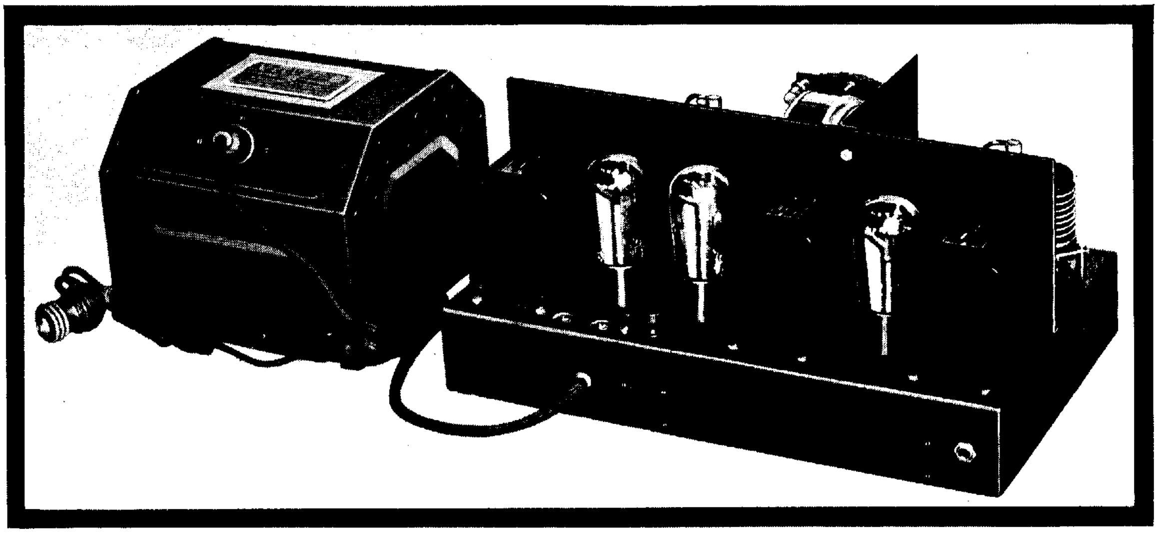


An *Analysis of* A. C. Operated Short-*Wave* Receiver Design

It Is Paying Attention to Detail That Counts in Producing a Satisfactory Receiver, Especially When That Receiver Happens to Be of the A.C. Short-Wave Type. Condenser Design, Closed-Loop Circuits, a Suitable Power Supply and Coil Construction Are Only a Few of the Items Which Contribute to the Success or Failure in Operation

By James Millen
in collaboration with
Robert S. Kruse

REALIZING that before short-wave receivers could come into popular use they must be made to operate with very nearly the same ease and convenience as a modern broadcast receiver, we made a study of their weak points. A receiver was needed that would not only hold its own against any of the older type battery operated jobs for general amateur and experimental reception, but would also meet every requirement of the non-technical owner who, when he felt so inclined, wanted to hear 5SW in London, 2ME in Melbourne, Australia, or any one of a dozen other foreign broadcasting stations without the necessity of waiting for possible re-broadcasts of these stations.

As a result of this survey, the following essentials of a good short-wave receiver were brought to light:

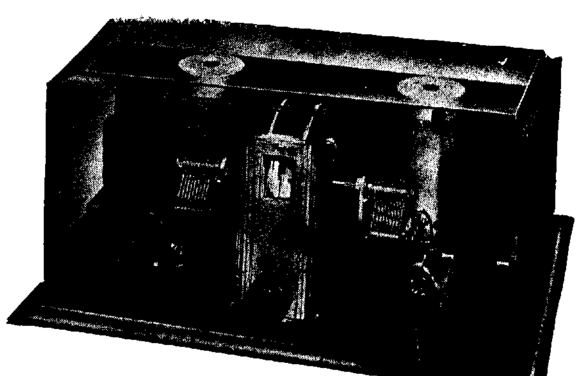
1—Absolutely humless a.c. operation, 2—Single dial control, 3—Loud speaker reception from foreign broadcast stations, 4—Good tone quality, 5—Non-critical tuning, 6—Neat appearance.

Most of these problems have heretofore been unsurmountable in receiver design.

Now, after nearly a year of work on the development of such a receiver in the laboratories of the National Company, in collaboration with a number of well-known short-wave authorities (including, in particular, Robert S. Kruse, who spent a great deal of time both in the National Company's laboratory and in his own laboratory at Hartford, in making investigations into the causes of the various types of hum encountered in such receivers), a new a.c. short-wave receiver has been developed.

While the accompanying illustrations will give a good general idea of the commercial result of this research, the circuit diagram should not be taken too seriously, as all the circuit diagrams in the world mean little, if anything, when it comes to short-wave receivers. In fact, the circuit of the new receiver, as given in Fig. 1, is to all appearances quite conventional in every way.

When dealing with short waves, it is not so much the diagram which counts, but the manner in which the circuit is used. Little things, like the order in which the tube heaters are wired, the insulation of the bearings in the variable condensers, the type of material used in the coil forms, and so on without end, is what makes the difference between successful design and one which is a failure.



A front view of National's new a.c. operated short-wave receiver. Special constructional features, as outlined in the text, are incorporated in the design of this receiver to make it exceptionally satisfactory for a.c. operation

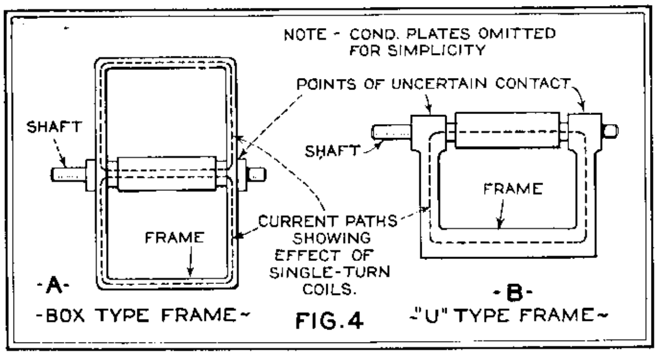
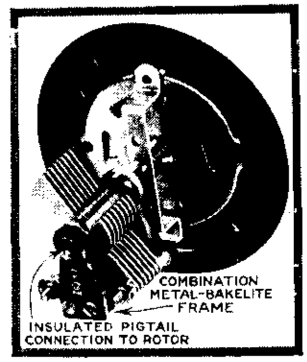
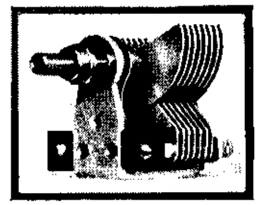


Fig. 4. The frame and shaft of the condenser form a single-turn coil. As the shaft is turned the bearing contacts change and the single turn is partly opened and closed, tending to produce noises in nearby tubes or those coupled to the condenser



This specially designed short-wave receiver (at the right) is unlike other small tuning condensers, in that its frame is part metal and part insulation, thus preventing production of a shorted turn, a feature to be avoided in short-wave receiver construction



Below, a general view of the revamped tuning condenser especially adapted to short-wave use

The circuit itself comprises a tuned screen-grid radio-frequency stage, in which provision has been made, if desired, for the use of the heater type pentode tube, where slight additional gain at the expense of selectivity is wanted; a screen-grid regenerative detector; a two-stage transformer-coupled audio amplifier, employing push-pull in the second stage and with provision for plugging 'phones into the output of the first stage when desired; and a separate power pack especially designed for short-wave work.

Occasionally good hum-free a.c. operation on short waves may be obtained by the mere substitution of the heater type a.c. tubes for the more conventional d.c. types in a standard battery operated short-wave circuit. Such instances, however, are few and far between, as they seem to be the result of an unusually good a.c. line condition, plus a "better than average" set of heater tubes. In most cases the mere use of conventional heater type a.c. tubes results in a quite pronounced and annoying hum that tends to vary somewhat on the different short-wave bands.

Thus, in our work on the development of an a.c. short-wave receiver, we soon found that while we would seem to be securing excellent results on one power line, it was essential that we take the entire outfit to another part of town or to a town in another state which was known to have a particularly poor and troublesome power system, in order to "check and double-check" all results.

After considerable experimentation of the so-called "cut and try" variety, it was found that there were some dozen or so very definite sources of hum trouble to be encountered in the short-wave receiver that would not cause the slightest trouble in a broadcast receiver. It was the identification and the elimination of these concealed sources of hum that finally made possible an a.c. short-wave receiver in which the hum is as low as in a battery powered set.

First, the tubes themselves must not only be of the heater type, but also, for complete freedom from hum, must be carefully selected. This is especially true of the detector tube which may be found to be quite noisy when just on the edge of oscillation, unless it is selected with care.

The cause of hum when using some types of heater tubes is apparently due to two things; one being direct leakage across the ceramic insulating column between one side of the heater and the cathode, and the other to an unneutralized 60 cycle field around the heater.

In general, the –27's, when operated on the verge of oscillation, are less troublesome than the –24's. At first thought this quieter performance of the –27 would tend to recommend its use as the detector. It was soon found, however, that, though more noisy when approaching oscillation, the –24 screen-grid detector was, under practical operating conditions, actually quieter due to its improved sensitivity, eliminating the necessity for full regeneration for the same signal output as obtained with the –27. Improved tone quality was a further by-product obtained from this decreased amount of regeneration.

The second point that must be given careful consideration if successful a.c. operation is to be had, is the power supply unit. This unit should be entirely separate from the receiver itself, completely shielded and located at least three feet from the receiver proper.

It should have exceedingly low inherent hum in its output; (i.e., at least a double section filter using good quality chokes and plenty of condenser capacity must be employed). The power transformer should have an electrostatic shield between the primary and the other windings in order to prevent line disturbances from getting into the power unit and into the set. The rectifier tube must also have an r.f. filter, comprising a radio-frequency choke and by-pass condenser in its output, directly preceding the hum filter. It is this r.f. filter system in the power unit which provides one of the two things necessary to eliminate the so-called "tunable" hum; that is, a hum that shows up only on certain wave-lengths but which nevertheless is quite pronounced. Apparently such hum results from disturbances set up in the rectifier tube itself.

Strange as it may seem, separate heater windings on the power transformer seem to give no improvement over the use of a single winding.

The set proper should be completely enclosed in a steel cabinet in order to exclude stray low-frequency magntic fields. Incidentally, these stray fields seem to be the cause of the "a.c." hum frequently encountered with some battery operated short-wave receivers. In order to make the shielding all the more effective, the power supply potentiometer with its associated by-pass condensers should be located inside the set in order to eliminate any external leads which might contain some radio-frequency currents.

It has been found that almost every .5 mfd. condenser of the conventional paper

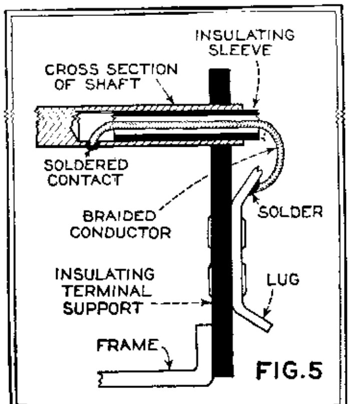


Fig. 5. The new condenser uses one insulated bearing. The connection from the tuned circuit to the rotor is made through a pigtail of the constant impedance type

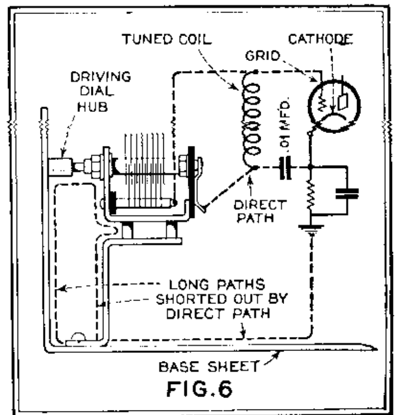
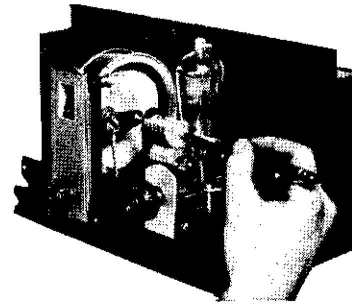


Fig. 6. Note that by means of the connection providing a direct path from rotor to coil, the longer loop circuits constituting short-circuited turns are removed from the immediate vicinity of the tuned circuits thereby nullifying the detrimental effects

The circuit comprises a tuned screen-grid radio-frequency stage, with provision for using a heater type Pentode tube; a screen-grid regenerative detector; a two-stage transformer-coupled audio amplifier employing push-pull in the second stage when desired; a separate specially designed power pack supplies A and B voltages



A side view of the receiver showing the method of mounting the specially designed tuning condensers. Shielding is employed not only to isolate the tuned circuit from each other but also to shield the audio channel from the tuner section

variety now on the market has a materially higher r.f. impedance at the lower wavelengths than a good .01 mica condenser. It is evident, therefore, that even though the cost be slightly more, the use of the smaller mica by-pass condenser will prove more effective and in many instances will completely eliminate a hum that is quite pronounced when using the paper condenser (hum resulting from common coupling through impedance of condenser.)

Along with low impedance by-pass condensers, should also be mentioned center-tap resistors of low ohmic value. That is, they should be of not over 20 ohms, rather than the conventional 60 ohm type employed in broadcast receivers. Furthermore, it will be generally found that a noticeable improvement can be obtained, when operating on a poor power line, if this resistor is of the flat type rather than the round type, which apparently has considerable radio-frequency impedance at the extreme high frequency on which we are working. One side of the center-tap resistor had best be by-passed by one of the small mica condensers previously mentioned.

While the jack for headphone reception is located so as to cut out the final or push-pull stage, there is bound to be a time, especially when listening to some of the foreign stations, when it may be desirable to connect the 'phones in place of the loudspeaker and use all of the obtainable amplification. But this possible use of the headphones in the output of the complete receiver is not the reason for the employment of push-pull in the final audio stage. Should a single output tube have been employed in place of the push-pull, an unbalanced drain of considerable magnitude would have been imposed upon the power pack, which, in turn, would have produced an infinitesimal fluctuation in some of the bias resistors, resulting in the introduction of hum in the detector and first audio-frequency circuits, which then would be amplified and passed on to the listener, even though the 'phones were plugged into the first stage jack, and the final stage not in use.

And now comes a method of hum control that will perhaps seem more logical than those already described; that is the location and arrangement of the wiring. As will be seen from the photographs, the receiver is constructed on a metal sub-panel to which

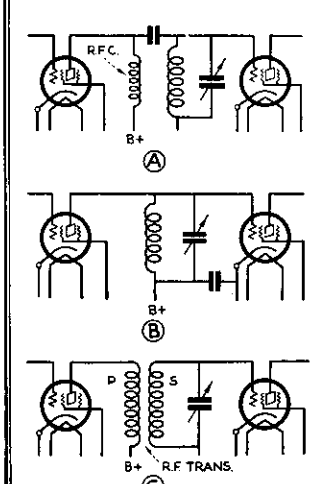


FIG.7

Fig. 7. After using a tuned impedance as the interstage coupling device, as shown at left—first as in "A", then "B"—the hum that was developed was found to be objectionable. It was eliminated by the use of a radio-frequency transformer as a coupling medium, as shown in "C"

Fig. 8. To make a short-wave receiver operate satisfactorily from a socket powered B supply, it is necessary that extra special precautions be taken in the design and construction of the power unit to incorporate r.f. chokes and bypass condensers so as to make the receiver stable in operation

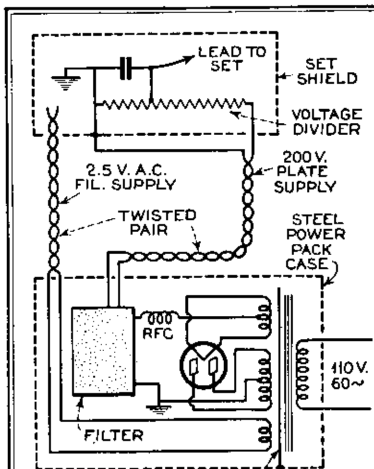
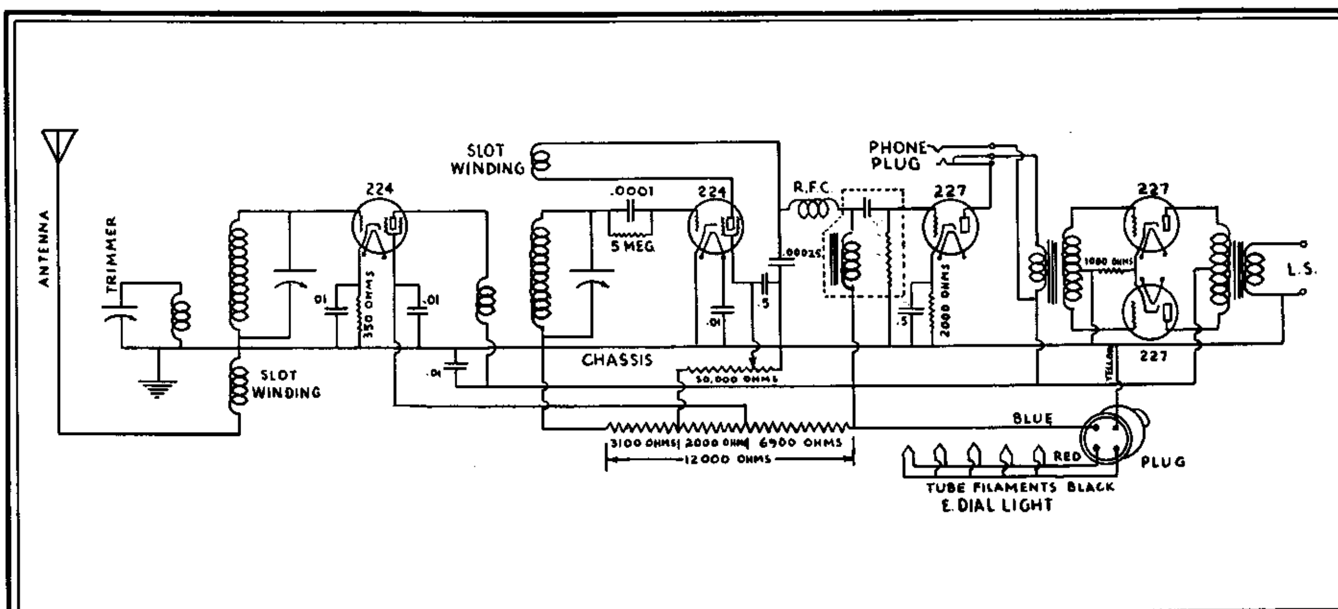


FIG.8



is also added a metal bottom shield. By being careful to see that practically all of the radio-frequency leads are located above the sub-panel, while all of the power supply leads are located in the enclosed compartment beneath the sub-panel, much is done to eliminate troubles from so-called modulation hum.

And now for the final and perhaps least expected of all sources of hum trouble—the interstage r. f. transformer. In order to simplify construction, an attempt was at first made to use a tuned impedance as the interstage coupling device, first as shown in Fig. 7-A and then as in Fig. 7-B, where the stopping condenser is located in the grid return circuit of the detector rather than in the plate circuit of the screen-grid amplifier. In both of these instances the receiver not only lacked the sensitivity obtainable when using a transformer but also suddenly developed a new hum.

Interstage R. F. Transformer

Apparently both of these r. f. coupling devices were capable of passing on to the grid of the detector tube some of the hum frequencies developed in the r. f. circuit. The loss of sensitivity was due seemingly to the fact that there is no such thing as an r. f. choke of infinite impedance at all frequencies, which spoiled the effectiveness from a "gain" point of the circuit. The stopping condenser in the grid return circuit at "B" apparently had considerable impedance at some frequencies which also prevented that circuit from performing at par.

The solution is obviously a radio-frequency transformer as shown at "C", Fig. 7, in which not only is the sensitivity of the receiver kept up where it belongs, due to the complete omission of shunt radio frequency chokes and series blocking condensers, but also all low-frequency coupling between any part of the r. f. amplifier circuit and the detector tube grid is completely eliminated.

There are quite a number of regeneration control systems, each of which seems to have some particular short-wave band in which it operates to best advantage. Where the plug-in coils are used, as in this case, to cover an extremely wide frequency range, it is necessary to find some means of regeneration control that will be smooth at all times, and not result in uncontrollable fringe howl, bad hand capacity effects and interlocking.

Of the four most generally used methods, namely, variable plate by-pass condenser, series plate resistor, tickler shunt resistor, and screen-grid voltage control, the screen-grid voltage control method, when accompanied by other circuit details results in uniformly satisfactory performance at all wavelengths.

Tuned Circuits

Good tuned circuits are at the bottom of a good receiver of any sort. Since a tuned circuit comprises a coil and condenser, let us consider both of these units in turn.

Until recently there have been no proper high-frequency tuning condensers, designed for that purpose. The practice has been rather to use some sort of a broadcast-range condenser with a few lonesome plates providing the small capacity actually needed. Some improved designs have appeared quite lately, also some of the more recent "vernier" condensers have by good fortune been well adapted to some high-frequency needs and have been much used for such purposes.

One of the early steps taken in the development of the new receiver, therefore, was the design of the special short-wave condenser. Unlike other small tuning condensers it may be mounted in all of the regulation manners—screwed to a panel, screwed to the base or secured to a panel by the hexagon nut on the front bearing in conventional "single hole mounting" style. At high frequencies any condenser with two bearings tends to be noisy, either at once or else after it has had some use. This tendency can be decreased by the use of a good jumper from rotor to frame and by the use of spring tension to secure good bearing contact. Both devices have in the past been used with varying success. Single-bearing condensers of the "vernier" type, however, are noticeably quieter than 2-bearing types and the difference grows with frequency until at about 60,000 kc. (5 meters) the 2-bearing type has become nearly useless. There are several possible reasons for this trouble. Prominent among them is the effect shown in Fig. 4. The frame and shaft of the condenser form a single-turn coil. As the shaft is turned the bearing contacts change and the single turn is partly opened and closed, tending to produce noises in nearby tubes or those coupled to the condenser. At ordinary frequencies the effect is not serious and therefore need not be worried about, but at high frequencies it is well worth avoiding. The new condenser accordingly uses but one bearing and that bearing is insulated. The connection from the tuned circuit to the rotor is made through a pigtail of the patented constant impedance type. (See Fig. 5.) The pigtail does not go to the frame, but to a terminal lug on an insulating support at the rear end of the condenser. The stator terminals are close to this terminal, permitting very short leads if desired.

The dial appearance alone was not the only reason for the selection. The projection feature eliminates paralax. This dial has two inherent characteristics that make its use particularly valuable in short-wave work. The first is that the projection feature eliminates parallex in the scale reading which prevents accurate logging at the various dial settings without being extremely careful at just what angle the dial is being viewed. The other is the electrically silent vernier drive which is obtained by the use of a non-metallic cord. The silent drive feature, as in the case of the insulated condenser bearing, is very important when tuning in on wavelengths below 20 meters.

The new battery type Radiotrons UX230, UX231 and UX232, are ideally suited for use in place of the UY224s and 227s in this new NATIONAL SW5 "Thrill Box" where A. C. supply is not available. The accompanying blueprints give all necessary data on circuit changes.

Operating Notes

There's little more to bringing in those elusive foreign short-wave broadcasters than merely sitting down to your receiver, flipping the filament switch and carelessly twiddling the dials. Yet, many a broadcast listener has been led to believe that it's just as easy as listening to a local program. Not only must the operator of a short-wave receiver exercise greater care in tuning in to a distant station, but he must use his judgment as to when to listen. All the tuning on earth won't bring in a station if it doesn't happen to be on the air. Matters become more complicated in this respect because of the difference of time between the location of the receiver and the transmitter. There's no doubt about it, a fellow's got to use

Coil Tuning Ranges

"Brown"	*(No. 10) Range*	*9 to 15 meters*	*or 33.3 to 20.0*	*Megacycles*
"Red"	*(No. 12) Range*	*23 to 41 meters*	*or 13.0 to 7.33*	*Megacycles*
"Black"	*(No. 11) Range*	*14 to 25 meters*	*or 21.2 to 12.0*	*Megacycles*
"White"	*(No. 13) Range*	*38 to 70 meters*	*or 7.9 to 4.30*	*Megacycles*
"Green"	*(No. 14) Range*	*65 to 115 meters*	*or 4.70 to 2.61*	*Megacycles*
"Blue"	*(No. 15) Range*	*110 to 200 meters*	*or 2.73 to 1.5*	*Megacycles*

Dial Readings

STATION	COUNTRY	COILS	WAVE	DIAL
PHI	*Holland*	*Black*	*16.88*	*85*
PCL	*Holland*	*Black*	*18.07*	*112*
W6XN	*U. S. A.*	*Red*	*23.35*	*03*
G5SW	*England*	*Red*	*25.53*	*55*
VK2ME	*Australia*	*Red*	*28.5*	*85*
PCL	*Holland*	*Red*	*31.4*	*100*
W2XE	*New York City*	*White*	*49.02*	*90*
W3XAU	*Philadelphia*	*White*	*49.5*	*92*
W8XK	*Pittsburgh*	*White*	*62.5*	*140*

Showing the coil ranges and approximate dial readings for important stations. Antenna and r.f. coils are identical

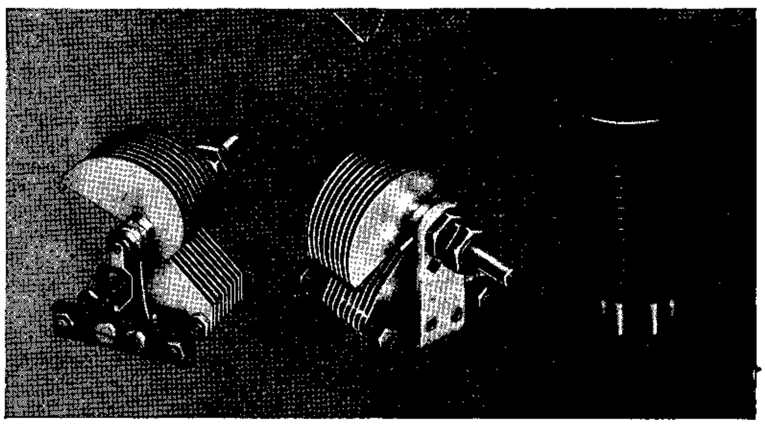
his head when tuning in on the short waves. The list of short-wave broadcasters on the following pages is the most authoritative and latest which it has been possible to compile.

Although the reception of foreign short-wave broadcasting stations is no longer an unusual experience for thousands of radio fans, there are still many owners of short-wave receivers who have never heard anything outside of the United States or Canada. Their disappointing failures can be explained usually by either or both of two reasons: they do not exercise enough patience in tuning their sets, or they do not know when and where to listen.

From his contacts with several thousand purchasers of a popular short-wave receiver kit, the writer would say that nontechnical people have been somewhat oversold on the idea that foreign reception is merely a matter of flipping a switch. It isn't at all. Troublesome hand-capacity effects have been pretty well eliminated but you still have to hang a bit tensely over the dials and wait for signals to fade in to an understandable level. The advent of short-wave broadcasting (as distinctly distinguished from "ham" radio telegraphy) has revived the fine art of dial twisting, and unless the set owner masters it he will never know the thrill of hearing VK2ME in Sydney, or RA97 in Siberia, or that German jawbreaker at Koenigswusterhausen.

The Fine Art of Tuning

The most important dial or knob is the one that controls the regenerative action of the detector. This is true for all types and makes of short-wave receivers, as they all use a regenerative detector, with and without tuned or untuned r. f. amplification and with one, two or three stages of variously coupled a. f. amplification. Simply keep the detector in a continual state of oscillation by rocking the regeneration dial back and forth as you turn the tuning dial a fraction of a degree at a time. When you encounter a carrier wave you will hear a tell-tale whistle. If the signal is fairly strong, you can back down the regeneration until the whistle disappears; if the signal is rather weak, it is best to "zero-beat" it. This is the process of keeping the circuit in oscillation, but tuning it so that the frequency of the local oscillation is exactly the same as that of the incoming carrier wave. Under this condition no whistle is generated, there being no heterodyne action, and the voice of music can be distinguished. The signals will sound rather "mushy" if they are zero-beated, but at least they will be recognizable. Sometimes, after a station is brought in by the zero-beat method, its strength may increase so much that the detector can be thrown out of oscillation; the signals will then clear up considerably.



Special condensers and coils have been designed for this receiver, and contribute to its high efficiency

Unless a very short antenna is used, the tuned r. f. stage is rather broad. The trimmer condenser serves to compensate for various lengths of antenna that may be used, and need be set but once, when the receiver is first put in operation. As it affects the operation of the detector stage, it should be adjusted and then forgotten, in order that the stations may be logged accurately.

The aligning procedure is simple; the detector is put just under the edge of oscillation and the trimmer condenser turned until a point is found where oscillation is maximum. Of course, the detector may still be made to stop oscillating by simply retarding the regeneration control. This method of alignment is much more accurate than the usual custom of tuning in a station for maximum volume.

Having a good receiver in good operating condition is only half the battle. You have to know when to listen, and at what points on the dials. The accompanying list of stations, with their hours of operation in Eastern Standard time, should be of great assistance to you in this respect.

One thing many people cannot seem to get into their heads is that time is different in different places in the world. Many short-wave set owners finish their suppers at 7:00 or 7:30 in the evening and then sit down to their receivers with the innocent expectations that there will be short-wave stations to hear all evening. This is not always so. Seven o'clock New York time is midnight in London, and G5SW, the famous British Broadcasting Company's short-waver, is just signing off for the night. The writer has read hundreds of letters from people who complain of their inability to bring in London for their bridge guests—at nine o'clock. This is an age of scientific achievement, but even a dozen short-wave sets won't bring in a station that isn't transmitting.

Right now the best times to hear foreign stations are early in the morning and about the middle of the afternoon. Between four and about eight a. m. the stations in Australia, Siam, Siberia, the Dutch East Indies and Holland are quite active, and they deliver astoundingly strong signals. VK2ME, in Sydney, is testing pretty regularly with Schenectady and with the British Post Office stations in England, and comes through with fair reliability. He is not on every morning, but if you don't get him one day you probably will the next.

Those Dutch stations are by far the best ones. PLE and PLF, in Java, working with PHI, PCO and PCK in Holland, operate powerful transmitters, and if you tune way down low on your smallest coil you can get them loud enough to wake up the family next door.

If you have always confined your listening hours to the early evening, you won't know your set in the early morning. The air is comparatively clear and quiet and the very low-wave stations skip in without much coaxing.

During the afternoon the German stations get busy, and come through just a little under WGY. In England G5SW starts at 2 p. m. E. S. T., and is an old stand-by.

As you know, skip distance effects vary with wavelength time of day, and the condition of the atmosphere. Therefore, divide your listening schedule something like this: 14 to about 20 meters, best from daybreak to about 2:00 p. m., and then fades out as darkness approaches; it is useless to listen below 20 meters after dark. 20 to 35 meters Europeans from 1:00 p. m. to about ten in the evening (if they happen to be putting on late programs). 35 to 75 meters, best between twilight and daybreak.

You can locate many of the foreigners by spotting some of the American stations. For instance, you can get W2XAF (WGY) pretty easily on 31.48 meters; crawl just under him and look for PCJ, NRH, and the German station at Koenigswusterhausen. Little NRH, in Costa Rica, is about two degrees below these. You can spot this group of stations because they are about ten degrees below a very powerful code station on about 33 meters. This is XDA, in Mexico City, which also occasionally uses voice. When it does it sounds just about as WJZ does to a receiver located in Bound Brook. The usual broadcast antenna can, of course, be used, and if connected to the short wave receiver through a small condenser, such as .000005 mfd. capacity, both receivers may be left connected permanently to the common antenna. However, a good ground is rather essential to the stable, quiet operation of the high frequency set. A secure water pipe connection is desirable. Tubes of known reliability are to be preferred to possibly inferior grades.