

**LESSON
36 R**

THE SUPER- HETERODYNE RECEIVER



RADIO-TELEVISION TRAINING SCHOOL, INC.

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THE SUPERHETERODYNE RECEIVER

The modern superheterodyne receiver is the outgrowth of experiments performed by Major Edwin H. Armstrong who, while a student at Columbia University, discovered the famous feedback or regenerative circuit. Armstrong was the first to reveal that with a certain value of feedback coupling between the plate and grid circuits of a vacuum tube, he could produce a high frequency generator.

WHY THE SUPERHETERODYNE WAS DEVELOPED

The superheterodyne circuit was developed primarily to overcome the difficulty encountered in radio frequency amplification on account of self-oscillations. Due to the internal tube capacity, a regenerative or feedback action takes place between the plate and the grid; and unless proper precautions are taken, this regeneration will result in violent oscillations. The higher the frequency, that is, the shorter the wave length, the more prominent does this feedback action become; and at the frequencies at which radio broadcasting is now carried on, the effects are especially disturbing. Any method used to control these oscillations inherently involves a waste of energy, which results in diminishing the efficiency of the amplifying system.

In the superheterodyne circuit this problem is solved by raising the wave length of the signals to several thousand meters and then passing them through the radio frequency amplifier. At these higher wave lengths the feedback action within the tubes becomes negligible, and all tendency toward oscillation is removed. More complete amplification is thus secured, and on account of the greater operating stability, an increased number of amplifying stages can be employed. It is due to these conditions that the superheterodyne is so sensitive and can so easily pick up weak signals from distant stations.

THE SUPERHETERODYNE PRINCIPLE

The term superheterodyne is really a combination of the words super-audible heterodyne, that is, a heterodyne, of such a high frequency that it is above audibility, or cannot be heard. The word heterodyne, in turn, is also derived from two words - hetero meaning other or different, and dyne meaning force or power. Heterodyne thus means a "different force." Its specific meaning in radio refers to the use of a locally generated high frequency current that has a frequency slightly different from that of the oscillations coming in from the antenna, and to combining or superimposing these two so that a new current is produced that has a frequency equal to the difference between the frequencies of the two currents thus combined. This process of combining two currents of different frequencies is known as heterodyning, and the resulting current is often referred to as a "beat" current. If the apparatus is arranged so that this beat current has a comparatively low frequency, that is, a high wave length, it can be amplified more readily and more efficiently, with the result that the difficulties ordinarily met with in radio frequency amplification are eliminated.

The term "beat" is a musical expression which refers to the rise and fall in the intensity of a sound heard when two tones of nearly the same pitch are sounded together. If the two tones are exactly in tune (of the same pitch), no beat will be heard; but if the two differ slightly there will be a gradual swelling and waning in the sound. If the difference in pitch is made greater, the sound outbursts or variations in intensity become more rapid and a quick staccato beat will be heard. A further increase in the difference will cause the beats to be so rapid that they cannot be distinguished separately, but are heard as a rasping or grating noise. A still further increase in the difference will cause the harshness to disappear and the beat note will become a musical tone. At first this tone is of a very low pitch, but gradually rises, providing the frequencies of the two beating tones are high enough.

An excellent illustration of such a beat note is heard when a regenerative receiver is being tuned. If too much regeneration is cut in, the detector tube is thrown into oscillation and generates an oscillating signal of a frequency depending upon the relative amount of inductance and capacity in the grid and plate circuits. This locally generated signal then combines with that coming in from the antenna and produces a beat note that sounds like a whistle or howl in the phones and of a pitch depending upon the difference in frequency between the two signals. As the detector circuit is tuned by adjusting the tuning condenser, the frequency of the locally generated signal is varied, with the result that the frequency of the beat note is also changed. In this manner a varied sound can be produced ranging from a shrill high pitched whistle to a low rolling rumble.

In a superheterodyne the action is very similar. By means of a local oscillator a high frequency signal is generated. This signal is then superimposed upon that coming in from the antenna and a beat signal is produced. However, the apparatus is designed and arranged so that this resulting beat signal is of such a high frequency that it is above audibility. Frequencies ranging from 70,000 to 456,000 cycles per second are used for this beat signal. In a very popular superheterodyne circuit a beat frequency of 456,000 cycles per second is used. It is this beat frequency which is then sent through the successive intermediate amplifier stages for further amplification.

THE COMPLETE SUPERHETERODYNE CIRCUIT

A complete superheterodyne circuit can be divided into six individual parts, known respectively as the tuner, the oscillator, the modulator or first detector, the intermediate amplifier, the second detector, and the audio frequency amplifier. Each of these is a complete unit in itself and has its own individual functions

to perform. When these parts are suitably arranged and interconnected, the action of the complete circuit is as follows.

The various parts of a superheterodyne circuit are illustrated diagrammatically in Fig. 1. By means of the tuner the signals or waves of the desired frequency are selected and all other frequencies are excluded. The output of this tuner is delivered to the first detector or modulator. By means of the oscillator there is generated the local high frequency current. This oscillator is also provided with a tuning element so that the frequency of the generated oscillation can be adjusted to differ from the incoming oscillations by the necessary amount. The output of this oscillator is also delivered to the modulator.

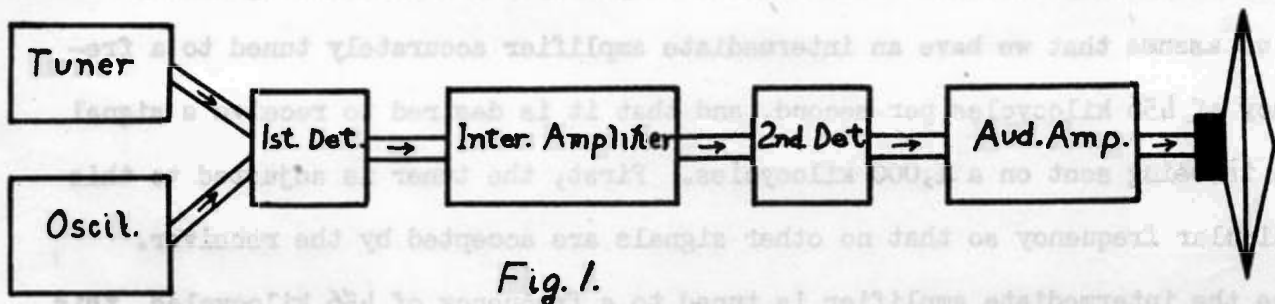


Fig. 1.

In the modulator the beat note is produced. On account of the rectifying action or detecting effect of this tube, it is often called the first detector. Sometimes it is also known as the frequency changer. The output of this modulator or first detector is a pulsating current of the superheterodyne frequency, or as it is more frequently called, the intermediate frequency. This current is modulated with the desired signal in the same manner as the original incoming high frequency current that was delivered by the tuner. The current is then sent through the intermediate amplifier, called so because it is designed to amplify the current while it is at the intermediate frequency. This is a highly efficient amplifying system accurately tuned to the intermediate frequency, and in it the

current can be stepped up to any desired degree. This high amplifying efficiency together with the fact that it can be used without any readjustments for all frequencies within the range of the tuner and oscillator, are the two chief reasons for the superiority of the superheterodyne over all other circuits.

After the signals have passed through the intermediate amplifier, they are sent through a second detector in which they are reduced or demodulated to an audio frequency capable of producing audible sounds in the loudspeaker.

The heterodyne action can be further explained in the following manner.

Let us assume that we have an intermediate amplifier accurately tuned to a frequency of 456 kilocycles per second, and that it is desired to receive a signal that is being sent on a 1,000 kilocycles. First, the tuner is adjusted to this particular frequency so that no other signals are accepted by the receiver.

Since the intermediate amplifier is tuned to a frequency of 456 kilocycles, this will also be the frequency of the heterodyne or intermediate frequency amplifier.

In other words, the oscillator must be tuned to such a frequency that the difference between it and 1,000 kilocycles will be equal to 456 kilocycles. The oscillator can thus be tuned to either 1,456 kilocycles or to 544 kilocycles, for in either case the difference between its frequency and that of the incoming waves is 456 kilocycles. This difference in frequency in any circuit is always equal to the frequency to which the intermediate amplifier is tuned. Since the oscillator can be set for two frequencies, one above and the other below the frequency of the incoming waves, local stations can be brought in on two different dial settings on many superheterodyne receivers.

It is good practice to have the oscillator above rather than below the incoming wave as this will prevent the oscillator from feeding into the intermediate amplifier and overloading it. There are only two major tuning circuits to

every superheterodyne - one for adjusting the tuner to the frequency of the desired signals, and the other for adjusting the oscillator so that the difference between its frequency and that of the incoming waves will be equal to the frequency for which the intermediate amplifier system has been designed. Various values have been chosen by the radio manufacturers for this different frequency, each claiming certain particular advantages for his choice.

TYPES OF SUPERHETERODYNES

A large number of different superheterodyne receivers have been developed and placed on the market; but if all are thoroughly analysed, it will be found that essentially they all follow a standard arrangement, and differ only in some one or two individual features that form the basis for special claims for every particular circuit.

Practically all superheterodynes were designed for loop operation, because it is claimed the use of an outdoor antenna results in considerably broader tuning and in more noisy operation. Some of the earlier ones employed a stage of tuned radio frequency amplification ahead of the modulator or first detector; but in the more recent circuits this has been dropped, for it was not considered really necessary and only complicated things. There has also been considerable argument and discussion as to the best frequency to use for the heterodyne or intermediate frequency current. Another subject of discussion has been the arrangement of the intermediate amplifier. The various types of receivers also differ in the construction of the oscillator coils, etc. A number of circuits employ regeneration on the first detector tube. This is accomplished in a number of ways, although the most common one is to use a loop that has a tap at its midpoint and then connect one side of the loop through a midget variable condenser

to the plate of the tube.

It will be impossible to consider every one of the numerous superheterodyne circuits here; but if one or two of the standard receivers are taken up in detail, it will be found that the same principles can generally be applied to all the rest. A good plan is to obtain blue prints and instruction books from the different manufacturers and to study these carefully.

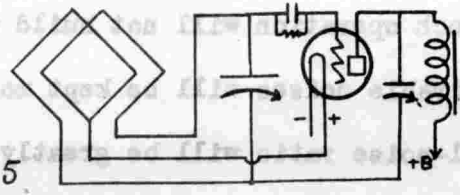
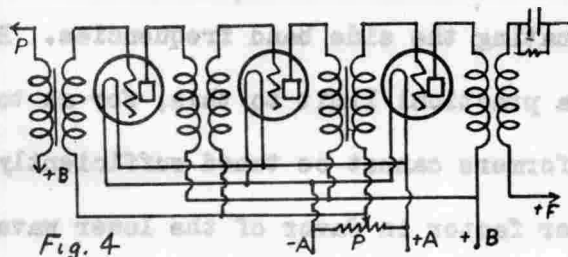
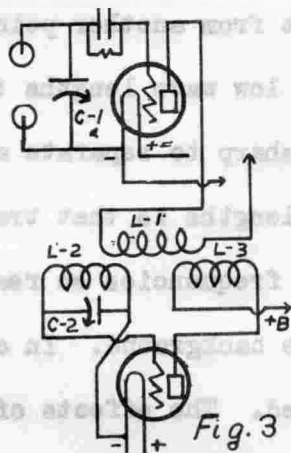
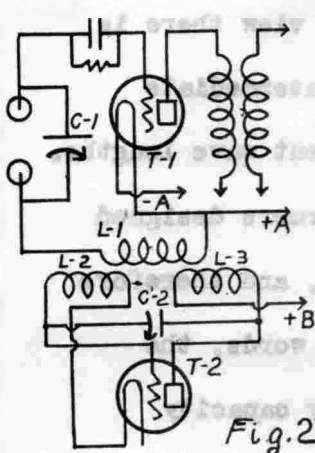
THE TUNER AND OSCILLATOR SYSTEM

For the purpose of explaining the detailed operation of a superheterodyne circuit, it is convenient to put the tuner, oscillator and modulator (first detector) into one group and consider them together.

With all modern superheterodynes the energy collector generally consists of a loop shunted by a variable condenser for tuning purposes. These are connected directly into the grid-filament circuit of the first detector tube. This circuit is illustrated in Fig. 2. Then there is the oscillator by means of which the local energy is generated. This oscillator consists of the tube T-2 and the grid and plate coils L-2 and L-3, both tuned by the variable condenser C-2. Coupled to these two coils is the pickup coil L-1 which is connected into the grid circuit of the detector tube T-1. It is through this coil that the energy of the oscillator is fed into the tube T-1.

In this modulator tube the two currents are combined, the resulting output being the long wave or intermediate frequency current that is then sent through the intermediate amplifier. The actual value of this intermediate frequency is predetermined by the design of the transformer system, and the oscillator must therefore be built so that its output when combined with the incoming waves will produce a current of this predetermined frequency.

In some circuits the pickup coil L-1 is placed in the plate circuit of the detector tube instead of the grid circuit. This is illustrated in Fig. 3, which is the arrangement used in a recently developed commercial superheterodyne circuit. There also is some difference of opinion regarding the use of a grid leak and condenser or a C-battery with this first detector. Advantages are claimed for each, and there are many successful circuits on the market making use of one or the other. If a grid leak and condenser are used, it is very important that the leak be of the correct value. However, a little experimental work will readily determine which gives the best results.



THE INTERMEDIATE AMPLIFIER

The intermediate amplifier is really the heart of the superheterodyne, for upon its efficiency depends the success of the entire circuit performance. The function of this amplifier is to receive the modulated intermediate frequency current and amplify it to whatever extent it is necessary or desired. It is the power unit of the entire system, for it is here that the energy is developed and the signal built up preparatory to being rectified in the second detector tube. The amplifier must perform its duty at the greatest possible efficiency per stage, and it must accomplish this without causing any distortion in the

passing wave forms. No false harmonics must be introduced, and no desirable ones must be eliminated. In other words, the side band frequencies of the modulated current component must all pass through the transformer and undergo nearly uniform amplification.

The wave length at which this intermediate amplifier is designed to operate, is an important factor to consider. For example, it can be shown mathematically that at the lower wave length there is less danger of distortion caused by eliminating the side band frequencies. But from another point of view there is also a practical limit to this, for at too low wave lengths the intermediate transformers cannot be tuned sufficiently sharp to separate adjacent wave lengths. Another factor in favor of the lower wave lengths is that transformers designed for such operation will not build up audio frequencies so readily, and therefore undesirable noises will be kept more in the background. In other words, the signal-noise ratio will be greatly increased. The effects of body capacity caused by placing the hands on the tuning dials are also less prominent at the lower wave lengths.

But even more important than the preceding advantages is the fact that at the lower wave lengths the two points at which the same station can be tuned in on the oscillator dial can be separated so far that when a low wave station is tuned in, it will not be heard the second time until the high wave lengths have been passed. That is, the oscillator can be designed so as to cover merely the sum or the difference of the two component frequencies that are being heterodyned, with the result that the stations are heard on only one setting of the oscillator dial.

From these considerations it can readily be seen that the lower frequencies are the more desirable for the intermediate amplifiers. Intermediate frequency amplifiers operate on frequencies between 70 and 456 kilocycles in standard broad-

cast band radio receivers. Communication and television as well as frequency modulation types of superheterodyne radio receivers employ intermediate amplifier frequencies of higher values.

In order to secure maximum efficiency from the intermediate amplifier, it is desirable to confine its amplifying action to the rather narrow band of wavelengths for which the circuit is designed. This is accomplished by inserting at some point in the amplifier system a sharply tuned transformer which will permit only that frequency to pass for which the transformers are designed.

This tuned transformer is generally known as the filter, and can be connected either ahead of or after the intermediate transformers. In one case it would be an input filter and in the other an output filter. The circuit will work well either way, but general practice has been to use it as an input filter. The advantage claimed is that the signal is weak at the beginning and can be filtered and sharpened much more easily by doing this necessary tuning before it is sent through several stages of amplification than afterward. After the signal has been amplified, the volume is so great that the tuned filter is not so effective and will let some undesired frequencies pass on.

Another arrangement that has been found very good is to use two tuned filter transformers arranged alternately with the untuned transformers. If well designed filter transformers are used, this practice insures excellent selectivity, for whatever undesired frequencies escape through the first filter are caught by the second. The general circuit arrangement of an intermediate frequency amplifier consisting of two tuned and two untuned transformers, is illustrated in Fig. 4. The untuned transformers are those illustrated with an iron core, while the tuned transformers have an air core. It is not customary to show the filter tuning condensers in a schematic diagram of this kind as it generally forms an integral part of the transformer.

THE SECOND DETECTOR

In the second detector the output of the intermediate frequency amplifier is demodulated, that is the signals are reduced to an audio frequency so that they are capable of producing audible sounds. Both methods are used with this second detector, grid rectification and plate rectification. It is frequently argued that the grid bias method (plate rectification) is the more desirable because with its use the detector tube is less likely to be overloaded and any possibilities of distortion are eliminated. However, both methods are found in use, and outside of the argument advanced previously it is difficult to argue in preference of either one.

THE AUDIO FREQUENCY AMPLIFIER

The audio frequency amplifier serves to amplify the output of the second detector so that a loud speaker can be operated effectively. Of course, only the best audio transformers should be employed, for it would be poor policy to invest in expensive tuning and other equipment and then skimp on the audio transformers. The quality of tonal output depends chiefly upon the performance of the audio transformers, and therefore only units with a large iron core and a high impedance primary should be used.

Besides good transformers, it is also advisable to employ a power tube in the second or output stage. Good audio transformers and a large capacity power tube operated from a well built power supply, will produce the finest reproduction.

A REGENERATIVE FIRST DETECTOR

Many superheterodyne receivers employ regeneration with the first detector in order to increase both the sensitivity and selectivity of the tuning system. The most common method of introducing this regeneration is by means of a 3-tap loop arrangement such as is illustrated in Fig. 5. A center tapped loop is used

with the tuning condenser connected across the entire loop. One end of the loop is connected directly to the grid of the detector tube, the center tap serves as the filament or grid return, and the other end of the loop is connected through a midget variable condenser to the plate of the tube. The R.F. oscillations are fed back through this midget condenser into one section of the loop where they strengthen or reenforce the incoming signals so that stronger potential variations are impressed on the grid. The action of a three-tap loop was explained in detail in a previous lesson.

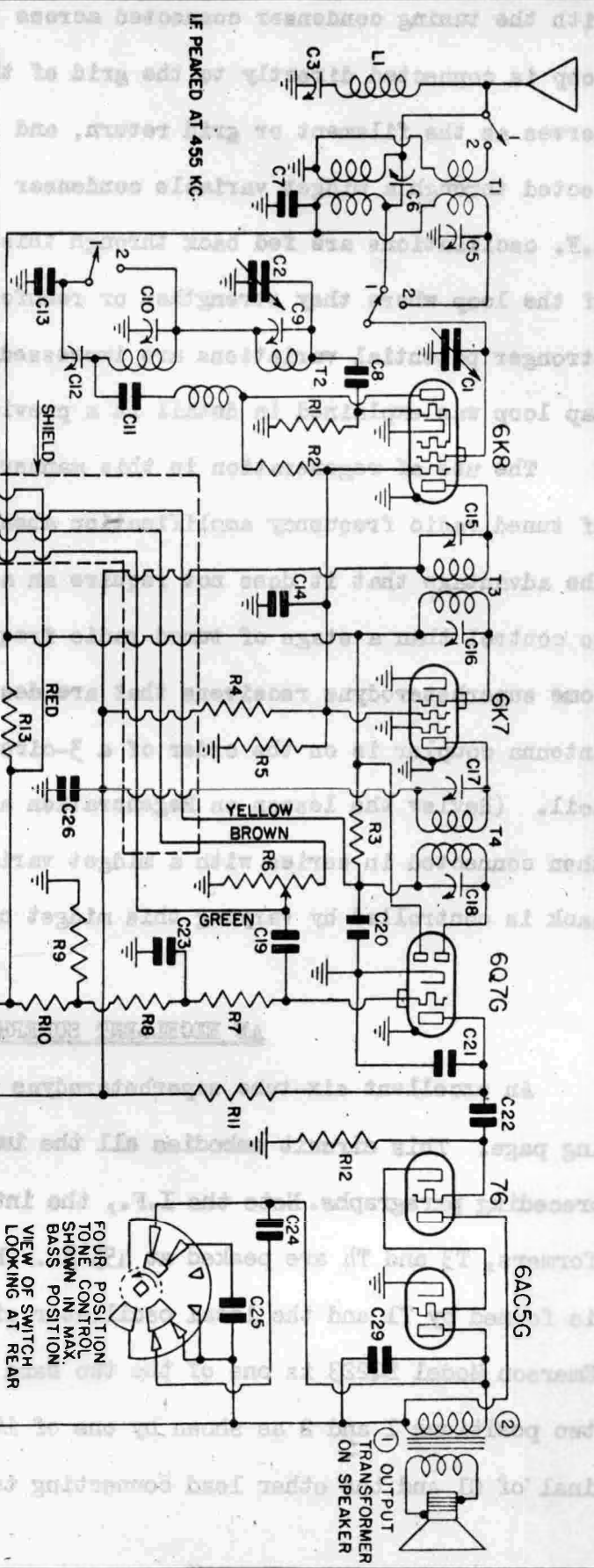
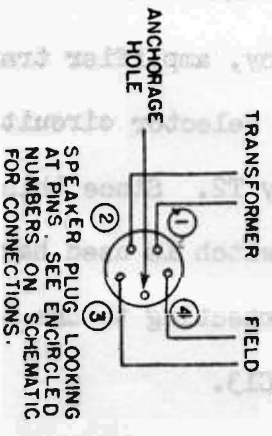
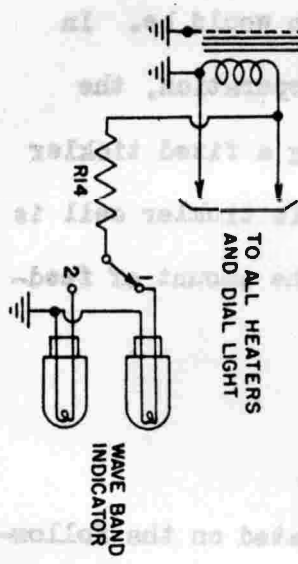
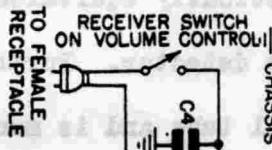
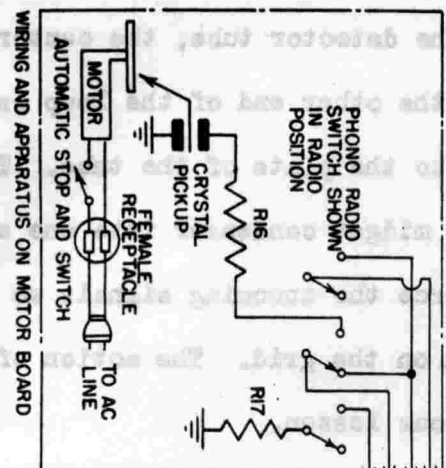
The use of regeneration in this manner is practically equivalent to a stage of tuned radio frequency amplification ahead of the detector. Further, it has the advantage that it does not require an additional tube and is much easier to control than a stage of tuned radio frequency amplification would be. In some superheterodyne receivers that are designed for antenna operation, the antenna coupler is on the order of a 3-circuit tuner employing a fixed tickler coil. (Review the lesson on Regeneration at this point.) This tickler coil is then connected in series with a midget variable condenser. The amount of feedback is controlled by varying this midget condenser.

AN EXCELLENT SUPERHETERODYNE RECEIVER

An excellent six-tube superheterodyne circuit is illustrated on the following page. This circuit embodies all the important principles set forth in the preceding paragraphs. Note the I.F., the intermediate frequency, amplifier transformers, T3 and T4 are peaked at 455 Kc. The input frequency selector circuit is formed by T1 and the local oscillator circuit is formed by T2. Since this Emerson Model BQ223 is one of the two band type a selector switch is used having two positions 1 and 2 as shown by one of its common leads connecting to one terminal of C1 and the other lead connecting to one terminal of C13.

SCHEMATIC DIAGRAM

WAVE BAND SWITCH SHOWN IN BROADCAST POSITION
 POSITION NO.1 BROADCAST
 POSITION NO.2 SHORT WAVE



MODEL BQ-223