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A Short-Wave Super-Heterodyne Receiver

A Paper Delivered Before the Radio Club of America on June 8, 1926

By George J. Eltz, Jr.

Radio Sales Manager, Manhattan Electrical Supply Company

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A Short-Wave Super-Heterodyne Receiver

A Paper Delivered Before the Radio Club of America Showing How a Simple Short-Wave Regenerative Receiver is Converted into a Vastly More Sensitive Short-Wave Super Heterodyne—Constructional and Operating Suggestions

By GEORGE J. ELTZ, Jr.

Radio Sales Manager, Manhattan Electrical Supply Company

THE reception of short-wave radio signals, both telephone and telegraph, has been almost universally accomplished by means of the single-circuit regenerative receiver. This type of receiver, while it has been practically abandoned for the reception of longer wavelengths, is excellent in operation on about 3000 kc. (wavelengths of 100 meters, or under). Indeed, so well has the single-circuit receiver operated that perhaps sufficient attention was not given to other methods of reception. With this thought in mind, the author decided to investigate the possibilities of the super-heterodyne method of reception and, as a result, the receiver described was evolved. The receiver was constructed and first operated in October, 1925.

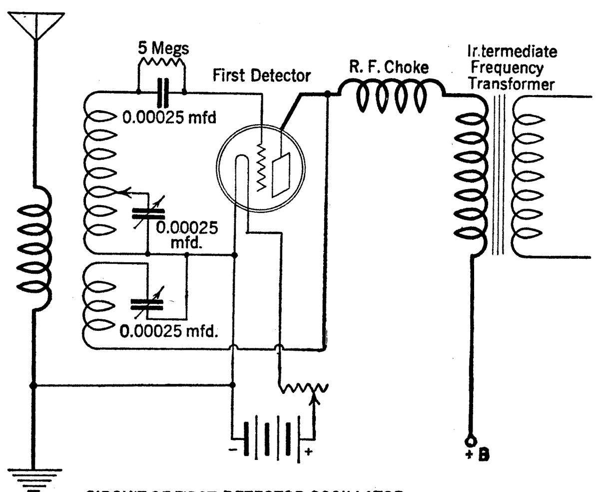
The super-heterodyne used for the reception of short waves differs somewhat from that used for the reception of broadcasting, although of course the general theory is identical.

The super-heterodyne method of reception consists of tuning the incoming frequency, beating with it another frequency, and then amplifying and detecting the beat note. The actual signal listened to has in it none of the original frequency or the frequency which caused the beat note. In the reception of broadcast programs or other signals between 1500 and 600 kc. (200 and 500 meters) the beat note selected is a frequency somewhere between 30 and 80 kilocycles. This relatively high frequency is selected to prevent the introduction of distortion by elimination of the side-band frequencies in the intermediate amplifier and filter.

In the reception of short waves, particularly the reception of c. w., this element of distortion may be disregarded, and such has been the case in this receiver, the assumption being that most of the signals received will be c. w.

The ordinary "super" used for broadcast reception has two tunings: first, the loop or antenna circuit and, second, the oscillator circuit. This short-wave "super" has only one tuning arrangement, in which is combined both the tuning operations indicated above. This method of tuning was selected because of its simplicity and because it makes possible the construction of what is practically a single-control set.

The intermediate frequency chosen is 22 kilocycles, which, while too low a frequency for good telephone reception, when simple tuned circuits are used, is satisfactory for c. w. or telegraph signals. The selection of this frequency necessitates detuning the set 22 kilocycles from the incoming signal, but at the frequencies corresponding to wavelengths of 100 meters or under, this detuning is of no importance in decreasing signal strength.



CIRCUIT OF FIRST DETECTOR-OSCILLATOR

FIG. I

The reader will recognize the description above as applying to the "autodyne" or "self-heterodyne" type of "super." The beat note of 22 kc. is created in the same manner as in the broadcast set but at a lower frequency. For the reception of short-wave telephone signals, the amplification and detection of the 22-kc. beat note is accomplished in the usual manner. When c. w. signals are to be received, another beat note must be created either by means of another oscillator tube or by a self-heterodyne beat note in the second detector tube. This latter method has been selected, a beat note of 1000 cycles being chosen as the most satisfactory. This detuning of the second detector circuit, while it may appear to be inefficient because of the low intermediate frequency is not so bad as it seems, since the amplification in the intermediate circuit is very great and there is plenty of energy to spare.

To summarize, the action of the entire receiver is as follows:

1. Approximate tuning to the incoming frequency by the first detector tube (which is also an oscillator) and the creation of a 22-kc. beat note.
2. Amplification of the 22-kc. beat note.
3. Detection of the beat note with:
   a. Straight detector for telephone.
   b. Oscillating detector for c. w.
4. Amplification at audio frequency.

The entire action is controlled by one dial.

DESCRIPTION OF THE SET

THE first detector and oscillator circuit may be any of the conventional short-wave receiving circuits. The one chosen is given in Fig. 1. Two variable condensers are shown but all the tuning is done with the one in the grid circuit. The condenser in the plate circuit must be set for each band of frequencies covered; for instance, from 7096 kc. to 6663 kc. (40 to 45 meters), 6663 kc. to 5996 kc. (45 to 50 meters), etc. This setting is not critical, the only requirement being that the tube oscillate strongly but not so violently that it blocks.

The coils, condensers, choke coil,

The Facts About This Receiver

Name of Receiver	Eltz Short-Wave Super-Heterodyne Receiver.
Type of Circuit	Super-heterodyne
Number of Tubes	Five: 1st detector; two intermediate-frequency stages; 2nd detector, and one stage of audio frequency amplification.

Radio-frequency amplifiers at short wavelengths have not generally been found satisfactory, so the accepted short-wave receiver, without r.f. amplification, has remained the stand-by. In such receivers, a detecter tube is made to oscillate and beat with the incoming c.w. signal to produce a note of about 1000 cycles. In the Eltz super-heterodyne receiver described here, the same system is employed with the exception that the beat note is caused to be 22 kc. or 22000 cycles, which is inaudible. This is readily amplified by the intermediate-frequency amplifying stages, then again detected or rectified, and finally amplified at audio frequencies.

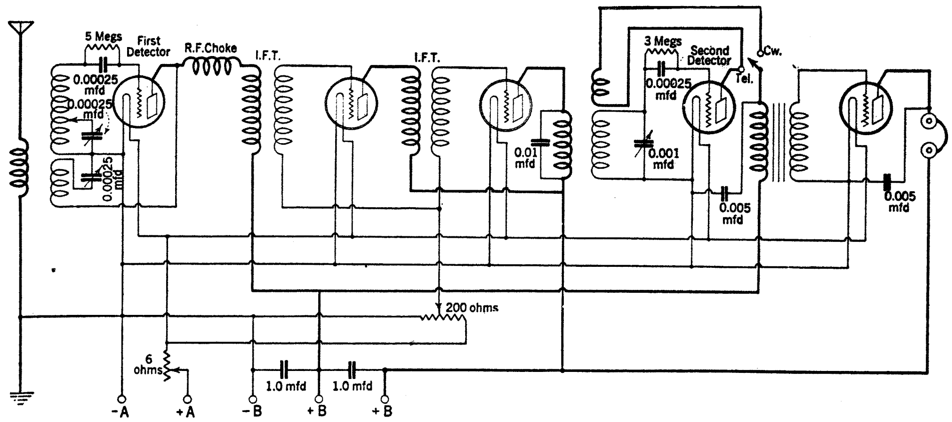
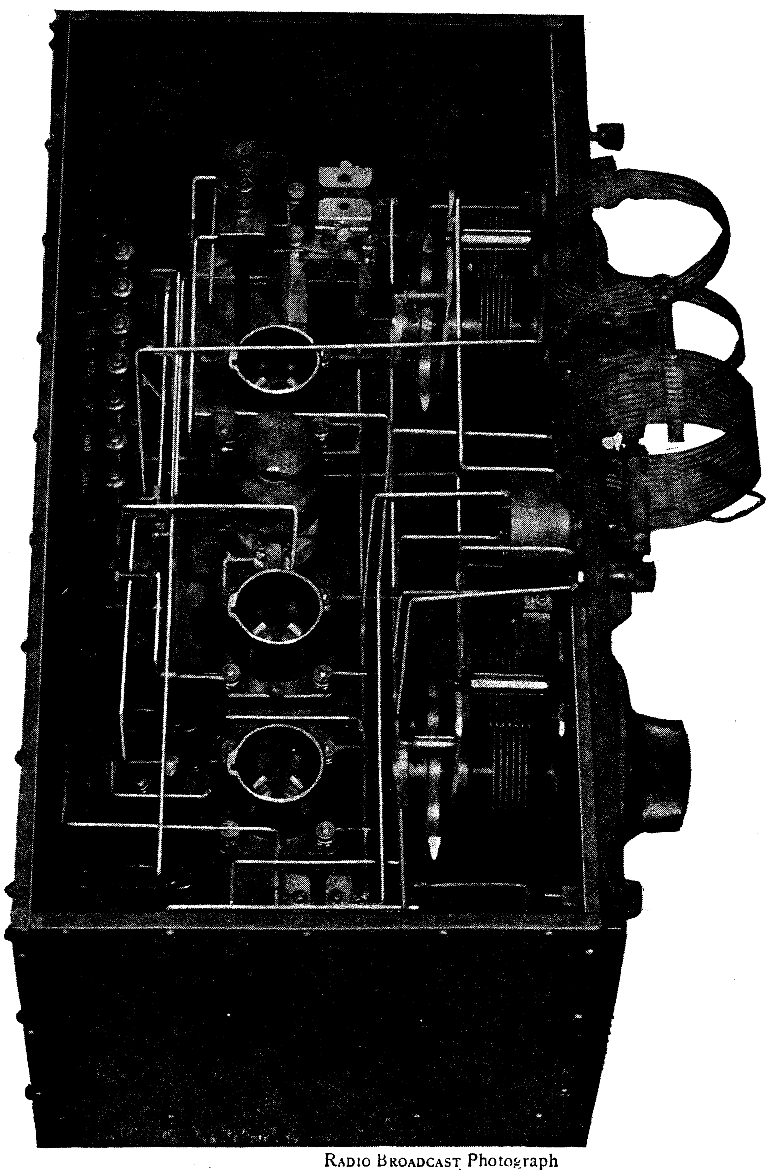


FIG. 2

etc., are identical with those which would be used in the construction of a regenerative set. The variable condenser in the grid circuit must be provided with some means of close adjustment as the setting is rather critical. The plate circuit condenser can be set with an ordinary knob or dial, without trouble.

The choke coil consists of 100 turns wound on a wooden form 1 inch in diameter and 2 inches long. A honeycomb or similar coil of 150 or 250 turns will also serve very nicely. The intermediate transformer must be one capable of amplifying the rather low frequency of 22 kc. In this set, those manufactured by the General Radio Company were used, but there are probably any number of others which will serve.

The coils used in the antenna, grid, and plate circuits are made by winding bare copper wire of No. 16 gauge over a form on which are placed four narrow strips of celluloid, equally spaced. The wire is spaced with string and, when completely wound, the string is removed and the wire cemented to the strips by means of liquid celluloid. The construction of this type of coil is familiar to anyone who has followed the development of the short-wave regenerative receiver.



Radio Broadcast Photograph

THE INTERIOR

Of the Eltz five-tube short-wave super-heterodyne is shown in this illustration. The coils, starting at the lower one, are: (1) A-B; (2) C; (3) D. These letters may be explained by reference to Fig. 3 on this page. The flexible lead for tapping A-B may be clearly discerned

The diameter of the coils is 3 inches for whatever frequency band the coil is designed to cover. Figs. 3 and 4 show the number of turns to be used for each frequency band. Three coils were used by the author to cover the amateur bands.

The figures given for the coils are only approximately correct, as the method of wiring, mounting, etc., all affect the capacity of the coils and, in consequence, the number of turns required to cover a given frequency range.

Where the operator or constructor has a satisfactory regenerative receiver already in operation, there is no need to change, even though the circuit differs from the one shown. The only requirement is that the primary of the first intermediate transformer be free of a capacity shunt greater than 0.00025 mfd.

THE INTERMEDIATE AMPLIFIER

THE complete circuit of the receiver is shown in Fig. 2. By reference to this circuit it will be observed that two untuned intermediate transformers are used and one tuned or filter transformer of special construction. As already mentioned, the intermediate transformers used are those manufactured by the General Radio Company type number 271. These particular transformers have a flat characteristic which permits a considerable gain at 22 kc. Others of different make but of nearly similar characteristic are probably available.

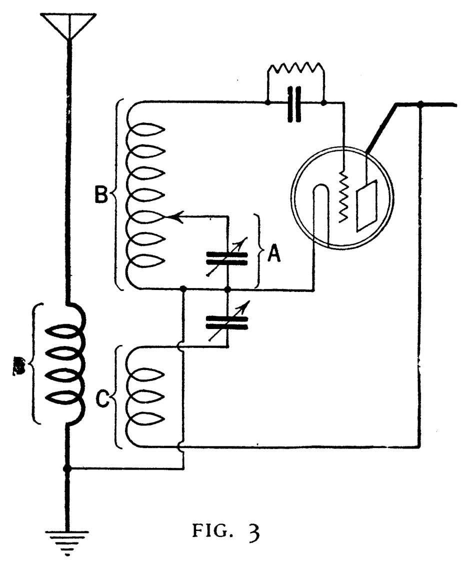


FIG. 3

No particular description of the intermediate circuit is required The circuit is a conventional one and the same precautions observed in the construction of any super-heterodyne should be followed. To prevent undue feed-back in the untuned circuits, space the tubes and transformers liberally and keep them in line.

THE FILTER CIRCUIT

BECAUSE of the low intermediate frequency, the filter transformer must be of a special design. By reference

COIL

WAVE BAND	A	B	C	D
40	4	13	3	6
50	6	28	4	6
80	8	28	4	8

FIG. 4

to Fig. 3, it will be also observed that three coils are used. The coil in the plate circuit of the tube preceding the detector and the coil in the grid circuit of the detector comprise the tuning or filter circuit. The coil in the plate circuit of the detector tube is the feed-back coil by means of which the beat note of 1000 cycles is created in the second detector tube.

The specifications of these coils are given in Fig. 5. In winding these coils no particular care need be used, random winding is perfectly satisfactory. Approximately the number of turns specified, however, should be wound, otherwise the frequency of the intermediate circuit will be changed. In Fig. 4, the spacing between coils is shown. No hard and fast rule can be given on the point, as the arrangement of the circuit placing of the coils, etc., will have some effect. Once adjusted, however, there is no need for further change. The coils shown make a rather small assembly. If the space occupied is no factor, honeycomb, duo-lateral, or other form wound coils of similar nature can be used. The coils should be arranged as in Fig. 6. The spacing can be somewhat greater than that specified for the home-made assembly.

The variable condenser shown across the grid coil is of 0.001-mfd. capacity. Because of the rather large space occupied by a 43-plate air condenser of this capacity, a variable mica condenser was chosen. The air condenser is probably better from a standpoint of efficiency. The condenser across the grid coil determines the frequency of the beat note which is heard in the telephone. Keep this frequency as low as possible since the lower the note, the more closely will the primary and secondary circuits be in tune.

If telephone signals are to be received, a switching arrangement should be provided to permit cutting the plate coil of the second detector in and out of the circuit. Radio telephone signals can be received when the second detector is oscillating, but reception is extremely difficult as the "zero beat" method must be used, and the slightest change in frequency at either the receiver or transmitter causes an audio beat.

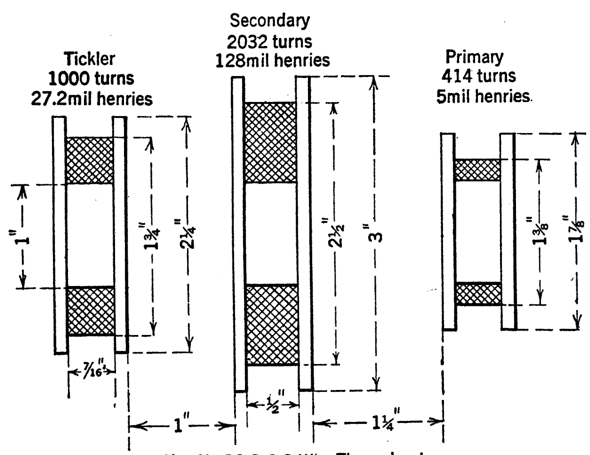
No particular instructions are required here. Any good audio transformer is satisfactory. If radio telephone signals are to be received as well as c.w., the transformer should be of good design. For c.w. reception only, a transformer having a high ratio between primary and secondary is best, since, although some distortion may be introduced, the amplification is higher and the distortion is of no importance.

Two fixed condensers are shown in the audio circuit. These condensers are required as a bypass for the 22-kc. frequency, which otherwise would feed back through the head telephones and the body to the input and cause trouble.

GENERAL COMMENTS ON CONSTRUCTION AND OPERATION

THE particular receiver to which the foregoing remarks apply was one with complete shielding of the intermediate, second detector, and audio circuits. The coils comprising the first detector circuit were not shielded but acted as loops for the reception of moderately distant stations.

The principal advantage in the shielding came in the elimination of long-wave interference. Subsequently, it was found that by regulation of the amount of regeneration in the untuned intermediate transformers, practically the same result could be obtained, and at no sacrifice in sensitivity. It is recommended that the set first be made unshielded and then the shielding applied if the long-wave c.w. interference is bad. In another model of this same receiver, constructed by Mr. C. R. Runyon, no shielding was used and results were entirely satisfactory.



Use No.32 D.S.C.Wire Throughout
Distances between coils must be variable to determine best setting

FIG. 5

It is difficult to form a definite opinion of the merits of this receiver over the simple regenerative set. There is absolutely no question of its increased sensitivity, but strange as it may seem, there is some question of its selectivity. The reason for this is the presence of two widely separated tuning points for each station as against the presence of two closely placed tuning points always found with the regenerative set. The selectivity of the super-heterodyne is better than the selectivity of the regenerative set for each point, but if it chances that another station is 44 kc. away from that being tuned, it will also be heard. If this is the only interfering station, it can be eliminated by tuning the oscillator to the other point.

In a section where interference is bad, the widely separated double tuning point unquestionably is a disadvantage, but on the other hand, the same condition also occurs to a certain extent with the regenerative set. Here the interference is measured by the sensitiveness of the ear, the wider the frequency band it is possible for one to hear, the greater the interference. As a matter of fact, the super-heterodyne can effect a separation between two stations impossible with a regenerative set, and yet be less effective than the regenerative set if it so happens that stations are in operation, 44 kc. removed.

While the arguments set forth above appear to place the super-heterodyne at a disadvantage compared to the regenerative set, as a matter of fact, the selectivity is about the same for all practical purposes and the sensitivity of the super-heterodyne superior. Signals which are just about audible on the regenerative set are unpleasantly loud with the super-heterodyne. In a good location for loop reception, the small coils of the first detector circuit are all that are required for ordinary reception over distances comparable with those possible with a regenerative set and a good antenna.

If a good antenna is used, the distance possibilities of the short-wave super-heterodyne are limited only by the static level. For the reception of signals from a certain station, or stations, where it may be possible to remove interference caused by double tuning by changing the transmitting frequency, the super-heterodyne receiver is most satisfactory.

In operation, the plate condenser is set for strong oscillation and all the tuning accomplished with the grid condenser. Here the action differs from the regenerative set with which it is necessary to adjust the plate condenser for each frequency. Because of this single control the manipulation of the receiver is simpler and the possibility of picking up stations increased.

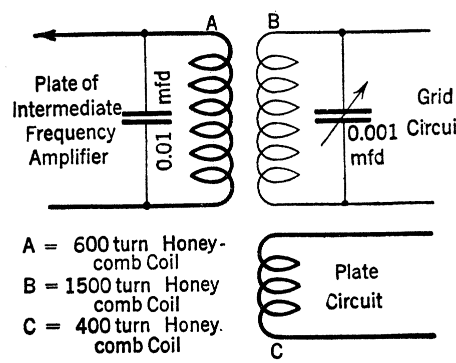


FIG. 6

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