:

Messages received by stations shall be delivered immediately.

Every domestic message shall be relayed within forty-eight (48) hours after receipt or if it cannot be relayed within this time shall be mailed to the addressee.

Messages for points outside North America must not be held longer than half the length of time required for them to reach their destination by mail.

We are primarily a radio organization, and the bulk of our messages should go by radio, not by mail. The point is that messages should not be allowed to fall by the way, and that they should be sent on or delivered just as quickly as possible. When a message cannot be delivered, or if it is unduly delayed, a "service" message should be written and started back to the "office of origin."

Each operator who reads these pages is asked to assume *personal responsibility* for the accuracy and speed of each message handled so that we can each have reason to take personal pride in our operating work and so that we will have just cause for pride in our League as a whole. Do *your* part that we may approach a 100% delivery figure.

The Service Message

A service message is a message sent by one station to another station relating to the service which we are or are not able to give in message handling. The service message may refer to non-deliveries, to delayed transmission, or to any phase of message handling activity.

Whenever a message is received which has insufficient address for delivery and no information can be obtained from the telephone book or the city directory, a service message should be written asking for a better address. While it is not proper to abbreviate words in the texts of regular messages, it is quite desirable and correct to use abbreviations in these station-to-station messages relating to traffic-handling work.

The prefix "svc" in place of the usual "msg" shows the class of the message and indicates at once that a station-to-station message is coming through. Service messages should be handled with the same care and speed that are given other messages.

Suppose a regulation message is received by W3CA for some one in Roanoke, Va. Suppose that the message cannot be delivered because of insufficient address. The city and station of origin of the message are given as "Pasco Washn W7GE." In line with the practice outlined above W3CA makes up a service message asking W7GE to "give better address," of course obtaining the address from the party that gave him the message. W3CA will give the message to anyone in the west, of course trying to give it to the station nearest Pasco, Washington, and sending it over the greatest distance permitting reliable communication. The message looks something like this:

HR SVC FM ROANOKE VA W3CA NR 291 AUG 19
To RADIO W7GE
L C MAYBEE
110 SOUTH SEVENTH AVE
PASCO WASHN —...—
UR NR 87 AUG 17 TO CUSHING SIG BOB HELD HR UNDLD PSE GBA —...—
(sig) *WOHLFORD W3CA*

Counting Messages

So that we can readily keep run of our messages and compare the number originated and delivered each month to learn some facts about the "efficiency" of our work in handling messages, a method of counting is used. Each time a message is handled by radio it counts one in the total.

A message received in person, by telephone, by telegraph, or by mail, *filed at the station and transmitted by radio* in proper form, counts as *one originated.*

A message *received by radio and delivered* in person, by telephone, telegraph, or mail, counts as *one delivered.*

A message *received by radio and sent forward by radio* counts as two messages *relayed* (one when received and again one when sent forward).

All messages counted under one of the three classes mentioned must be handled within a 48-hour (maximum) delay period to count as "messages handled" with but one exception. Messages for all continents except North America may be held one-half the length of time it would take them to reach their destination by mail. A "service" message counts the same as any other type of message.

The message total shall be the *sum* of the messages originated, delivered and relayed. Each station's message file and log shall be used to determine the report submitted by that particular station. Messages with identical texts (so-called rubber-stamp messages) shall count once only for *each* time the complete text, preamble and signature are sent by radio.

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By following the above rules, the messages handled during the "message month" may be counted readily. A monthly report should be sent to the local traffic official of the A.R.R.L. as mentioned under the subject of "Reporting." The closing date of the "message month" is the 15th of each month (the last of the month in Hawaii and the Philippines). Reports must go forward the next day.

Let us assume that on the 15th of the month one operator of a large amateur station receives several messages from another station. (a) Some of these messages are for relaying by radio. (b) Some of them are for local delivery. (c) There are still other messages the disposal of which cannot be accurately predicted. They are for the immediate neighborhood but can be either mailed or forwarded to another amateur by radio. A short-haul toll telephone call will deliver them but the chances of landing them nearer the destination by radio are pretty good. This operator's "trick" ends at midnight on the 15th and he must make out the report with some messages "on the hook" to be carried over for the next month's report.

(a) The messages on the hook that are to be relayed have been received and are to be sent. They count as "1 relayed" in the report that is made out now, and they will also count as "1 relayed" in the next month's report (the month during which they were forwarded by radio).

(b) By mailing the messages or phoning them at once, they can count as "1 delivered" for the current month's report. By holding them until the next day they will count in the next report as "1 delivered."

(c) The messages in this class should be carried forward into the next month. If they have to be mailed they will count in the next report as "1 delivered." If they are relayed, we count them as "2 relayed"; "1 received" in the preceding month being carried forward and added to "1 sent" makes the "2 relayed." If the operator wishes to count this message at once (for the current month) it must be mailed promptly and counted as "1 delivered."

Some examples of counting:

The operator of Station A gets a message by radio from Station B addressed to himself. This counts as "1 delivered" by himself and by Station A.

The operator of Station A takes a verbal message from a friend for relaying. He gives it to Station B over the telephone. Operator A does not handle the message by radio. Station B and operator B count the message as "1 originated." A cannot count the message in any manner.

The operator and owner of Station A visits Station B and *while operating* there takes a message for relaying. The operator and owner of B cannot operate for a day or two so the message is carried back to Station A by operator A who relays it along within a few hours. The traffic report of both Station A and Station B shows "1 relayed" for this work.

Please note that "handling" a message always includes the transmission and receipt of radio acknowledgment (QSL) of same, and the entry of date, time, and station call on the traffic, as handled, for purposes of record. Only messages properly handled, shall be counted in A.R.R.L. totals.

"Rubber-Stamp" Messages

Because, now and again, our stations fall into the habit of originating quantities of so-called "rubber-stamp" messages with such texts as "Your card received will QSL"; "Greetings by radio" and the like, the identical text being addressed to a large number of addressees, it becomes necessary to reaffirm our policy with respect to such messages. The history of our organization shows the demoralizing effect of an influx of such stereotyped messages in quantity. The net effect is to clog the hooks of traffic-handling stations until they can no longer function. This must be prevented by stopping uncalled for messages right at their source.

Obviously, a station in handling a rubber-stamp message has to exert only a small amount of effort in receiving the text and signature once. Then by handling the address to different points *en groupe* a large number of messages (?) can be received and transmitted with little time and effort. The League's system for crediting points for messages handled is based on giving one credit each time a *complete* message is handled by amateur radio, i.e., one credit for each originated message, one credit for each delivered message and two credits for each relayed message (one credit for the work in receiving it and one for the work in transmitting it). *Only* every message handled by radio *with a complete preamble, address, text, and signature* shall be counted, except in the case of *deliveries*, each mailed, telephoned or otherwise delivered message shall count "one delivered" regardless of handling in "book" form (with text sent once only).

Example (showing a claimed and revised count on R.S. messages): A certain station takes an R.S. message to 10 addresses and relays it onward to another station, claiming "relayed 20" for his work. This station shall be credited with "relayed 2"; one for receiving a complete preamble, address, text, and signature, one for sending a complete message on its way. For receiving and relaying to three stations (requiring the complete message to be sent three times) a total of four might be justly claimed in the relayed column. (This should not be construed to mean that any message to a single address should be given to more than a single reliable station.) For receiving and *delivering to three addresses* this work should be credited as "three delivered."

Reporting

Whether the principal accomplishments of the station are in traffic handling or other lines, what you are doing is always of interest to A.R.R.L headquarters. Our magazine, *QST*, covers the entire amateur field, keeping a record of the messages handled in different sections of the country, giving mention of the outstanding work that is done in communicating over great distances using small amounts of power, and summarizing all the activities.

We have mentioned the Official Relay Stations and the Communications Department organization. A section of *QST* is devoted to Communications Department reports. Form postals are sent the active stations in the relay system for reporting purposes. There is space to tell about the traffic handled, the frequency used during the reporting month, the "DX" worked, and other station records and activities, together with a list of the stations with whom schedules are kept. Items of general interest, changes in the set, and addresses of new amateurs also come in on this card.

Every operator of an active amateur station in the United States and Canada is cordially invited to report. Each month on the 16th (the 1st in Hawaii and the Philippines) the active stations send reports to their local officials. These officials forward condensed reports to Headquarters. Representative space is given each section of the country depending on the number reporting. Reports must have the dead material edited out of them to allow room for as much active and interesting news as can be gotten in. The more worth while a report is, the more of it gets in print. Traffic figures and calls of active stations always get full space. Readers of this Handbook are invited to send in their reports to the local traffic official just as soon as they have a station in operation. Write the nearest traffic official whose name appears on page 5 of each *QST*. Make your report as informative and interesting as possible.

Especially important work having a high news value should be reported direct to League Headquarters at Hartford.

Contributions to *QST* are welcomed by the Editors! Authors must remember that only a small percent of the received material can be printed and that it is impossible for an organization like ours to pay for articles. Ours is a "family" organization supported by and for the amateur. By carefully selecting material the members get the best magazine that can be made. *QST* is noted for its technical accuracy. "Breaking into print" in *QST* is an honor worth working for.

Operating on Schedules

Traffic handling work can be most advantageously carried on by arranging and keeping a few schedules. By arranging schedules and operating the station in a business-like way, using an accurate frequency meter and a clock, it has been proven many times that a maximum amount of business can be moved in a minimum of time and effort. The message "hook" can be cleared in a few minutes of work on schedule and the station will be free for DX or experimental work.

Every brass-pounder is urged to write letters to some of the reliable and regular stations heard, asking if some schedules cannot be kept a few times a week especially for traffic handling. The Route Manager is very frequently able to help in arranging schedules. Write your S.C.M. (see page 5, *QST*) and through him get lined up with your R.M. With reliable schedules in operation it is possible to advertise the fact that messages for certain points can be put through with speed and accuracy, and the traffic problem will take care of itself.

The Five-Point System

To make our relaying more systematic the "five-point system" of arranging schedules was proposed and has worked out very nicely on many cases. After getting the station in good operating condition, each station's operator arranges to work four stations, one north, one east, one south, and one west. These directions are not exact but general. The distances are not too great but they must be distances that can be worked with absolute certainty under any conditions.

A good way to select the four stations is to listen in and to pick out the stations heard most regularly, operating most consistently, and in the right direction. It is a good scheme to work these stations a few times. Write them letters and get acquainted; then try to arrange some schedules. Short schedules are the best. A half or quarter hour each day is enough. In an hour one can call four stations, clear traffic, and be free to work other groups of "five-pointers."

When there is no traffic, a few pleasantries are in order during the scheduled time of working. Several advantages of handling messages on schedule are evident from whatever angle the situation is approached.

Traffic Handling Develops Skill

The dispatch of messages makes operators keen and alert. The better the individual operator, the better the whole organization. Proper form in handling traffic, getting fills, and in general operating procedure develops operators who excel in "getting results." Station performance depends 90% on operating ability, and 10% on the equipment involved, granting of course that station and operator are always inter-dependent. Experience in message handling develops a high degree of operating "intelligence."

Interest in relaying amateur radiograms has always been the important basic activity around which A.R.R.L. organization revolved. There are several good reasons why. Message handling leads to organization naturally, through the need for schedules and coöperation between operators. It offers systematic training in "real" operating. It leads to planned, useful, unselfish, constructive, work for others at the same time it represents the highest form of operating "skill" and enjoyment to its devotees. Emphasis should be placed on the importance of traffic handling in training operators in the use of procedure — and in general operating reliability. The value of the amateur (as a group), in cases of local or national emergency, depends to a great extent on the *operating ability* of individual operators. This ability is largely developed in message handling work.

Practise in handling traffic familiarizes one with detailed time-saving procedure, and develops general skill and accuracy to a higher extent than obtains in "just rag-chewing" or haphazard work. This work provides a definite aim. Message handling is a vital link in guiding the interest of operators to the point where many accept additional responsibilities in the Signal Corps organization (A.A.R.S.), or the Volunteer Communication Reserve (U.S.N.R.). The interest amateurs show in these services is directly reflected by a full measure of appreciation and important backing by Uncle Sam whenever amateur rights are threatened with encroachment of any kind. Message handling work represents an advanced form of amateur operating activity in which all amateurs sooner or later become interested.

APPENDIX

The Continental Code

Letter or Figure Symbol		*Phonetic*
A	.—	Dit darr
B	—...	Darr dit dit dit
C	—.—.	Darr dit darr dit
D	—..	Darr dit dit
E	.	Dit
F	..—.	Dit dit darr dit
G	——.	Darr darr dit
H	....	Dit dit dit dit
I	..	Dit dit
J	.———	Dit darr darr darr
K	—.—	Darr dit darr
L	.—..	Dit darr dit dit
M	——	Darr darr
N	—.	Darr dit
O	———	Darr darr darr
P	.——.	Dit darr darr dit
Q	——.—	Darr darr dit darr
R	.—.	Dit darr dit
S	...	Dit dit dit
T	—	Darr
U	..—	Dit dit darr
V	...—	Dit dit dit darr
W	.——	Dit darr darr
X	—..—	Darr dit dit darr
Y	—.——	Darr dit darr darr
Z	——..	Darr darr dit dit
1	.————	Dit darr darr darr darr
2	..———	Dit dit darr darr darr
3	...——	Dit dit dit darr darr
4	....—	Dit dit dit dit darr
5	.....	Dit dit dit dit dit
6	—....	Darr dit dit dit dit
7	——...	Darr darr dit dit dit
8	———..	Darr darr darr dit dit
9	————.	Darr darr darr darr dit
0	—————	Darr darr darr darr darr
Period (.)	.. .. ..	Dit dit dit dit dit dit
Question (?)	..——..	Dit dit darr darr dit dit
Break (double dash) (=)	—...—	Darr dit dit dit darr
Exclamation (!)	——..——	Darr darr dit dit darr darr
Received (O.K.)	.—.	Dit darr dit
Bar Indicating Fraction (Oblique stroke)	—..—.	Darr dit dit darr dit
Wait	.—...	Dit darr dit dit dit
Comma (,)	.—.—.—	Dit darr dit darr dit darr
Colon (:)	———...	Darr darr darr dit dit dit
Semicolon (;)	—.—.—.	Darr dit darr dit darr dit
Quotes (“ ”)	.—..—.	Dit darr dit dit darr dit
Parenthesis ( )	—.——.—	Darr dit darr darr dit darr
Attention Call to precede every transmission	—.—.—	Darr dit darr dit darr
End of each message (cross)	.—.—.	Dit darr dit darr dit
Transmission finished (end of work)	...—.—	Dit dit dit darr dit darr
Invitation to transmit (go ahead)	—.—	Darr dit darr

* * *

A dash is equal to three dots.

The space between parts of the same letter is equal to one dot.

The space between two letters is equal to three dots.

The space between two words is equal to five dots.

Foreign Letters

Ä (German)	.—.—	Dit darr dit darr
Á or Å (Spanish-Scandinavian)	.——.—	Dit darr darr dit darr
CH (German-Spanish)	————	Darr darr darr darr

É (French)
..—.. Dit dit darr dit dit

Ñ (Spanish)
— —.— — Darr darr dit darr darr

O (German)
— — —. Darr darr darr dit

U (German)
..— — Dit dit darr darr

The "Q" Code

In the regulations accompanying the existing International Radiotelegraph Convention there is a very useful internationally agreed code designed to meet major needs in international radio communication. This code follows. The abbreviations themselves have the meanings shown in the "Answer" column. When an abbreviation is followed by an interrogation mark (?) it assumes the meaning shown in the "question" column.

Abbreviation	*Question*	*Answer*
QRA	What is the name of your station?	The name of my station is ....
QRB	At what approximate distance are you from my station?	The approximate distance between our stations is ...... nautical miles (or ...... kilometers).
QRC	By what private company (or government administration) are the accounts for charges of your station liquidated?	The accounts for charges of my station are liquidated by the .... private company (or by the government administration of ....).
QRD	Where are you going?	I am going to ......
QRE	What is the nationality of your station?	The nationality of my station is ....
QRF	Where do you come from?	I come from....
QRG	Will you indicate to me my exact wave length in meters (or frequency in kilocycles)?	Your exact wave length is ...... meters (or .... kilocycles).
QRH	What is your exact wave length in meters (frequency in kilocycles)?	My exact wave length is .... meters (frequency .... kilocycles).
QRI	Is my tone bad?	Your tone is bad.
QRJ	Are you receiving me badly? Are my signals weak?	I can not receive you. Your signals are too weak.
QRK	Are you receiving 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	Must I increase power?	Increase power.
QRP	Must I decrease power?	Decrease power.
QRQ	Must I send faster?	Send faster (...... words per minute).
QRS	Must I send more slowly?	Send more slowly (........ words per minute).
QRT	Must I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.
QRV	Must I send a series of V's?	Send a series of V's.
QRW	Must I advise .... that you are calling him?	Please advise .... that I am calling him.
QRX	Must I wait? When will you call me again?	Wait until I have finished communicating with .... I will call you immediately (or at .... o'clock).
QRY	Which is my turn?	Your turn is No. .... (or according to any other indication).
QRZ	By whom am I being called?	You are being called by ....
QSA	What is the strength of my signals (1 to 5)?	The strength of your signals is .... (1 to 5).
QSB	Does the strength of my signals vary?	The strength of your signals varies.
QSC	Do my signals disappear entirely at intervals?	Your signals disappear entirely at intervals.
QSD	Is my keying bad?	Your keying is bad. Your signals are unreadable.
QSE	Are my signals distinct?	Your signals run together.
QSF	Is my automatic transmission good?	Your automatic transmission fades out.

Abbreviation	*Question*	*Answer*
QSG	Must I transmit the telegrams by a series of 5, 10 (or according to any other indication)?	Transmit the telegrams by a series of 5, 10 (or according to any other indication).
QSH	Must I send one telegram at a time, repeating it twice?	Transmit one telegram at a time, repeating it twice.
QSI	Must I send the telegrams in alternate order without repetition?	Send the telegrams in alternate order without repetition.
QSJ	What is the charge to be collected per word for .... including your internal telegraph charge?	The charge to be collected per word for .... is .... francs, including my internal telegraph charge.
QSK	Must I suspend traffic? At what time will you call me again?	Suspend traffic. I will call you again at .... (o'clock).
QSL	Can you give me acknowledgment of receipt?	I give you acknowledgment of receipt.
QSM	Have you received my acknowledgment of receipt?	I have not received your acknowledgment of receipt.
QSN	Can you receive me now? Must I continue to listen?	I can not receive you now. Continue to listen.
QSO	Can you communicate with .... directly (or through the intermediary of ....)?	I can communicate with .... directly (or through the intermediary of ......).
QSP	Will you relay to .... free of charge?	I will relay to .... free of charge.
QSQ	Must I send each word or group once only?	Send each word or group once only.
QSR	Has the distress call received from .... been attended to?	The distress call received from .... has been attended to by ....
QSU	Must I send on .... meters (or .... kilocycles) waves of type A1, A2, A3, or B?*	Send on .... meters (or on .... kilocycles), waves of Type A1, A2, A3 or B.* I am listening for you.
QSV	Must I shift to the wave of .... meters (or of .... kilocycles), for the balance of our communications, and continue after having sent several V's?	Shift to wave of .... meters (or of ... kilocycles) for the balance of our communications and continue after having sent several V's.
QSW	Will you send on .... meters (or on .. kilocycles) waves of Type A1, A2, A3 or B?*	I will send on .... meters (or .... kilocycles) waves of Type A1, A2, A3 or B.* Continue to listen.
QSX	Does my wave length (frequency) vary?	Your wave length (frequency) varies.
QSY	Must I send on the wave of .... meters (or .... kilocycles) without changing the type of wave?	Send on the wave of .... meters (or .... kilocycles) without changing the type of wave.
QSZ	Must I send each word or group twice?	Send each word or group twice.
QTA	Must 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 word count?	I do not agree with your word count; I shall 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 ....
QTD	Is the word-count which I am confirming to you accepted?	The word count which you confirm to me is accepted.
QTE	What is my true bearing? (or) What is my true bearing relative to?	Your true bearing is .... degrees (or) Your true bearing relative to .... is.... degrees at .... (o'clock).
QTF	Will you give me the position of my station based on the bearings taken by the radiocompass stations which you control?	The position of your station based on het bearings taken by the radiocompass stations which I control is .... latitude .... longitude.
QTG	Will you transmit your call signal for one minute on a wave length of .... meters (or .... kilocycles) in order that I may take your radiocompass bearing?	I am sending my call signal for one minute on the wave length of .... meters (or .... kilocycles) in order that you may take my radiocompass bearing.

Abbreviation	*Question*	*Answer*
QTH	What is your position in latitude and longitude (or according to any other indication)?	My position is .... latitude .... longitude (or according to any other indication).
QTI	What is your true course?	My true course is .... degrees.
QTJ	What is your speed?	My speed is .... knots, or .... kilometers per hour.
QTK	What is the true bearing of .... relative to you?	The true bearing of .... relative to me is .... degrees at .... (o'clock).
QTL	Send radio signals to enable me to determine my bearing with respect to the radio beacon.	I am sending radio signals to permit you to determine your bearing with respect to the radio beacon.
QTM	Send radio signals and submarine sound signals to enable me to determine my bearing and my distance.	I am sending radio signals and submarine sound signals to permit you to determine your bearing and your distance.
QTN	Can you take the bearing of my station (or of ....) relative to you?	I can not take the bearing of your station (or of ....) relative to my station.
QTP	Are you going to enter the dock (or the port)?	I am going to enter the dock (or the port).
QTR	What is the exact time?	The exact time is ....
QTS	What is the true bearing of your station relative to me?	The true bearing of my station relative to you is .... at .... (o'clock).
QTU	What are the hours during which your station is open?	My station is open from .... to ....

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* Waves are classified as follows in Art. 4, General Regulations. A1: unmodulated continuous waves, varied by telegraphic keying. A2: continuous waves modulated at audible frequency, with which is combined telegraphic keying. A3: continuous waves modulated by speech or by music. B: damped waves.

Miscellaneous Abbreviations

The following miscellaneous abbreviations have universal agreement and should not be employed in other than the meanings specified, nor should other than the specified abbreviation be employed to convey any meaning listed in this table.

Abbreviation	*Meaning*
C	Yes.
N	No.
P	Announcement of private telegram in the mobile service (to be used as a prefix).
W	Word or words.
AA	"All after .... " (to be used after a question mark to request a repetition).
AB	"All before .... " (to be used after a question mark to request a repetition).
AL	"All that has just been sent" (to be used after a question mark to request a repetition).
BN	"All between .... " (to be used after a question mark to request a repetition).
BQ	Announcement of reply to a request for rectification.
CL	"I am closing my station."
CS	Call signal (to be used to ask repetition of a call signal).
DB	"I can not give you a bearing, you are not in the calibrated sector of this station."
DC	"The minimum of your signal is suitable for the bearing."
DF	Your bearing at .... (o'clock) was .... degrees, in the doubtful sector of this station, with a possible error of two degrees.
DG	Please advise me if you note an error in the bearing given.
DI	Bearing doubtful in consequence of the bad quality of your signals.
DJ	Bearing doubtful because of interference.
DL	Your bearing at .... (o'clock) was .... degrees in the doubtful sector of this station.
DO	Bearing doubtful. Ask for another bearing later, or at ...... (o'clock).
DP	Beyond 50 miles, possible error of bearing can attain two degrees.
DS	Adjust your transmitter, the minimum of your signal is too broad.
DT	I cannot furnish you with a bearing; the minimum of your signal is too broad.
DY	This station is bilateral, what is your approximate direction in degrees relative to this station?
DZ	Your bearing is reciprocal (to be used only by the central station of a group of radio-compass stations when it is addressed to other stations of the same group).

Abbreviation	*Meaning*
ER	"Here ......" (to be used before the name of the mobile station in the sending of route indications).
GA	"Resume sending" (to be used more especially in the fixed service).
JM	"If I may send, make a series of dashes. To stop my transmission, make a series of dots." Not to be used on 600 meters (500 kilocycles).
MN	Minute or minutes (to be used to indicate the duration of a wait).
NW	"I resume transmission" (to be used more especially in the fixed service).
OK	"We are in agreement."
RQ	Announcement of a request for rectification.
SA	Announcement of the name of an aircraft station (to be used in the sending of indications of passage).
SF	Announcement of the name of an aeronautic station.
SN	Announcement of the name of a coast station.
SS	Announcement of the name of a ship station (to be used in the transmission of indications of passage).
TR	Announcement of the request or of the sending of indications concerning a mobile station.
UA	"Are we in agreement?"
WA	"Word after ......" (to be used after a question mark to request a repetition).
WB	"Word before ......" (to be used after a question mark to request a repetition).
XS	Atmospherics.
YS	"See your service advice."
ABV	"Shorten the traffic by using the International Abbreviations." or "Repeat (or I repeat) the figures in abbreviation form."
ADR	Address (to be used after a question mark to request a repetition).
CFM	"Confirm" or "I confirm."
COL	"Collate" or "I collate."
ITP	"The punctuation counts."
MSG	Announcement of telegram concerning ship service only (to be used as a prefix).
PBL	Preamble (to be used after a question to request a repetition).
REF	"Referring to ......" or "Refer to ......"
RPT	"Repeat" or "I repeat" (to be used to ask or to give repetition of all or part of the traffic by making the corresponding indication after the abbreviation).
SIG	Signature (to be used after a question mark to request a repetition).
SVC	Announcement of service telegram concerning private traffic (to be used as a prefix).
TFC	Traffic.
TXT	Text (to be used after a question mark to request a repetition).

Ham Abbreviations

In amateur work many of the most commonly used radio and ordinary English words are frequently abbreviated, either by certain generally recognized methods or, as often occurs, on the spur of the moment according to the ideas of the individual operator. Beginning amateurs are likely to be confused by these "ham abbreviations" at first, but will probably pick them up quickly enough in the case of the more or less standard ones, and get the general idea governing the construction of the unusual ones occasionally encountered.

A method much used in short words is to give the first and last letters only, eliminating all intermediate letters. Examples: Now, nw; check, ck; would, wd.

Another method often used in short words employs phonetic spelling. Examples: Some, sum; good, gud; says, sez; night, nite.

A third method uses consonants only, eliminating all vowels. Examples: Letter, ltr; received, rcd; message, msg.

Replacing parts of a word with the letter "x" is a system occasionally used in abbreviating certain words. Examples: Transmitter, xmtr; weather, wx; distance, dx; press, px.

In listing below a short list of some of the more frequently encountered amateur abbreviations, we want to caution the beginner against making too great an effort to abbreviate or to scatter abbreviations wholesale throughout his radio conversation. A judicious use of certain of the short-cut words is permissible and saves time — the only legitimate object of abbreviations, of course. To abbreviate everything one sends, and to do so in many cases to extremes, is merely ridiculous.

ABT	About
ACCT	Account
ACCW	Alternating current C. W. (Not rectified before application to plate circuit of transmitting tubes)
AGN	Again
AHD	Ahead
AMP	Ampere
AMT	Amount
ANI	Any
AUSSIE	Australian amateur
BCL	Broadcast listener
BD	Bad

BI	By
BKG	Breaking
BLV	Believe
BN	Been, all between
BPL	Brass Pounders' League
BUG	Vibroplex key
CANS	Phones
CK	Check
CKT	Circuit
CL-CLG-CLD	Call, calling, called, closing (station)
CM	Communications Manager
CONGRATS	Congratulations
CRD	Card
CUD	Could
CUL	See you later
CW	Continuous wave
DH	Dead head, service message
DLD-DLVD	Delivered
DLY	Delivery
DX	Distance
ES	And
FB	Fine business, excellent
FIL	Filament
FM	From
FONES	Telephones
FR	For
FREQ	Frequency, frequently
GA	Go ahead (resume sending)
GB	Good-bye
GBA	Give better address
GE	Good evening
GG	Going
GM	Good morning
GN	Gone, good night
GND	Ground
GSA	Give some address
HAM	Amateur, brass-pounder
HI	Laughter, high
HR	Here, hear
HRD	Heard
HV	Have
ICW	Interrupted continuous wave
LID	"Lid," a poor operator
LTR	Later, letter
MA	Milliampere
MG	Motor-generator
MILS	Milliamperes
MO	Master oscillator
ND	Nothing doing
NIL	Nothing
NM	No more
NR	Number, near
NSA	No such address
NW	Now (I resume transmission)
OB	Old Boy, Official Broadcast
OM	Old man
OO	Official Observer
OPN	Operation
OP-OPR	Operator
ORS	Official Relay Station
OT	Oscillation transformer, old timer, old top
OW	Old woman
PSE	Please
PUNK	Poor operator
R	Are, all right, O.K.
RAC	Rectified alternating current
RCD	Received
RCVR	Receiver
RI	Radio Inspector
RM	Route Manager
SA	Say
SCM	Section Communications Manager
SED	Said
SEZ	Says
SIG-SG	Signature
SIGS	Signals
SINE	Sign, personal initials, signature
SKED	Schedule
TC	Thermo couple
TKS-TNX	Thanks
TNG	Thing
TMW	Tomorrow
TT	That
U	You
UR	Your, you're
URS	Yours
VT	Vacuum tube
VY	Very
WD	Would, word
WDS	Words
WKD	Worked
WKG	Working
WL	Will
WT	What, wait, watt
WUD	Would
WV-WL	Wave, wavelength
WX	Weather
XMTR	Transmitter
YL	Young lady
YR	Your
ZEDDER	New Zealander
73	Best regards
88	Love and kisses

International Prefixes

The nationality of a radio station is shown by the initial letter or letters of its call signal. The International Radiotelegraph Convention, supplemented by provisional action of the Berne Bureau, allocates the alphabet amongst the nations of the world for that purpose. Every station call of a nation must be taken from the block of letters thus assigned it. The amateur station call commonly consists of one or two initial letters thus chosen (to indicate nationality), a digit (assigned by the local government to indicate the subdivision of the nation in which the station is located), and two or three additional letters (to identify the individual station). .

In the list which follows, the first column shows the international allocation of blocks of call signals. This list is useful in identifying the nationality of any call heard, whether amateur or not. In the second column appears the area to which the calls are assigned. In the third column the amateur prefixes, the beginning letters of amateur calls, are listed. In most cases we know these prefixes to have been officially designated by the government concerned, but in some cases we have listed, of our own initiative, the proper prefix when there can be no choice about it. For instance, Haiti is assigned the calls from HHA to HHZ and therefore every Haitian amateur call must begin with the letters HH, whether that government so proclaims or not. Where a prefix is shown in brackets, it indicates that that government has more than one assignment of initial letters and that the indicated letter will be found assigned, in another part of the list, to that country. The list:

Block	*Assigned to*	*Amateur Prefix*[6]
CAA-CEZ	Chile	CE
CFA-CKZ	Canada	[VE]
CLA-CMZ	Cuba	CM
CNA-CNZ	Morocco	CN
CPA-CPZ	Bolivia	CP
CQA-CRZ	Portuguese colonies:	
	Cape Verde Ids	CR4
	Portuguese Guinea	CR5
	Angola	CR6
	Mozambique	CR7
	Portuguese India	CR8
	Macao	CR9
	Timor	CR10
CSA-CUZ	Portugal:	
	Portugal proper	CT1
	Azores Ids	CT2
	Madeira Ids	CT3
CA-CVZ	Rumania	CV
CWA-CXZ	Uruguay	CX
CZA-CZZ	Monaco	CZ
D	Germany	D
EAA-EHZ	Spain	EAR[1]
EIA-EIZ	Irish Free State	EI
ELA-ELZ	Liberia	EL
ESA-ESZ	Esthonia	ES
ETA-ETZ	Ethiopia (Abyssinia)	ET

F	France (including colonies):	
	France proper	F
	French Indo-China	FI
	Tunis	FM4
	Algeria	FM8
G	United Kingdom:	
	Great Britain except Ireland	G
	Northern Ireland	GI
HAA-HAZ	Hungary	HA
HBA-HBZ	Switzerland	HB
HCA-HCZ	Ecuador	HC
HHA-HHZ	Haiti	HH
HIA-HIZ	Dominican Republic	HI
HJA-HKZ	Colombia	HJ
HRA-HRZ	Honduras	HR
HSA-HSZ	Siam	HS
I	Italy and colonies	I
J	Japan	J
K	United States of America:	
	Continental United States	[W]
	Philippine Ids	KA
	Porto Rico and Virgin Ids	K4
	Territory of Hawaii	K6
	Territory of Alaska	K7
LAA-LNZ	Norway	LA
LOA-LVZ	Argentine Republic	LU
LZA-LZZ	Bulgaria	LZ
M	Great Britain	[G]
N	United States of America	[W]
OAA-OCZ	Peru	OA
OFA-OHZ	Finland	OH
OKA-OKZ	Czechoslovakia	OK
ONA-OTZ	Belgium and colonies	ON
OUA-OZZ	Denmark	OZ
PAA-PIZ	The Netherlands	PA
PJA-PJZ	Curacao	PJ
PKA-POZ	Dutch East Indies	PK
PPA-PYZ	Brazil	PY
PZA-PZZ	Surinam	PZ
RAA-RQZ	U.S.S.R. ("Russia")	RA[2]
RVA-RVZ	Persia	RV
RXA-RXZ	Republic of Panama	RX
RYA-RYZ	Lithuania	RY
SAA-SMZ	Sweden	SM
SPA-SRZ	Poland	SP
STA-SUZ	Egypt:	
	Sudan	ST
	Egypt proper	SU
SVA–SZZ	Greece	SV
TAA-TCZ	Turkey	TA
TFA-TFZ	Iceland	TF
TGA-TGZ	Guatemala	TG
TIA-TIZ	Costa Rica	TI
TSA-TSZ	Territory of the Saar Basin	TS
UHA-UHZ	Hedjaz	UH
UIA-UKZ	Dutch East Indies	[PK]
ULA-ULZ	Luxemburg	UL
UNA-UNZ	Yugoslavia	UN
UOA-UOZ	Austria	UO
UWA-VGZ	Canada	VE
VHA-VMZ	Australia	VK
VOA-VOZ	Newfoundland	VO
VPA-VSZ	British colonies and protectorates:	
	British Guiana	VP
	Fiji, Ellice Ids., Zanzibar	VP1
	Bahamas, Barbados, Jamaica	VP2
	Bermuda	VP9
	Fanning Id.	VQ1
	Northern Rhodesia	VQ2
	Tanganyika	VQ3
	Kenya Colony	VQ4
	Uganda	VQ5
	Malaya (including Straits Settlements)	VS1–2–3
	Hongkong	VS6
	Ceylon	VS7
VTA-VWZ	British India	VU
W	United States of America:	
	Continental United States	W
	(For others, see under K.)	
XAA-XFZ	Mexico	X[3]
XGA-XUZ	China	(AC)[4]
YAA-YAZ	Afghanistan	YA
YHA-YHZ	New Hebrides	YH
YIA-YIZ	Iraq	YI
YLA-YLZ	Latvia	YL
YMA-YMZ	Danzig	YM
YNA-YNZ	Nicaragua	YN[5]
YSA-YSZ	Republic of El Salvador	YS
YVA-YVZ	Venezuela	YV
ZAA-ZAZ	Albania	ZA
ZBA-ZHZ	British colonies and protectorates:	
	Transjordania	ZC1
	Palestine	ZC6
	Nigeria	ZD
	Southern Rhodesia	ZE1
ZKA-ZMZ	New Zealand:	
	Cook Ids	ZK
	New Zealand proper	ZL
	British Samoa	ZM
ZPA-ZPZ	Paraguay	ZP
ZSA-ZUZ	Union of South Africa	ZS ZT ZU

Measuring Distances

Often it is interesting to know just how far away some station is located. In measuring distances it is customary to measure along the shortest path on the surface of the earth. This distance is along the arc of a Great Circle, and for very short distances is practically a straight line. Distances of a thousand miles or so may be measured with sufficient accuracy on an ordinary map with a ruler, using the "scale of miles" indicated on the map.

For longer distances where the curvature of the earth cannot be neglected, the simplest way of measuring distance is by means of a common globe of the type used in school-rooms. The globe should be at least eight inches in diameter for good results. A piece of string should be stretched between the two points in question, and when pulled taut will automatically align itself along the Great Circle route between them. The length of the string between the two points when converted into miles according to the scale of the globe, will be the distance between the two points.

The globe will be found useful in other ways also, as for instance in determining the direction in which a distant spot lies from the station. Flat maps of the world (on Mercator's projection) give a wholly misleading impression of both distance and direction between points widely separated, especially if located in the extremes of latitude.

Circular Time-and-Date Chart

A method of comparing different times with each other and with G.C.T. (Greenwich Civil Time) is necessary to get time, weather, and press schedules, announced in almost every case in local time. In the chart shown, the two discs *A* and *B* should be drawn carefully and mounted on cardboard. When centered and pinned together we have a convenient device to use in working international schedules and in checking QSL-cards. The chart is based on the fact that time changes an hour for each 15° of arc.

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[1] Improperly assigned by Spain; should have only two letters.

[2] U.S.S.R. is not party to the I.R.C. Some Soviet amateurs still use as a prefix the old I.A.R.U. intermediate EU, and some Siberian amateurs similarly use AU, either separately or in combination with RA.

[3] Improperly assigned by Mexico; should have two letters to distinguish from China.

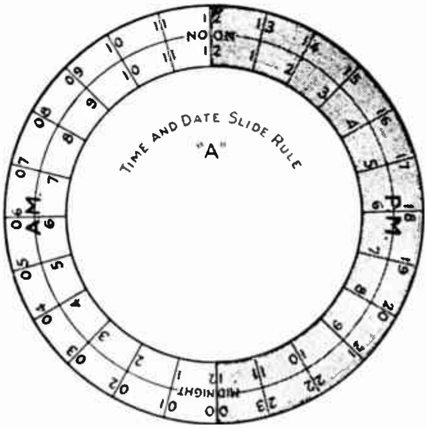
[4] Unofficial prefix, heritage from I.A.R.U. intermediates, still used by some amateurs in China. They would be better advised to use XG, which would establish nationality.

[5] Most Nicaraguan amateurs apparently use NN, particularly amateur stations operated by U. S. Marines in Nicaragua. YN is preferable, as it will indicate nationality.

[6] The following unofficial prefixes, in limited or temporary use, are also listed for information:

Syria	AR	Guam	OM
Canal Zone	NY	Formosa	YK

To find local time from a given G.C.T., simply set the G.C.T. mark on the given time and read the local time directly at its mark. Let us take an example. Set the G.C.T. mark at 00 G.C.T. Then by direct reading it is 6 p.m. Chicago time or 9 a.m. Tokio time. If we in Tokio wanted to find what time it was in New York at 6 p.m. Tokio time, we would set the Tokio pointer at 6 p.m. and read 4 a.m. for New York time.



Finding dates: Suppose an operator in Los Angeles works a station in Tokio at 11 p.m. P.S.T. on June 10. Then the slide rule shows that it will be 4 p.m. Tokio time. The next thing is to find whether it is *to-day* or *to-morrow* in Tokio, that is, June 10th or 11th. Now with the rule all set we run our eye around it in a *clockwise* direction *from* Los Angeles *to* Tokio. If at any point in that space the midnight mark on disc *A* is encountered it is *to-morrow* in Tokio, i.e. June 11th. If the midnight mark is not encountered in this space it is *to-day* in Tokio. For example: Suppose the Los Angeles station works the station in Tokio at 1 a.m. P.S.T. June 10th. Then the Los Angeles operator will know from the slide rule that it is 6 p.m. June 10th Tokio time.

Let us work from the Eastern Hemisphere back to the Western. Suppose the operator at the Tokio station is doing the figuring. He works the Los Angeles station, let us say, at 9 p.m. June 15th, Tokio time. He wants to know what time it is in Los Angeles and also what the date is. He sets the rule to 9 p.m. Tokio time and finds at once that it is 4 a.m. in Los Angeles. Now for the date. He reads around disc *B* from Tokio to Los Angeles in a *clockwise* direction. Notice that it is always clockwise from the local station to the distant station. If at any place in that path the midnight mark is encountered it is *to-day* in Los Angeles, in other words, June 15th.

Suppose the Tokio station works the station in Los Angeles at 1 a.m. Tokio time. It would be 8 a.m. Los Angeles time, and since the midnight mark is not encountered between the two, in a clockwise direction from Tokio to Los Angeles, it is *yesterday* in Los Angeles, i.e. June 14th.

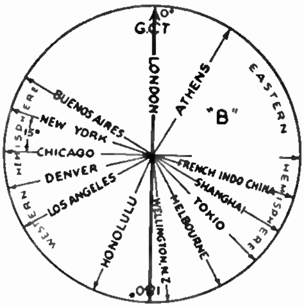
Now to find the difference in dates between two stations in the same hemisphere. Consider that half of the disc *B* and disregard the other half altogether. If the midnight mark does not come between them, within that semicircle, they are both *to-day*. If, however, the midnight mark comes in between them the one to the right is one day ahead of the one to the left, or inversely, the one to the left is a day behind the one to the right.

The Decibel

The decibel (abbreviated *db*) is a convenient unit for the measurement of electrical or acoustic power ratios on a logarithmic scale. The number of decibels equivalent to the ratio between two amounts of power is

$$db. = 10 \log_{10} \frac{P_1}{P_2}$$

Since the decibel is a logarithmic unit, successive gains and losses expressed in db can be added algebraically. If the ratio of the two power values is greater than 1 there is a power gain; if the ratio is less than 1 there is a loss of power. A gain is expressed in "plus db"; a loss in "minus db."



The decibel also can be used to express ratios between voltages and currents provided the circuit conditions are the same for the two quantities whose magnitudes are being compared; i.e., if the impedances and power factors of the circuits are the same.

The decibel is primarily a unit which specifies gains or losses with reference to the power value at some point in a system regardless of the actual value of the reference power. In telephone and radio work, however, it is convenient to assume a reference power level and express the power at a point in a circuit in terms of "plus db." or "minus db." above or below this reference level. A standard reference level in radio work is .006 watts, or 6 milliwatts.

Good Books

Every amateur should maintain a carefully selected bookshelf; a few good books, consistently read and consulted, will add immeasurably to the interest and knowledge of the owner. We suggest a selection among the following works, all of which have been gone over carefully and are recommended in their various fields.

Principles of Radio, by Keith Henney, is an excellent book for the amateur who wants to acquire a better understanding of the fundamentals of radio transmission and reception. The book is thoroughly modern and, generally speaking, is a "non-mathematical" treatment. Recommended to every amateur. Price, $3.50.

Radio Engineering, by Prof. F. E. Terman, is written from the viewpoint of the practical engineer engaged in design and experimental work on modern transmitters and receivers, and covers all phases of radio communication with the thoroughness of a complete reference book. A knowledge of advanced mathematics is helpful, but not necessary. Price, $5.00.

Excellent theoretical works, requiring some knowledge of mathematics (algebra, at least) are *Elements of Radio Communication*, by Prof. J. H. Morecroft, price $3.00, and *Radio Engineering Principles*, by Lauer and Brown, price $3.50. Both books are in the "first-year" student class. Probably the best-known of all theoretical works is *Principles of Radio Communication*, by Morecroft, priced at $7.50, but a familiarity with mathematics is essential to anyone who expects to derive much benefit from this book.

Two valuable recent books cover the general field of electricity and communications, with fitting emphasis on the radio aspects. *Electricity — What It Is and How It Acts*, by A. W. Kramer, is an easily understood treatment of modern electrical theory, including comprehensive discussions of vacuum-tube and electro-magnetic wave phenomena. It is written in two volumes, price $2.00 each. *Communication Engineering*, by Prof. W. L. Everitt, is a thorough treatment of all types of communications networks. A certain amount of training in d.c. and a.c. current theory as well as mathematics through calculus is needed for fullest appreciation of this work. The price is $5.00.

For the experimenter, there is Prof. R. R. Ramsey's *Experimental Radio*, price $2.75, which describes in detail 128 experiments designed to bring out the principles of radio theory, instruments and measurements. *Radio Data Charts*, an English publication by R. T. Beatty, is a series of abacs (graphic charts) which enables most of the problems connected with radio design to be solved easily without recourse to mathematical calculations. Another standard reference work for basic radio formulas, measurements, etc., is *Radio Instruments and Measurements*, Circular No. 74 of the Bureau of Standards, which can be obtained for sixty cents (no stamps or checks) from the Superintendent of Documents, Government Printing Office, Washington, D. C. This book requires a knowledge of mathematics.

For practical handbooks covering just about the entire field of radio, we recommend either *Radio Theory and Operating*, by Loomis, price $4.25, *The Radio Manual*, by Sterling, at $6.00, or *Radio Telegraphy and Telephony*, by Duncan and Drew, at $7.50. All of these are over 900 pages and are of the type used as texts in radio schools; while they contain a moderate amount of theory, they are essentially practical handbooks for commercial and broadcast operators. Any one of them is well worth having.

Amateurs who are interested in studying for commercial operators' licenses will be interested in the following, in conjunction with the volumes listed in the preceding paragraph: *How to Pass U. S. Government Radio License Examinations*, by Duncan and Drew, price $2.00, which is written to supplement the other work by the same authors, mentioned above; and *Radio Operating Questions and Answers*, by Nilson and Hornung, $2.50, which is intended to supplement *Practical Radio Telegraphy* (by the same authors, price $3.00), in preparation for commercial licenses.

Van der Bijl's *Thermionic Vacuum Tube* still remains the best text available for the theory of operation of vacuum tubes. Beginners should steer clear of it, however; it is strictly an engineering work and requires a thorough knowledge of higher mathematics. The price is $5.00.

Any of the above books (with the exception of Circular No. 74) may be obtained from the Book Department of the A.R.R.L. at the prices stated. Readers are referred to the Book Department's advertisement, in the advertising section of this Handbook, for a list which includes additional volumes of interest to amateurs.

QST is the official organ of the American Radio Relay League. It is published monthly, containing up-to-date information on amateur activities and describing the latest developments in amateur radio. It is a magazine devoted exclusively to the radio amateur. Written by and for the amateur, it contains knowledge supplementary to the books we have mentioned. *QST* is found on the bookshelves of earnest amateurs and experimenters everywhere. Good books are a worth-while investment. A subscription to *QST* is equally valuable.

Standard Letter Symbols for Electrical Quantities

Admittance	Y, y
Angular velocity ($2\pi f$)	ω
Capacitance	C
Conductance	G, g
Current	I, i
Difference of potential	E, e
Dielectric constant	K or ϵ
Energy	W
Frequency	f
Impedance	Z, z
Inductance	L
Magnetic intensity	H
Magnetic flux	Φ
Magnetic flux density	B
Mutual inductance	M
Number of conductors or turns	N
Permeability	μ
Phase displacement	θ or ϕ
Power	P, p
Quantity of electricity	Q, q
Reactance	X, x
Resistance	R, r
Susceptance	b
Speed of rotation	n
Voltage	E, e
Work	W

Letter Symbols for Vacuum Tube Notation

Grid potential	E_g, e_g
Grid current	I_g, i_g
Grid conductance	g_g
Grid resistance	r_g
Grid bias voltage	E_c
Plate potential	E_p, e_p
Plate current	I_p, i_p
Plate conductance	g_p
Plate resistance	r_p
Plate supply voltage	E_b
Emission current	I_s
Mutual conductance	g_m

Amplification factor	μ
Filament terminal voltage	E_f
Filament current	I_f
Filament supply voltage	E_a
Grid-plate capacity	C_{gp}
Grid-filament capacity	C_{gf}
Plate-filament capacity	C_{pf}
Grid capacity ($C_{gp}+C_{gf}$)	C_g
Plate capacity ($C_{gp}+C_{pf}$)	C_p
Filament capacity ($C_{gf}+C_{pf}$)	C_f

NOTE.—Small letters refer to instantaneous values.

Abbreviations Commonly Used in Radio

Alternating current	a.c.
Antenna	ant.
Audio frequency	a.f.
Continuous waves	c.w.
Cycles per second	~
Decibel	db.
Direct current	d.c.
Electromotive force	e.m.f.
Frequency	f.
Ground	gnd.
Henry	h.
Intermediate frequency	i.f.
Interrupted continuous waves	i.c.w.
Kilocycles (per second)	kc.
Kilowatt	kw.
Megohm	MΩ
Microfarad	μfd.
Microhenry	μh.
Micromicrofarad	μμfd.
Microvolt	μv.
Microvolt per meter	μv/m.
Milliampere	ma.
Milliwatt	mw.
Ohm	Ω
Power factor	p.f.
Radio frequency	r.f.
Volt.	v.

Metric Prefixes Often Used with Radio Quantities

μ	$\frac{1}{1{,}000{,}000}$	One-millionth	micro-
m	$\frac{1}{1{,}000}$	One-thousandth	milli-
c	$\frac{1}{100}$	One-hundredth	centi-
d	$\frac{1}{10}$	One-tenth	deci-
	1	One	uni-
dk	10	Ten	deka-
h	100	One hundred	hekto-
k	1,000	One thousand	kilo-
	10,000	Ten thousand	myria-
	1,000,000	One million	mega-

Figuring the Capacitance of a Condenser

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

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

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

The Specific Inductive Capacity (k) is a property of the dielectric used in a condenser. It determines the quantity of charge which a given separation and area of plates will accumulate for a given applied voltage. The "inductivity" of the dielectric varies as in the above table. "k" is the ratio of the capacitance of a condenser with a given dielectric to the capacitance of the same instrument with air dielectric.

Table of Dielectric Constants

Dielectric	"*k*"	*Puncture voltage* *Kilovolts per cm.*	*Kilovolts per inch.*
Air (normal pressure)	1.00	7.8–9.0	19.8–22.8
Flint Glass	6.6 to 10	900	2280
Mica	4.6 to 8	1500	3810
Paraffin Wax (solid)	2.0 to 2.5	400	1017
Sulphur	3.9 to 4.2	—	—
Castor Oil	4.7	150	381
Porcelain	4.4	—	—
Quartz	4.5	—	—
Resin	2.5	—	—
Olive Oil	3.1	120	305
Gutta Percha	3.3 to 4.9	80–200	203–508
Shellac	3.1	—	—
Common Glass	3.1 to 4.0	300–1500	762–3810
Turpentine	2.23	110–160	280–406
Dry Oak Wood	2.5 to 6.8	—	—
Formica, Bakelite, etc.	5 to 6	—	—

When the air dielectric in a variable condenser is replaced with some other fluid dielectric its maximum and minimum capacitance values are multiplied by "k" and the "sparking" potential is increased.

Fluid dielectrics repair themselves after a breakdown unless an arc is maintained that carbonizes the oil. Dry oil is a good dielectric with quite low losses. When solid dielectric is used it should be borne in mind that dielectric strength (breakdown voltage) becomes lower as temperature rises. Breakdown is a function of time as well as voltage. A condenser that stands up under several thousand volts for a few seconds might break down when connected to a 2000-volt line for a half-hour.

Example of finding condenser capacitance: We have 3 plates, 3″ x 5″, in air. The plates are separated ⅛″. 1″ = 2.54 centimeters.

$k=1$. $A=7.62\times 12.70=96.8$ sq. cm. $d=.3175$ cm. $n-1=2$.

$$C=.0088\frac{1\times 96.8}{.32}2\times 10^{-5}=.00005325\ \mu\text{fd. or } 53\tfrac{1}{4}$$

micromicrofarads.

The capacity formula becomes as follows, when A is the area of one side of one plate *in square inches* and d is the separation of the plates *in inches*.

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

If we put the condenser of our example in castor oil the increase in capacitance, owing to the greater value of k, will make our condenser have a capacitance of

$$53\tfrac{1}{4}\times 4.7=250 \text{ micromicrofarads.}$$

The air condenser might spark over at about 7.8×.3175 cm.=2.475 kv. (2,475 volts).

In oil (castor oil) it would have 150/7.8 (or 381/19.8) times the breakdown voltage of air.

$$\frac{150}{7.8}=19.25$$

$$19\tfrac{1}{4}\times 2475=47{,}600 \text{ volts}$$

We can find the same value directly:

150×.3175 cm.=47,600 volts (peak).

Using the formulas for "reactance" we can find what the voltage drop across this condenser will be when carrying current at a specified high frequency.

$$E_x=X_cI \qquad X_c=\frac{1}{2\pi fc}$$

where E_x is the reactance voltage drop, C is the capacitance of the condenser (farads),

f is the frequency (cycles per second), X_c is the reactance of the condenser in ohms.

Suppose we are using the 3-plate fixed air condenser in our antenna circuit, and that a radio-frequency ammeter is in series with it. We are operating on an 80-meter wavelength (3,750,000 cycles) and the meter right next the condenser reads 1.3 amperes. What is the voltage drop across the air condenser?

$$X_c=\frac{1}{2\quad(3.1416)\quad(3{,}750{,}000)\quad(53.25)\quad 10^{-12}}$$

$$=\frac{1}{1257\times 10^{-6}}=\frac{10^6}{1257}=797 \text{ ohms}$$

E_x=(797) (1.3)=1034 volts (root mean square value).

If the wave is a sine wave, this value multiplied by 1.414 will give the "peak" or maximum value

$$1034\times 1.414=1462 \text{ volts (peak)}$$

Our radio-frequency ammeter measures the heating effect of all the instantaneous values of current during the radio-frequency cycle. The direct current, the square of which equals the average of the squares of all the values of alternating current over a whole cycle, produces the same heat as the alternating current. Alternating current meters generally used for a.c. switchboard work read the *effective* or *root mean square values* which we mention above.

Inductance Calculation

The lumped inductance of coils for transmitting and receiving is fairly easy to calculate.

$$L=\frac{.0395a^2n^2}{b}K$$

(for single-layer solenoids)

Where L is the inductance in microhenries

n is the number of turns

a is the mean radius of the coil (cm.)

b is the length of coil (cm.)= nD

D is the distance between the centers of two adjacent turns

K is the coil shape factor depending on the ratio 2 a/b (see chart).

Start with the given coil diameter. Using the overall length of the coil find a value for K. If the diameter is 5″ and the length 5″ go to the right from "5" on the diameter scale. At the same time go "up" from "5" on the length scale. Notice where the two lines meet. They meet at "X" between the lines "6" and "7". We estimate the value of K at .688 and proceed.

Assume a transmitting coil having 10 turns of ¼″ brass strip, flatwise wound, 5″ diameter (6.35. radius), and spaced ¼″ between turns, making the overall length (nD) 12.7 cm.

a= 6.35
n= 10.
b= 12.7

$$\frac{2a}{b}=1$$

K is about .688 (from chart)

$$L=\frac{.0395\ (6.35)^2\ (10)^2}{12.7}.688=8.64 \text{ microhenries.}$$

Greek Alphabet

Since Greek letters are used to stand for many electrical and radio quantities, the names and symbols of the Greek alphabet with the equivalent English characters are given.

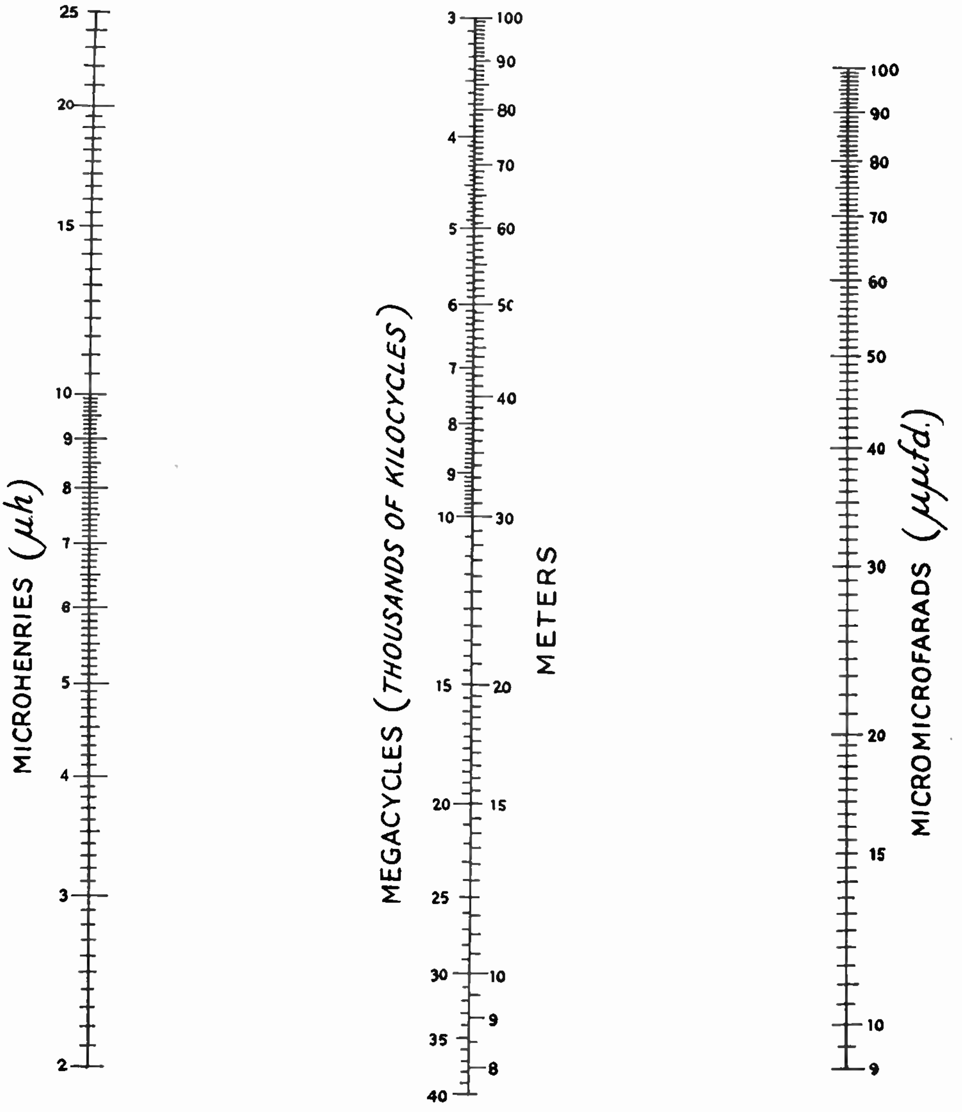
Greek Letter	*Greek Name*	*English Equivalent*
Α α	Alpha	a
Β β	Beta	b
Γ γ	Gamma	g
Δ δ	Delta	d
Ε ϵ	Epsilon	e
Ζ ζ	Zeta	z
Η η	Eta	ē
Θ ϑ	Theta	th
Ι ι	Iota	i
Κ κ	Kappa	k
Λ λ	Lambda	l
Μ μ	Mu	m
Ν ν	Nu	n
Ξ ξ	Xi	x
Ο ο	Omicron	ŏ
Π π	Pi	p
Ρ ρ	Rho	r
Σ σ	Sigma	s
Τ τ	Tau	t
Υ υ	Upsilon	u
Φ φ	Phi	ph
Χ χ	Chi	ch
Ψ ψ	Psi	ps
Ω ω	Omega	ō

COPPER WIRE TABLE

Gauge No. B. & S.	Diam. in Mils[1]	Circular Mil Area	Turns per Linear Inch[2]				Turns per Square Inch[2]			Feet per Lb.		Ohms per 1000 ft. 250 C.	Current-Carrying Capacity at 1500 C.M. per Amp.[3]	Diam. in mm.	Nearest British S.W.G. No.
			Enamel	S.S.C.	D.S.C. or S.C.C.	D.C.C.	S.C.C.	Enamel S.C.C.	D.C.C.	Bare	D.C.C.				
1	289.3	82690	—	—	—	—	—	—	—	3.947	—	.1264	55.7	7.348	1
2	257.6	66370	—	—	—	—	—	—	—	4.977	—	.1593	44.1	6.544	3
3	229.4	52640	—	—	—	—	—	—	—	6.276	—	.2009	35.0	5.827	4
4	204.3	41740	—	—	—	—	—	—	—	7.914	—	.2533	27.7	5.189	5
5	181.9	33100	—	—	—	—	—	—	—	9.980	—	.3195	22.0	4.621	7
6	162.0	26250	—	—	—	—	—	—	—	12.58	—	.4028	17.5	4.115	8
7	144.3	20820	—	—	—	—	—	—	—	15.87	—	.5080	13.8	3.665	9
8	128.5	16510	7.6	—	7.4	7.1	—	—	—	20.01	19.6	.6405	11.0	3.264	10
9	114.4	13090	8.6	—	8.2	7.8	—	—	—	25.23	24.6	.8077	8.7	2.906	11
10	101.9	10380	9.6	—	9.3	8.9	87.5	84.8	80.0	31.82	30.9	1.018	6.9	2.588	12
11	90.74	8234	10.7	—	10.3	9.8	110	105	97.5	40.12	38.8	1.284	5.5	2.305	13
12	80.81	6530	12.0	—	11.5	10.9	136	131	121	50.59	48.9	1.619	4.4	2.053	14
13	71.96	5178	13.5	—	12.8	12.0	170	162	150	63.80	61.5	2.042	3.5	1.828	15
14	64.08	4107	15.0	—	14.2	13.3	211	198	183	80.44	77.3	2.575	2.7	1.628	16
15	57.07	3257	16.8	—	15.8	14.7	262	250	223	101.4	97.3	3.247	2.2	1.450	17
16	50.82	2583	18.9	18.9	17.9	16.4	321	306	271	127.9	119	4.094	1.7	1.291	18
17	45.26	2048	21.2	21.2	19.9	18.1	397	372	329	161.3	150	5.163	1.3	1.150	18
18	40.30	1624	23.6	23.6	22.0	19.8	493	454	399	203.4	188	6.510	1.1	1.024	19
19	35.89	1288	26.4	26.4	24.4	21.8	592	553	479	256.5	237	8.210	.86	.9116	20
20	31.96	1022	29.4	29.4	27.0	23.8	775	725	625	323.4	298	10.35	.68	.8118	21
21	28.46	810.1	33.1	32.7	29.8	26.0	940	895	754	407.8	370	13.05	.54	.7230	22
22	25.35	642.4	37.0	36.5	34.1	30.0	1150	1070	910	514.2	461	16.46	.43	.6438	23
23	22.57	509.5	41.3	40.6	37.6	31.6	1400	1300	1080	648.4	584	20.76	.34	.5733	24
24	20.10	404.0	46.3	45.3	41.5	35.6	1700	1570	1260	817.7	745	26.17	.27	.5106	25
25	17.90	320.4	51.7	50.4	45.6	38.6	2060	1910	1510	1031	903	33.00	.21	.4547	26
26	15.94	254.1	58.0	55.6	50.2	41.8	2500	2300	1750	1300	1118	41.62	.17	.4049	27
27	14.20	201.5	64.9	61.5	55.0	45.0	3030	2780	2020	1639	1422	52.48	.13	.3606	29
28	12.64	159.8	72.7	68.6	60.2	48.5	3670	3350	2310	2067	1759	66.17	.11	.3211	30
29	11.26	126.7	81.6	74.8	65.4	51.8	4300	3900	2700	2607	2207	83.44	.084	.2859	31
30	10.03	100.5	90.5	83.3	71.5	55.5	5040	4660	3020	3287	2534	105.2	.067	.2546	33
31	8.928	79.70	101.	92.0	77.5	59.2	5920	5280	—	4145	2768	132.7	.053	.2268	34
32	7.950	63.21	113.	101.	83.6	62.6	7060	6250	—	5227	3137	167.3	.042	.2019	36
33	7.080	50.13	127.	110.	90.3	66.3	8120	7360	—	6591	4697	211.0	.033	.1798	37
34	6.305	39.75	143.	120.	97.0	70.0	9600	8310	—	8310	6168	266.0	.026	.1601	38
35	5.615	31.52	158.	132.	104.	73.5	10900	8700	—	10480	6737	335.0	.021	.1426	38–39
36	5.000	25.00	175.	143.	111.	77.0	12200	10700	—	13210	7877	423.0	.017	.1270	39–40
37	4.453	19.83	198.	154.	118.	80.3	—	—	—	16660	9309	533.4	.013	.1131	41
38	3.965	15.72	224.	166.	126.	83.6	—	—	—	21010	10666	672.6	.010	.1007	42
39	3.531	12.47	248.	181.	133.	86.6	—	—	—	26500	11907	848.1	.008	.0897	43
40	3.145	9.88	282.	194.	140.	89.7	—	—	—	33410	14222	1069	.006	.0799	44

---

[1] A mil is 1/1000 (one thousandth) of an inch.
[2] The figures given are approximate only, since the thickness of the insulation varies with different manufacturers.
[3] The current-carrying capacity at 1000 C.M. per ampere is equal to the circular-mil area (Column 3) divided by 1000.



RELATION BETWEEN INDUCTANCE, CAPACITY AND FREQUENCY

With this chart and a straight-edge any of the above quantities can be determined if the other two are known. For example, if a condenser has a minimum capacity of 15 μμfd. and a maximum capacity of 50 μμfd., and it is to be used with a coil of 10 μh. inductance, what frequency range will be covered? The straight-edge is connected between 10 on the left-hand scale and 15 on the right, giving 13 mc. as the high-frequency limit. Keeping the straight-edge at 10 on the left-hand scale, the other end is swung to 50 on the right-hand scale, giving a low-frequency limit of 7.1 mc. The tuning range would, therefore, be from 7.1 mc. to 13 mc., or 7100 kc. to 13,000 kc. The center scale also serves to convert frequency to wavelength.

Numbered Drill Sizes

Number	*Diameter (mils)*	*Will Clear Screw*	*Drilled for Tapping Iron, Steel or Brass* *
1	228.0	—	—
2	221.0	12-24	—
3	213.0	—	14-24
4	209.0	12-20	—
5	205.5	—	—
6	204.0	—	—
7	201.0	—	—
8	199.0	—	—
9	196.0	—	—
10	193.5	10-32	—
11	191.0	10-24	—
12	189.0	—	—
13	185.0	—	—
14	182.0	—	—
15	180.0	—	—
16	177.0	—	12-24
17	173.0	—	—
18	169.5	8-32	—
19	166.0	—	12-20
20	161.0	—	—
21	159.0	—	10-32
22	157.0	—	—
23	154.0	—	—
24	152.0	—	—
25	149.5	—	10-24
26	147.0	—	—
27	144.0	—	—
28	140.5	6-32	—
29	136.0	—	8-32
30	128.5	—	—
31	120.0	—	—
32	116.0	—	—
33	113.0	4-36 4-40	—
34	111.0	—	—
35	110.0	—	6-32
36	106.5	—	—
37	104.0	—	—
38	101.5	—	—
39	099.5	3-48	—
40	098.0	—	—
41	096.0	—	—
42	093.5	—	4-36 4-40
43	089.0	2-56	—
44	086.0	—	—
45	082.0	—	3-48
46	081.0	—	—
47	078.5	—	—
48	076.0	—	—
49	073.0	—	2-56
50	070.0	—	—
51	067.0	—	—
52	063.5	—	—
53	059.5	—	—
54	055.0	—	—

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

Extracts from the Radio Law

The complete text of the Radio Act of February 23, 1927, would occupy many pages. Only those parts most applicable to amateur radio station licensing and regulation in this country (with which we should all be familiar) are given. Note particularly Secs. 26, 27, 28 and 29 and the penalties provided in Secs. 32 and 33.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act is intended to regulate all forms of interstate and foreign radio transmissions and communications within the United States, its Territories and possessions; to maintain the control of the United States over all the channels of interstate and foreign radio transmission; and to provide for the use of such channels, but not the ownership thereof, by individuals, firms, or corporations, for limited periods of time, under licenses granted by Federal authority, and no such license shall be construed to create any right, beyond the terms, conditions, and periods of the license. That no person, firm, company, or corporation shall use or operate any apparatus for the transmission of energy or communications or signals by radio . . . , except under and in accordance with this Act and with a license in that behalf granted under the provisions of this Act.

Sec. 3. That a commission is hereby created and established to be known as the Federal Radio Commission, hereinafter referred to as the commission, which shall be composed of five commissioners . . .

Sec. 4. Except as otherwise provided in this Act, the commission, from time to time, as public convenience, interest, or necessity requires, shall —

(a) Classify radio stations;

(b) Prescribe the nature of the service to be rendered by each class of licensed stations and each station within any class;

(c) Assign bands of frequencies or wavelengths to the various classes of stations, and assign frequencies or wavelengths for each individual station and determine the power which each station shall use and the time during which it may operate;

(d) Determine the location of classes of stations or individual stations;

(e) Regulate the kind of apparatus to be used with respect to its external effects and the purity and sharpness of the emissions from each station and from the apparatus therein:

(f) Make such regulations not inconsistent with law as it may deem necessary to prevent interference between stations and to carry out the provisions of this Act . . .

(i) Have authority to make general rules and regulations . . .

(C) To prescribe the qualifications of station operators, to classify them according to the duties to be performed, to fix the forms of such licenses, and to issue them to such persons as he finds qualified.

(D) To suspend the license of any operator for a period not exceeding two years upon proof sufficient . . . that the licensee (a) has violated any provision of any Act or treaty binding on the United States which the . . . commission is authorized by this Act to administer or by any regulation made by the commission . . . under any such Act or treaty; or (b) has failed to carry out the lawful orders of the master of the vessel on which he is employed; or (c) has wilfully damaged or permitted radio apparatus to be damaged; or (d) has transmitted superfluous radio communications or signals or radio communications containing profane or obscene words or language; or (e) has wilfully or maliciously interfered with any other radio communications or signals.

(E) To inspect all transmitting apparatus to ascertain whether in construction and operation it conforms to the requirements of this Act, the rules and regulations of the licensing authority, and the license under which it is constructed or operated.

(G) To designate call letters of all stations.

Sec. 14. Any station license shall be revocable by the commission for false statements either in the application or in the statement of fact which may be required by section 10 hereof, or because of conditions revealed by such statements of fact as may be required from time to time which would warrant the licensing authority in refusing to grant a license on an original application, or for failure to operate substantially as set forth in the license, for violation of or failure to observe any of the restrictions and conditions of this Act, or of any regulation of the licensing authority authorized by this Act or by a treaty ratified by the United States. . . .

Sec. 16. Any applicant for a construction permit, for a station license, or for the renewal or modification of an existing station license whose application is refused by the licensing authority shall have the right to appeal from said decision to the Court of Appeals of the District of Columbia; and any licensee whose license is revoked by the commission shall have the right to appeal from such decision of revocation to said Court of Appeals of the District of Columbia or to the district court of the United States in which the apparatus licensed is operated. . . .

Sec. 26. In all circumstances, except in case of radio communications or signals relating to vessels in distress, all radio stations, including those owned and operated by the United States, shall use the minimum amount of power necessary to carry out the communication desired.

Sec. 27. No person receiving or assisting in receiving any radio communication shall divulge or publish the contents, substance, purport, effect, or meaning thereof except through authorized channels of transmission or reception to any person other than the addressee, his agent, or attorney, or to a telephone, telegraph, cable, or radio station employed or authorized to forward such radio communication to its destination, or to proper accounting or distributing officers of the various communicating centers over which the radio communication may be passed, or to the master of a ship under whom he is serving, or in response to a subpoena issued by a court of competent jurisdiction, or on demand of other lawful authority; and no person not being authorized by the sender shall intercept any message and divulge or publish the contents, substance, purport, effect, or meaning of such intercepted message to any person; and no person not being entitled thereto shall receive or assist in receiving any radio communication and use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; and no person having received such intercepted radio communication or having become acquainted with the contents, substance, purport, effect, or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the contents, substance, purport, effect, or meaning of the same or any part thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto: *Provided*, That this section shall not apply to the receiving, divulging, publishing, or utilizing the contents of any radio communication broadcasted or transmitted by amateurs or others for the use of the general public or relating to ships in distress.

SEC. 28. No person, firm, company, or corporation within the jurisdiction of the United States shall knowingly utter or transmit or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto, nor shall any broadcasting station rebroadcast the program or any part thereof of another broadcasting station without the express authority of the originating station.

SEC. 29. Nothing in this Act shall be understood or construed to give the licensing authority the power of censorship over the radio communications or signals transmitted by any radio station, and no regulation or condition shall be promulgated or fixed by the licensing authority which shall interfere with the right of free speech by means of radio communications. No person within the jurisdiction of the United States shall utter any obscene, indecent, or profane language by means of radio communication.

SEC. 32. Any person, firm, company, or corporation failing or refusing to observe or violating any rule, regulation, restriction, or condition made or imposed by the licensing authority under the authority of this Act or of any international radio convention or treaty ratified or adhered to by the United States, in addition to any other penalties provided by law, upon conviction thereof by a court of competent jurisdiction, shall be punished by a fine of not more than $500 for each and every offense.

SEC. 33. Any person, firm, company, or corporation who shall violate any provision of this Act, or shall knowingly make any false oath or affirmation in any affidavit required or authorized by this Act, or shall knowingly make any false oath or affirmation in any hearing authorized by this Act, upon conviction thereof in any court of competent jurisdiction, shall be punished by a fine of not more than $5,000 or by imprisonment for a term of not more than five years or both for each and every such offense.

SEC. 34. The trial of any offense under this Act shall be in the district in which it is committed; or if the offense is committed upon the high seas, or out of the jurisdiction of any particular State or district, the trial shall be in the district where the offender may be found or into which he shall be first brought.

SEC. 35. This Act shall not apply to the Philippine Islands or to the Canal Zone. In international radio matters the Philippine Islands and the Canal Zone shall be represented by the Secretary of State.

United States Amateur Regulations

Pursuant to the basic radio law, general regulations for amateurs have been drafted by the Federal Radio Commission. Every amateur should be thoroughly familiar with these regulations.

Amateur Service

361. The term "amateur service" means a radio communication or experimental service carried on by amateur stations solely with a personal aim and without pecuniary interest.

362. The term "amateur station" means all of the transmitting apparatus, either fixed or portable, used for amateur service at one location and under the control of the licensee.

363. The term "amateur" when used without further descriptive words means a person interested in radio technique solely with a personal aim and without pecuniary interest.

364. The term "amateur radio operator" means a person holding a valid license . . . as a radio operator who is authorized under the regulations . . . to operate amateur radio stations.

365. The term "amateur radiocommunication" means radiocommunication between amateur radio stations solely with a personal aim and without pecuniary interest.

366. Amateur station licenses, in general, shall be issued only to amateur radio operators but may be issued to persons who are radio amateurs as defined herein, provided affirmative evidence is presented to show that the station, when licensed, will be operated by a licensed radio operator.

367. Amateur radio station licenses shall not be issued to corporations or associations: *Provided, however*, That in the case of a bona fide amateur radio society, a license may be issued to an authorized official of such society as trustee therefor.

368. Licenses for amateur mobile stations will not be granted.

369. In all cases of remotely controlled amateur transmitters, the location of the station shall be that of the control point except that where such control point is more than 5 miles from the radiating antenna, the location shall be that of the radiating antenna.

370. Amateur stations shall be used only for amateur service except that in emergencies or for testing purposes they may be used also for communication with commercial or Government radio stations and for communication with mobile stations and stations of expeditions which do not have general public service licenses and which may have difficulty in communicating with commercial or Government stations.

371. Amateur stations shall not be used for broadcasting any form of entertainment.

372. Amateur stations may be used for the transmission of music for test purposes of short duration in connection with the development of experimental radiotelephone equipment.

373. Amateur radio stations shall not be used to transmit or receive messages for hire, nor for communication for material compensation, direct or indirect, paid or promised.

374. The following bands of frequencies are allocated exclusively for use by amateur stations:

1,715 to 2,000
3,500 to 4,000
7,000 to 7,300
14,000 to 14,400
28,000 to 30,000
56,000 to 60,000
400,000 to 401,000

375. All bands of frequencies so assigned may be used for radiotelegraphy, type A-1 emission and also for type A-2 emission to the extent hereinafter provided. (See paragraph 382.)

376. The following bands of frequencies are allocated for use by amateur stations using radiotelephony, type A-3 emission:

1,875 to 2,000 kilocycles
56,000 to 60,000 kilocycles

377. Provided the station shall be operated by a person who holds an operator's license of a grade approved . . . for unlimited amateur radiotelephone operation, amateur radio stations may use radiotelephony, type A-3 emission, in the following additional bands of frequencies:

3,900 to 4,000 kilocycles
14,150 to 14,250 kilocycles

378. The following bands of frequencies are allocated for use by amateur stations for television, facsimile, and picture transmission:

1,715 to 2,000 kilocycles
56,000 to 60,000 kilocycles

379. Licensees of amateur stations shall be permitted to use any frequency within the service bands above assigned.

380. An amateur radio station shall not be located upon premises controlled by an alien.

381. The frequency of the waves emitted by amateur radio stations shall be as constant and as free from harmonics as the state of the art permits. For this purpose, amateur transmitters shall employ circuits loosely coupled to the radiating system or devices that will produce equivalent effects to minimize keying impacts and harmonics. Conductive coupling to the radiating antenna, even though loose, is not permitted, but this restriction does not prohibit the use of transmission-line feeder systems.

382. Licensees of amateur stations shall use adequately filtered direct-current power supply for the transmitting equipment or arrangements that produce equivalent effects to minimize frequency modulation and prevent the emission of broad signals. For example, the use of unrectified alternating-current power supply for the amplifier stages of oscillator-amplifier transmitters, so arranged that variations in plate voltage of this supply can not affect the frequency of the oscillator, will be considered satisfactory.

383. Licensees of amateur stations are authorized to use a maximum power input of one kilowatt to the plate circuit

of the final amplified stage of an oscillator-amplifier transmitter or to the plate circuit of an oscillator transmitter.

384. An operator of an amateur station shall transmit its assigned call at least once during each 15 minutes of operation and at the end of each transmission.

385. In the event that the operation of an amateur radio station causes general interference to the reception of broadcast programs with receivers of modern design, that amateur station shall not operate during the hours from 8 o'clock p.m. to 10.30 p.m., local time, and on Sundays from 10.30 a.m. until 1 p.m., local time, upon such frequency or frequencies as cause such interference.

386. Each licensee of an amateur station shall keep an accurate log of station operation, in which shall be recorded:

(a) The date and time of each transmission.

(b) The name of the person manipulating the transmitting key of a radiotelegraph transmitter or the name of the person operating a transmitter of any other type with statement as to nature of transmission.

(c) The station called.

(d) The input power to the oscillator, or to the final amplifier stage where an oscillator-amplifier transmitter is employed.

(e) The frequency band used.

This information shall be made available upon request by authorized Government representatives.

387. The licensee of a portable amateur station shall give to the supervisor of radio in the district where application was filed for said portable station license advance notice of all locations in which the station will be operated.

U. S. INSPECTION DISTRICTS

District	*Territory*	*Address, Radio Inspector*
No. 1	States of Maine, New Hampshire, Vermont, Massachusetts, Connecticut and Rhode Island.	Customhouse, Boston, Mass.
No. 2	City of Greater New York and the Counties of Suffolk, Nassau, Westchester, Rockland, Putnam, Orange, Dutchess, Ulster, Sullivan, Delaware, Greene, Columbia, Albany and Rensselaer of the State of New York, and the Counties of Bergen, Hudson, Passaic, Sussex, Warren, Morris, Essex, Union, Somerset, Middlesex, Monmouth, Mercer, Hunterdon of the State of New Jersey.	U. S. Subtreasury Building, New York, N. Y.
No. 3	City of Philadelphia and the Counties of Bucks, Montgomery, Philadelphia, Delaware, Chester, Lancaster, York, Adams, Cumberland, Perry, Dauphin, Lebanon, Berks, Schuylkill, Lehigh, Northampton, Carbon and Monroe of the State of Pennsylvania, and the Counties of Ocean, Burlington, Atlantic, Cape May, Cumberland, Salem, Gloucester and Camden of the State of New Jersey; State of Delaware.	Gimbel Building, 32 South Ninth St., Philadelphia, Pa.
No. 4	State of Maryland, the District of Columbia, and the Counties of Arlington, Loudoun, Fairfax, Prince William, Fauquier, Rappahannock, Page, Warren, Shenandoah, Frederick and Clark, of the State of Virginia.	Fort McHenry, Baltimore, Md.
No. 5	State of Virginia, except the Counties of Arlington, Loudoun, Fairfax, Prince William, Fauquier, Rappahannock, Page, Warren, Shenandoah, Frederick and Clark, and the State of North Carolina, except the Counties of Ashe, Watauga, Caldwell, Avery, Burke, McDowell, Yancey, Mitchell, Madison, Buncombe, Haywood, Swain, Graham, Cherokee, Clay, Macon, Jackson, Transylvania, Henderson, Polk, Rutherford and Cleveland.	Customhouse, Norfolk, Va.
No. 6	States of Alabama, Georgia, South Carolina, Tennessee, and the Counties of Ashe, Watauga, Caldwell, Avery, Burke, McDowell, Yancey, Mitchell, Madison, Buncombe, Haywood, Swain, Graham, Cherokee, Clay, Macon, Jackson, Transylvania, Henderson, Polk, Rutherford, and Cleveland of the State of North Carolina.	528 Postoffice Building, Atlanta, Ga.
No. 7	The State of Florida.	1424 Dade County Building, Miami, Fla.
No. 8	The States of Louisiana, Mississippi and Arkansas.	Customhouse, New Orleans, La.
No. 9	Counties of Jefferson, Chambers, Harris, Galveston, Fort Bend, Brazoria, Wharton, Matagorda, Jackson, Victoria, Calhoun, Goliad, Refugio, Aransas, San Patricio, Mueces, Jim Wells, Kleberg, Brooks, Kenedy, Willaey, Hidalgo, and Cameron of the State of Texas.	209 Prudential Bldg., Galveston, Texas
No. 10	State of Texas, except the Counties of Jefferson, Chambers, Harris, Galveston, Fort Bend, Brazoria, Wharton, Matagorda, Jackson, Victoria, Calhoun, Goliad, Refugio, Aransas, San Patricio, Mueces, Jim Wells, Kleberg, Brooks, Kenedy, Willacy, Hidalgo and Cameron, and the States of Oklahoma and New Mexico.	464 Federal Building, Dallas, Texas
No. 11	Counties of Monterey, Kings, Tulare, San Luis Obispo, Kern, Santa Barbara, Ventura, Los Angeles, Orange, San Diego, Imperial, Riverside, and San Bernardino of the State of California; the County of Clarke of the State of Nevada, and the State of Arizona.	1105 Rives-Strong Building, Los Angeles, Calif.
No. 12	State of California, except the Counties of Monterey, Kings, Tulare, San Luis Obispo, Kern, Santa Barbara, Ventura, Los Angeles, Orange, San Diego, Imperial, Riverside and San Bernardino, and the State of Nevada, except the County of Clark.	Customhouse, San Francisco, Calif.
No. 13	State of Oregon and the State of Idaho, except the Counties of Boundary, Bonner, Kootenai, Shoshone, Benewah, Latah, Clearwater, Nez Perce, Lewis and Idaho.	227 Postoffice Building, Portland, Ore.
No. 14	State of Washington, the Counties of Boundary, Bonner, Kootenai, Shoshone, Benewah, Lateh, Clearwater, Nez Perce, Lewis and Idaho of the State of Idaho; and the Counties of Lincoln, Flathead, Glacier, Toole, Pondera, Teton, Lake, Sanders, Mineral, Missoula, Powell, Lewis and Clarke, Cascade, Meagher, Broadwater, Jefferson, Granite, Ravalli, Deerlodge, Silver Bow, Beaverhead, Madison, Gallatin of the State of Montana, and Territory of Alaska.	1012 Exchange Building, Seattle, Wash.

U. S. INSPECTION DISTRICTS (Continued)

District	*Territory*	*Address, Radio Inspector*
No. 15	States of Colorado, Utah, Wyoming, and Montana except the Counties of Lincoln, Flathead, Glacier, Toole, Pondera, Teton, Lake, Sanders, Mineral, Missoula, Powell, Lewis and Clarke, Cascade, Meagher, Broadwater, Jefferson, Granite, Ravalli, Deerlodge, Silver Bow, Beaverhead, Madison and Gallatin.	538 Customhouse, Denver, Colo.
No. 16	States of South Dakota, North Dakota, Minnesota, the northern peninsula of Michigan, and the State of Wisconsin, except the Counties of Crawford, Richland, Sauk, Columbia, Dodge, Washington, Ozaukee, Milwaukee, Waukesha, Jefferson, Dane, Iowa, Grant, Lafayette, Green Rock, Walworth, Racine and Kenosha.	413 Federal Building, St. Paul, Minn.
No. 17	States of Nebraska, Kansas, Missouri and Iowa, except the Counties of Winneshiek, Allamakee, Fayette, Clayton, Buchanan, Delaware, Dubuque, Linn, Jones, Jackson, Clinton, Cedar, Johnson, Washington, Muscatine, Scott, Louisa, Des Moines, Henry and Lee.	231 Federal Building, Kansas City, Mo.
No. 18	States of Indiana, Illinois and the Counties of Winneshiek, Allamakee, Fayette, Clayton, Buchanan, Delaware, Dubuque, Linn, Jones, Jackson, Clinton, Cedar, Johnson, Washington, Muscatine, Scott, Louisa, Des Moines, Henry and Lee of the State of Iowa; and the Counties of Crawford, Richland, Sauk, Columbia, Dodge, Washington, Ozaukee, Milwaukee, Waukesha, Jefferson, Dane, Iowa, Grant, Lafayette, Green Rock, Walworth, Racine and Kenosha of the State of Wisconsin.	2022 Engineering Building, Chicago, Ill.
No. 19	State of Michigan, except the northern peninsula and the States of Ohio, Kentucky and West Virginia.	2909 David Stott Building, Detroit, Mich.
No. 20	State of New York, except the City of Greater New York and the Counties of Suffolk, Nassau, Westchester, Rockland, Putnam, Orange, Dutchess, Ulster, Sullivan, Delaware, Greene, Columbia, Albany, and Rensselaer; the State of Pennsylvania, except the City of Philadelphia, and the Counties of Bucks, Montgomery, Philadelphia, Chester, Delaware, Lancaster, York, Adams, Cumberland, Perry, Dauphin, Lebanon. Berks, Schuylkill, Lehigh, Northampton, Carbon and Monroe.	514 Federal Building, Buffalo, N. Y.

Hawaii is attached to District No. 12.

Porto Rico and the Virgin Ids., are attached to District No. 7.

INDEX

To Handbook Readers Who Are Not A. R. R. L. Members

WOULDN'T you like to become a member of the American Radio Relay League? We need you in this big organization of radio amateurs, the only amateur association that does things. From your reading of this Handbook you have gained a knowledge of the nature of the League and what it does, and of its purposes. We would like to have you become a full-fledged member and add your strength to ours in the things we are undertaking for Amateur Radio, and incidentally you will have the membership edition of *QST* delivered at your door each month. A convenient application form is printed below — clip it out and mail it today.

..............................19......

American Radio Relay League
38 La Salle Rd.
W. Hartford, Conn., U. S. A.

Being genuinely interested in Amateur Radio, I hereby apply for membership in the American Radio Relay League and enclose $2.50 (foreign $3.00) to cover one year's dues.*

It is understood that this entitles me to receive the league magazine "QST" for a similar period. Please begin my subscription with the...................... issue.

Send "QST" and my certificate of membership to the address below.

Name ....

....

....

A bona fide interest in amateur radio is the only essential qualification; ownership of a transmitting station and knowledge of the code are desirable but not necessary

Station call, if any..

Grade operator's license, if any..

Radio clubs of which a member..

Do you know a friend who is also interested in Amateur Radio, whose name you might give us so we may send him a sample copy of QST?..

....Thanks!

* The dues are $2.50 per year in the United States and Possessions, and Canada. All other countries $3.00 per year.

To Handbook Readers Who Are Already A.R.R.L. Members:

FOR telegraphing members, who hold amateur licenses, and who are interested in Communications Department work, here is an application blank for an appointment as Official Relay Station. Copy this, or cut and fill it out, and send it to A.R.R.L. Headquarters for routing to the proper Section Communications Manager, if you are interested. The Communications Department operates only in the United States and its territories, Canada, Newfoundland, Labrador, Cuba, the Isle of Pines, and the Philippine Islands. Foreign applications from outside these areas cannot be handled.

AMERICAN RADIO RELAY LEAGUE, INC.

38 LaSalle Road, W. Hartford, Connecticut, U. S. A.

Application for Appointment as Official Relay Station

Name .... *Call* ....

Street and Number ....

City .... *County* ....

State ....

Transmitting frequencies: .... *kc.*

In making application for appointment as Official Relay Station, I agree:

—— to obey the radio communication laws and regulations of the country under which this station is licensed, particularly with respect to quiet hours and observance of our frequency allocations.

—— to send monthly reports of station activities to the Section Communications Manager under whose jurisdiction this station comes.

—— to handle messages in accordance with good operating procedure, delivering messages within forty-eight (48) hours when possible, mailing to destination whenever impossible to relay to the next station in line within a 48-hour period.

—— to participate in every A.R.R.L. communication activity to the best of my ability, always trying to live up to those ideals set forth in "The Amateur's Code."

My membership in the A.R.R.L. expires ....
month year

I understand that an appointment as Official Relay Station may be suspended or cancelled at the discretion of the Section Communications Manager for violation of the agreement set forth above.

Please send detailed forms to submit to my S.C.M. in connection with this application.

Signed ....

NOTES

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* The dues are $2.50 per year in the United States and Possessions, and Canada. All other countries $3.00 per year.

To Handbook Readers Who Are Already A.R.R.L. Members:

FOR telegraphing members, who hold amateur licenses, and who are interested in Communications Department work, here is an application blank for an appointment as Official Relay Station. Copy this, or cut and fill it out, and send it to A.R.R.L. Headquarters for routing to the proper Section Communications Manager, if you are interested. The Communications Department operates only in the United States and its territories, Canada, Newfoundland, Labrador, Cuba, the Isle of Pines, and the Philippine Islands. Foreign applications from outside these areas cannot be handled.

AMERICAN RADIO RELAY LEAGUE, INC.

38 LaSalle Road, W. Hartford, Connecticut, U. S. A.

Application for Appointment as Official Relay Station

Name .... *Call* ....

Street and Number ....

City .... *County* ....

State ....

Transmitting frequencies: .... *kc.*

In making application for appointment as Official Relay Station, I agree:

—— to obey the radio communication laws and regulations of the country under which this station is licensed, particularly with respect to quiet hours and observance of our frequency allocations.

—— to send monthly reports of station activities to the Section Communications Manager under whose jurisdiction this station comes.

—— to handle messages in accordance with good operating procedure, delivering messages within forty-eight (48) hours when possible, mailing to destination whenever impossible to relay to the next station in line within a 48-hour period.

—— to participate in every A.R.R.L. communication activity to the best of my ability, always trying to live up to those ideals set forth in "The Amateur's Code."

My membership in the A.R.R.L. expires ....
month year

I understand that an appointment as Official Relay Station may be suspended or cancelled at the discretion of the Section Communications Manager for violation of the agreement set forth above.

Please send detailed forms to submit to my S.C.M. in connection with this application.

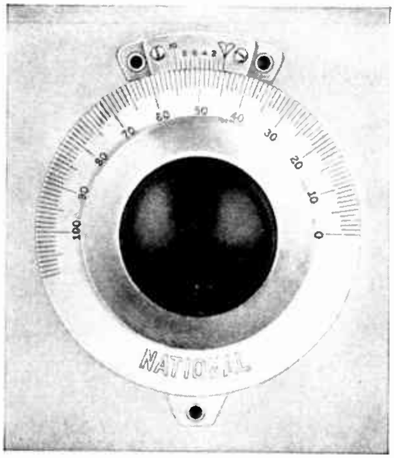
Signed ....

NOTES

NOTES

NOTES

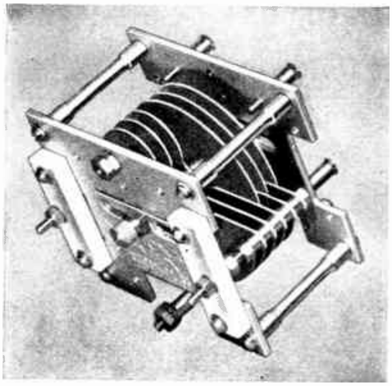
ACCURATE FREQUENCY METERS DEMAND ACCURATE EQUIPMENT



4-INCH TYPE N VELVET-VERNIER DIAL

Solid German Silver, All Divisions Engraved

For maximum precision of operation, this NATIONAL type N Dial is being used more and more by amateurs and experimenters in receiving and transmitting equipment, frequency meters, etc. Engraved flush-vernier gives exact readings to 1/10 dial division. Insulated flexible hub-coupler assures permanent accuracy by taking all strain off dial itself, and at the same time insulates exposed metal parts of dial from the shaft. The original and matchless NATIONAL Velvet-Vernier Mechanism is used, of course, but with materially increased driving power, so that drive-slip is practically impossible. (National Co. Inc. makes a complete line of dials of all types. Protected by U. S. Patent Nos. 1,744,675, 1,653,875, 1,656,532, 1,713,146. Other patents pending.)



Type 40–75 — Frequency Meter Condenser

This special condenser is designed for use in amateur frequency meter and monitor circuits. Adapted for use in High-C circuits, thus avoiding changes in calibration which would otherwise arise from differences in tube characteristics, temperature, etc. Spreads 160 and 80 meter bands over 80 divisions with 100 division dial. Min. cap. 40 mmf., max. cap. 75 mmf.

Write for the new National Company 18-page catalogue

NATIONAL COMPANY INC.

61 Sherman Street **Malden, Mass.**

Specially Engineered for Ultra H.F. Uses

SEU ULTRA-H.F. CONDENSERS

Heavy, double-spaced, 270° plates with rounded edges, Isolantite insulation, insulated front bearing, constant low impedance pigtail, for single hole panel or base mounting. Holds characteristics under any operating conditions. In any capacity up to 25 mmf. No shorted turns. Free from noise. Minimum losses.

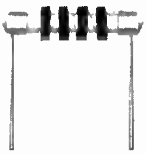
MIDGET H.F. R-39 COIL FORMS

Improved R-39, low loss ultra H.F. material, especially developed for National Company, makes these forms rigid and efficient. Have best form factor resulting in lowest RF resistance. R-39 material insures stability and calibration maintenance. In standard 4-prong type only, unwound and ungrooved. Standard large size R-39 forms in 4, 5 or 6 prongs.

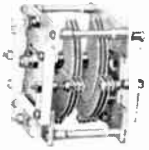
ULTRA H.F. ISOLANTITE SOCKETS

Ultra H.F. losses through improper sockets may be very large. The National Isolantite sockets with upper glazed surface will cut these losses to a minimum. Made for sub-panel or base mounting, in standard 4-, 5- and 6-prong types. Pin location groove makes tube insertion easy.

ULTRA H.F. CHOKE TYPE 100



Designed for minimum distributed-capacity, four narrow sections, each universal wound and spaced on Isolantite form. Fits clips, but supplied with stiff leads for mounting. Will carry 125 M.A., 50 ohms DC resistance.



SPLIT-STATOR CONDENSER TYPE EMP

Made for ultra H.F. Receivers and low power push-pull transmitters. Has special low-loss stator insulators, 1200 v. breakdown. In capacities up to 350 mmf. per sect.

3" MIDGET DIAL VELVET VERNIER — BM

Has same Vernier mechanism as National B Dial but without variable ratio feature. Ideal where space is limited. All the Velvet smoothness and lasting quality of National Velvet Vernier Dials.

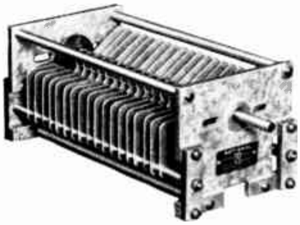
NATIONAL

PRECISION RADIO PARTS

Write for Catalog No. AH-33

NATIONAL CO. INC., MALDEN, MASS.

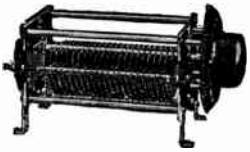
NATIONAL
Transmitting CONDENSERS



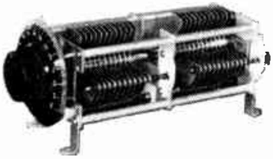
TMU

For high power, heavy-duty work. Highly polished plates with fully rounded edges. Lowest dielectric losses with genuine Micalex insulation. Constant low-impedance, high-current connection to rotor. Rugged mechanical construction with cast aluminum ends — insures permanence of electrical characteristics under the most severe operating conditions. ⅝" rotor shaft runs in self-aligning conical and ball bearings. Capacities from .00005 to .0005 mfd. Peak voltage ratings 5000 and 7500.

TM



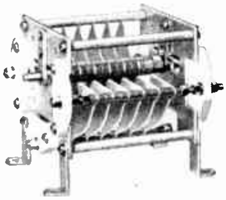
The standard NATIONAL Transmitting Condenser, established for years with leading amateurs. Light, rigid construction with ball and conical bearing shaft. Isolantite insulation, rounded and polished plates on rotor and stator. No sharp edges or points in high intensity sections of electrostatic field — resulting in minimum losses. Capacities from .000035 to .00045 mfd. 3000 and 6000 volt ratings.



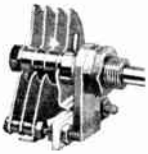
TMP

A split-stator condenser for medium power push-pull transmitters. Gives extremely accurate balance between two sides of tank coil. Especially fine for 5-meter work. Construction and plate spacing like Type TM. Made in 100 and 230 mmf. per section for 3000 volts; and 100 mmf. per section for 6000 volts.

TMN



A new, heavy-duty neutralizing-condenser. Peak voltage rating 6000 volts. Isolantite insulation, construction similar to Type TM. Suitable for use 203A, 852, 204A and similar tubes. Maximum capacity 50 mmf.



STN

A new NATIONAL neutralizing-condenser. Efficient, compact and rigid, for neutralizing 245, 247, 210 and similar tubes in amplifier, buffer or doubler stages. Has extremely low minimum capacity. Isolantite insulation. Polished, rounded plates. Peak voltage 3000 volts, maximum capacity 18 mmf.

Special Transmitting Condensers in TMU and TM construction types made to order. If you will submit your requirements, giving characteristics of circuit, we will gladly quote you without any obligation.

NATIONAL COMPANY INC.
61 Sherman Street Malden, Mass.

Universally USED

by Amateurs and made exclusively for them.

The NATIONAL SW-3 Amateur Receiver enjoys this popularity because of:

Ease of Handling

The SW-3 is easy to handle in every respect. It has real single control. The trimmer need be set only once to supply proper "padding" for transformer and antenna. Straight Frequency Line NATIONAL Short-Wave Condensers in a new dual unit with isolated rotors completely eliminate tendencies to interlock, as with ordinary condensers.

High Sensitivity Without Critical Control

By utilizing hitherto unemployed characteristics of the new 58 tube, the set may be worked up to the point of maximum sensitivity without the extremely critical setting usually found at that point. Several additional minor improvements have also been made to take full advantage of the new 58 type tubes, now used in R. F. and Detector Circuits. The 227 is still used for the audio-tube.

Calibrated Attenuation Control

The single audio stage makes possible an exclusive feature of the SW-3 in which *the volume control also serves as an audibility meter.* On the SW-3 the "R-rating" of signal can be read at sight from the position of the volume control. This is mounted so that it can be operated with the same hand as the tuning dial.

Band Spread Coils

wound on improved R-39, low-loss dielectric material, *are* supplied as *standard equipment for 14, 7 and 3.5 mc. amateur bands.* Bands can be accurately located to place each one over a large portion of the 270° dial scale.

Full AC or Part or Full Battery Operation

The SW-3 operates on full AC (with special humless R.C.A. Licensed NATIONAL 5880 Power Supply), or with AC on filaments and B batteries, or entirely on batteries, using the new 6-volt heater tubes.

Lowest Noise-Level

The SW-3 has the lowest noise-level and the highest signal-to-noise ratio of any commercially available short-wave receiver.

Compact — Portable

Dimensions are 9" x 9¾" x 7". Especially suitable for aircraft and expedition work.

Price is Right

The price of the NATIONAL SW-3 puts it in the easy reach of every amateur. Write us for particulars and prices.

NATIONAL SW-3 AMATEUR RECEIVER

NATIONAL CO. INC. MALDEN, MASS.

World Radio History

PARTS
of every kind

FOR

SHORT-WAVE WORK

Hammarlund,
National,
Etc.

Established ELEVEN YEARS

Catalogs on request

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CHICAGO
RADIO APPARATUS
COMPANY

415 South Dearborn Street
Chicago, Ill.

Proud of it?

Are you proud that you are an amateur — proud of your A.R.R.L. membership? Then proclaim it! Let the hams who meet you on the street, in the radio store, or traveling, know it. Wear your A.R.R.L. emblem!

The distinctive League emblem comes in four different forms. Its use by *members* is endorsed and encouraged by the League. Every member should endeavor to display the insignia of his organization in every possible way.

THE PERSONAL EMBLEM, in extra-heavy rolled gold and black enamel, just ½″ high, supplied in lapel button or pin-back style, is recognized as the sign of a good amateur. Wear your emblem, and feel proud of having taken your rightful place in the radio fraternity. Either style, $1.00, postpaid.

THE AUTOMOBILE EMBLEM, heavily enameled in yellow and black on sheet metal, will gain you friends. On the road, traveling, it identifies you as a real amateur. 5 x 2½″, holes top and bottom. 50c each, postpaid.

THE EMBLEM CUT, a mounted printing electrotype, the same size as the personal emblem, is for use by members on amateur printed matter, letterheads, cards, etc. $1.00 each, postpaid.

THE "JUMBO" EMBLEM, an attention-getter for the shack wall or that 100-footer, is a big yellow-and-black affair 19 x 8¼″, same style as the Automobile Emblem. $1.25 each, postpaid.

The

AMERICAN RADIO
RELAY LEAGUE

WEST HARTFORD, CONN.

World Radio History

The Four Corners of the Earth Are at Your Finger Tips with

COLLINS RADIO EQUIPMENT

Collins 30W

OUTPUT: 30 watts. FREQUENCY RANGE: 20, 40, 80 and 160 meters. Coils for one band standard equipment. TUBES: 247 Crystal Oscillator, 247 Buffer, 510 or 530 Output Amp. POWER: Self contained heavy duty dual unit. KEYING: Special Clickless Grid-Block. METERS: Weston surface type.

There's a real thrill in amateur radio when you operate a Collins outfit. Collins Transmitters are sold to discriminating amateurs who want transmitter performance which conforms to commercial standards. And that's precisely the kind of performance that a Collins job delivers. The sweet part of the story is the fact that users of Collins equipment have not invested more money than the average ham. There's genuine economy in buying a Collins job rather than building a similar outfit from composite parts.

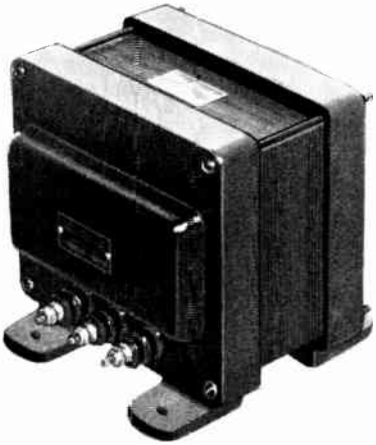
●

The Popular Collins 30W

If you want to make only a moderate investment in a transmitter, the Collins 30W is ideally suited to your needs. It is complete in itself and has a very high output for a transmitter employing inexpensive tubes. Yet its excellence of construction is attested by the fact that it is used as the basic unit in Collins CW and Radiophone Transmitters in all powers including the type 20B which employs two '04a's in the final stage with 1 KW input modulated by two '49's in Class B. The 30W itself has piled up a wonderful record of DX performance in the hands of enthusiastic users throughout the world.

●

COLLINS TRANSFORMERS

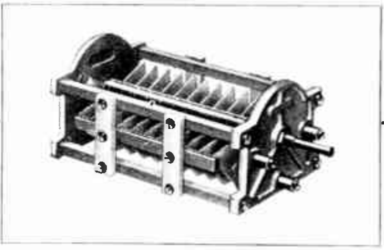


The complete line of Transformers designed for Collins Transmitters is available to the general transmitting field. The line includes over one hundred types of special Class B audio transformers, microphone and line transformers, heavy duty power transformers, and chokes, for every transmitting requirement.

Send 25c in coin for the complete Collins Manual

COLLINS RADIO COMPANY

CEDAR RAPIDS, IOWA



GOOD!

Because More Than 30 Years of Engineering Experience Is Built into Them

CHECK back over the earliest names in radio manufacturing, and you will find "Hammarlund" at the *top* of the *quality* group — just where it stands today.

Improved MIDGET CONDENSERS

Soldered brass plates. Sturdy frame. Smooth bearings. Four-point wiping rotor contact. Vibration-proof.

Isolantite insulation reduces dielectric losses to the minimum, under all conditions of temperature and humidity.

Eleven Stock Sizes 3 mmf. to 320 mmf. Capacity

Isolantite SOCKETS *and* COIL FORMS

Isolantite bases. Low-loss. Noiseless. Sockets have perfect spring grips for 4, 5 and 6 prongs.

Coil forms for low-wave and ultra low-wave work. With or without knobs. No drilling necessary. 4, 5 and 6 prongs.

Write Dept. AH-33 for complete catalog of precision equipment for receiving and transmitting.

HAMMARLUND MFG. CO.
424–438 W. 33rd Street, New York

For Better Radio
Hammarlund
PRECISION
PRODUCTS

PASSING THE EXAM

is more important than merely taking it

●

MAKE sure you do not flunk out; be prepared for any question you may be asked. Typical questions, and their answers, are given in the new reprint of *QST*'s popular articles on "Passing the Government Examination for Amateur Operator's License." Originally these articles appeared in the January and February, 1930 issues; so popular were they that the entire back copy supply of these issues was exhausted within a year. Rewritten, they were again published in October and November, 1931 and reprints prepared for distribution. This supply has again been exhausted, and now —

Revised in terms of latest amateur practice, with complete information on the new amateur regulations, a new reprint of the "Passing" articles is ready for distribution. In convenient, economical pamphlet form, you can find the answer to every exam question in it. 20c per copy postpaid.

THE AMERICAN
RADIO RELAY LEAGUE
West Hartford, Connecticut

World Radio History

HERE'S HOW

To Run Your Station the Way it Should be Run

OFFICIAL A.R.R.L. MESSAGE BLANKS — The proper and most convenient form. Designed by the A.R.R.L. Communications Department to make speedy and accurate handling easy. A great aid to good operating practices which reflect credit on your station. Bond paper, size 8½ x 7¼. Put up in pads of 100 sheets. *One pad 35c or three pads for $1.00. Postpaid.*

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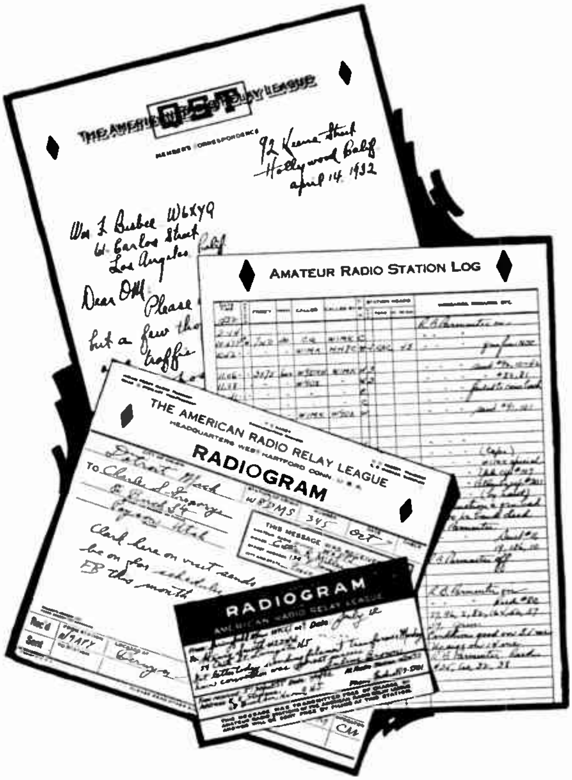
MEMBER'S CORRESPONDENCE STATIONERY

Write your radio letters on this A.R.R.L. stationery. It identifies you. Used by most old-timers and prominent amateurs. Excellently lithographed on 8½ x 11 bond paper. Now using heavier 20-lb. stock instead of 16-lb. as heretofore. *100 sheets — 50c; 250 sheets — $1.00; 500 sheets — $1.75. Postpaid.*



OFFICIAL A.R.R.L. LOG BOOK

A well-kept log is an essential part of a well-run station. This book, with 39 pages for operating records and 39 blank pages for miscellaneous notes, forms a complete history of your station — your most valuable radio record. Contains list of Q signals, message number sheet, bound-in page of cross section paper for receiver or frequency meter calibration, etc. Size 8½ x 10¾, bond paper, bound in heavy paper covers. *One book 40c or three books for $1.00. Postpaid.*

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MESSAGE DELIVERY CARDS

Neatest, simplest way to deliver a message by mail. Good looking and easy to use. Saves writing an explanation of method in which message was handled. *On U. S. stamped postals, 2c each; on plain cards (for Canada, etc.) 1c each. Postpaid.*

THE AMERICAN RADIO RELAY LEAGUE

West Hartford, Connecticut

ALL ABOUT THE

New Tubes

READERS OF THE RADIO AMATEUR'S HANDBOOK MAY OBTAIN EITHER AN RCA RADIOTRON MANUAL OR A CUNNINGHAM RADIO TUBE MANUAL, AND A SET OF TECHNICAL BULLETINS ON AMATEUR TRANSMITTING TYPES

FREE

ADDRESS DEPT. Q, E. T. CUNNINGHAM, INC., COMMERCIAL ENGINEERING SECTION, HARRISON, N. J.

ADDRESS DEPT. Q, COMMERCIAL ENGINEERING SECTION, RCA RADIOTRON CO., INC., HARRISON, N. J.

RCA RADIOTRONS

Cunningham
RADIO TUBES

THAT WOULD-BE AMATEUR—

is he a problem around your station? Does he represent a factor for consideration at your radio club meetings? He deserves a lot of attention, you know, for he is the new blood that amateur radio and the A. R. R. L. need. Yet it is difficult to take the time to answer all his questions, lead him carefully through all the early mysteries of radio.

Happily, the problem is easily solved. You can save yourself a lot of trouble and make the would-be amateur happy by suggesting that he get a copy of the new second edition of the League's special beginner's booklet — "How to Become a Radio Amateur." In its 32 pages it outlines the field of amateur radio, makes learning the code easy, and tells how to build a simple station with clear illustrations and easily followed building instructions — and there's concise dope on getting licenses and operating properly, too. An inexpensive introduction to amateur radio, and preliminary to the Handbook. The price is 25c postpaid.

★

AMERICAN RADIO RELAY LEAGUE
West Hartford, Connecticut

The Amateur's Bookshelf

GOOD TEXTBOOKS and operating manuals should be on every amateur's bookshelf. We have reviewed practically all the books in which the amateur would be interested, and have arranged to handle through the *QST* Book Department at A.R.R.L. Headquarters those volumes which we believe to be the best of their kind. Take pride in a small but good radio library; buy a few good books and get into the habit of reading them. Prices include postage.

Principles of Radio, by Keith Henney. This book is chock-full of meat for the experimenter. The subjects treated range from the fundamentals of electricity to the most modern concepts of modulation and detection. 477 pp., 306 illustrations.......... **$3.50**

Elements of Radio Communication, by Prof. J. H. Morecroft. This is a new book by the author of the "Principles" listed below. It is about half the size of the larger work, and the subject is treated in more elementary fashion. Simple algebra is sufficient. An excellent book for the "first-year" student. 269 pp., 170 illustrations.......... **$3.00**

Principles of Radio Communication, by Prof. J. H. Morecroft. An elaborate general textbook, and one of the recognized standards on theory for the engineering student. A working knowledge of mathematics is desirable for the reader who expects to get the greatest benefit from this work. 1001 pp., 5¾ x 9.......... **$7.50**

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Experimental Radio, by Prof. R. R. Ramsey. Revised Edition. A splendid book for the experimenter. This is a laboratory manual, describing 128 excellent experiments designed to bring out the principles of radio theory, instruments and measurements. 150 illustrations, 229 pp., 5¼ x 7.......... **$2.75**

Radio Theory and Operating, by Mary Texanna Loomis. Although giving a moderate amount of theory, it is essentially a practical handbook for commercial and broadcast operators, and as such ranks among the foremost publications of this sort. Used as a textbook by many radio schools. A good book for any amateur. 1000 pp., 800 illustrations.......... **$4.25**

The Radio Manual, by George E. Sterling. Another excellent practical handbook, especially valuable to the commercial and broadcast operator, and covering the principles, methods and apparatus of all phases of radio activity. Over 900 pp.......... **$6.00**

Radio Telegraphy and Telephony, by Duncan and Drew. Still another work along the lines of a general practical handbook. In size it is approximately the same as the two listed just previously, and the subject matter generally follows along the same lines. A good book in this class. 950 pp., 468 illustrations.......... **$7.50**

Practical Radio Telegraphy, by Nilson and Hornung. Written particularly for the student training for a commercial license, and covering theory and apparatus. A practical handbook. 380 pp., 223 illustrations.......... **$3.00**

Radio Data Charts, by R. T. Beatty. A series of graphic charts for solving, without the use of mathematics, most of the problems involved in receiver design. 82 pp., 8½ x 11.......... **$1.50**

Thermionic Vacuum Tube, by H. J. Van der Bijl. For many years this has stood out above all other works as a theoretical textbook and treatise on the vacuum tube and vacuum tube circuits. A knowledge of higher mathematics is required. Not a book for the beginner, but for the laboratorian and engineering student it is without a peer... **$5.00**

Radio Operating Questions and Answers, by Nilson and Hornung. Fourth Edition. A companion volume to "Practical Radio Telegraphy" by the same authors. The 1932 Revised Fourth Edition is very complete, covering Commercial and Broadcasting, Amateur, Aeronautical and Police Radio, Beacons, Airways, Meteorology, and Teletype Operating. 356 pp., 5½ x 8.......... **$2.50**

How to Pass U. S. Government Radio License Examinations, by Duncan and Drew. Intended as a companion volume to "Radio Telegraphy and Telephony" by the same authors, as a guide to the applicant for commercial licenses. It is not a text in itself. The chapter arrangement follows that of the sections of the commercial theoretical examination, each being made up of typical examination questions and their answers. 169 pp., 92 illustrations.. **$2.00**

Theory of Radio Communication, by Lt. John T. Filgate, S.C., U. S. Army. An excellent book on the theory of receivers, transmitters and associated equipment for those familiar with elementary electricity and magnetism. 250 pp., 180 illustrations.......... **$2.00**

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ABC of Television, by Raymond F. Yates. A practical treatment of television with particularly complete chapters on photo-electric cells, amplifiers and scanning methods. 205 pp., 78 illustrations.......... **$3.00**

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Radio Frequency Electrical Measurements, by H. A. Brown. A thoroughly practical book for the experienced amateur, the experimenter or engineer who has knowledge of the elementary principles of radio communication and of alternating currents.......... **$4.00**

Below Ten Meters, by James Millen and Robert S. Kruse. The contents include chapters on ultra-high-frequency oscillators, radiating systems, receivers, theories, measurements, television reception and other pertinent subjects, abundantly illustrated with photographs and diagrams. 64 pages.......... **$.50**

Radio Engineering, by F. E. Terman. A comprehensive treatment covering all phases of radio communication. A good all around book for students and engineers. 688 pp., 418 illustrations.......... **$5.00**

Servicing Receivers by Means of Resistance Measurements, by J. F. Rider. 203 pp., 94 illustrations. An excellent book for the Service Man.......... **$1.00**

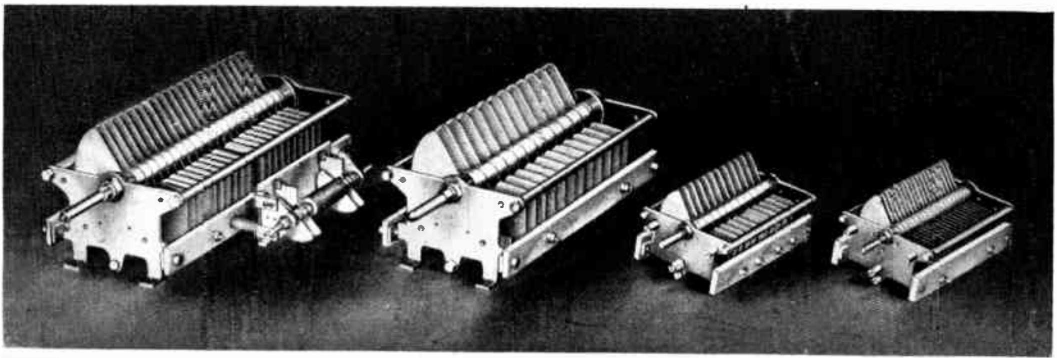
Electricity, What It Is and How It Acts, by A. W. Kramer. Tells in simple language all that is known about electricity today. It deals only with well known and accepted theories, presenting them simply and straightforwardly so that those not mathematically minded can understand them. Two Volumes. 592 pp., 242 illustrations...... **$4.00**

Communication Engineering, by W. L. Everitt. The most satisfying text on radio engineering. A general text for both first year and advanced courses. 567 pp., 335 illustrations.......... **$5.00**

AMERICAN RADIO RELAY LEAGUE, INC.

West Hartford, Connecticut

★ CARDWELL ★
FOR CONDENSERS



16-B for push pul — neutralizing condenser attached.

Standard 16-B Type 3276 — Max. Cap. 160 MMFDS

Type 512 A Split T-183

Type T-199

Mycalex Insulation is Standard on 16-B. Small extra charge for others.

Over 1500 different types and sizes, numbering, in the aggregate, many hundreds of thousonds of standard and special variable and fixed condensers, have been supplied by CARDWELL. A few standard listed sizes are shown on this page. . . . More stock condensers are illustrated and described in our literature, which is free for the asking. Send for it. . . . ANY CARDWELL CONDENSER CAN BE FURNISHED WITH MYCALEX INSULATION AT A SMALL EXTRA COST. . . . Special models for any purposes, to order.

We solicit your inquiries for our quotations. THE BEST IS THE CHEAPEST — USE CARDWELLS.

MIDWAY "FEATHERWEIGHT" CONDENSERS

RECEIVING

Type	No. Plates	Max. Cap. Mmfds.	List Prices	*2-Gang or Split Stator—List
401-B	3	26	$2.10	***$3.60**
402-B	5	50	2.20	***3.80**
403-B	7	70	2.30	***4.00**
404-B	11	105	2.40	***4.20**
405-B	15	150	2.50	***4.40**
406-B	25	260	2.75	Not furnished double but can be split.
407-B	35	365	3.00	

TRANSMITTING

Type	No. Plates	Max. Cap. Mmfds.	List Prices	*2-Gang or Split Stator—List
†408-B	5	22	$2.60	***$4.60**
†409-B	7	35	2.80	***5.00**
†410-B	11	50	3.20	***5.80**
†411-B	15	70	3.60	Not furnished double but can be split.
†412-B	21	100	4 25	
†413-B	31	150	5 50	

*Cap. ea. section is same as shown for single condenser to the left.

†Heavy rounded-edge and polished plates.

"STANDARD" SIZE TRANSMITTING CONDENSERS

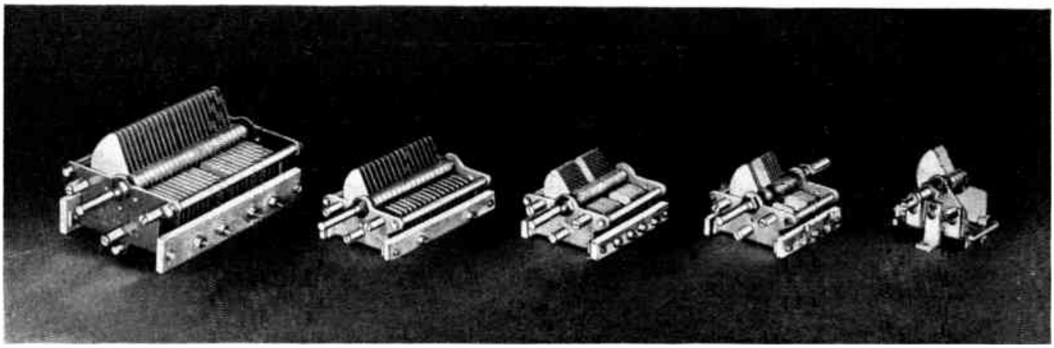
Type No.	Max. Cap. Mmfds.	Airgap Bet. Rotor and Stator Pl.	Plate Thickness	Number of Plates	List Price.
T-183	110	.171"	.040"	23	**$10.00**
164-B	220	.070"	.0253"	21	**5.00**
T-199	330	.084"	.040"	37	**10.00**
147-B	440	.070"	.0253"	43	**8.00**
511-B	23	.171"	.040"	5	**4.00**
513-B	50	.171"	.040"	11	**7.00**
515-B	56	.230"	.040"	15	**12.00**

SPLIT STATOR CONDENSERS

Type No.	Max. Cap. Mmfds.	Airgap Bet. Rotor and Stator Pl.	Plate Thickness	Number of Plates	List Price.
*156-B	500	.030"	.0253"	21	**$7.00**
197-B	80	.070"	.0253"	9	**7.00**
157-B	210	.070"	.0253"	21	**12.00**
510-B	110	.171"	.040"	23	**32.00**
512-B	50	.171"	.040"	11	**12.00**

*Receiving condenser spacing (.030")

ALSO MADE TO SPECIAL REQUIREMENTS—SEND PARTICULARS



157-B A split 147 B

413-B The Famous Midway

405-B A Split Midway

518 Bandspread

519 Neutralizing for 852 tubes

THE ALLEN D. CARDWELL MANUFACTURING CORP.

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