June 16, 1942. E. W. HEROLD 2,286,412

FREQUENCY MODULATION RECEIVER TUNING INDICATOR

Filed March 25, 1941 2 Sheets-Sheet 1

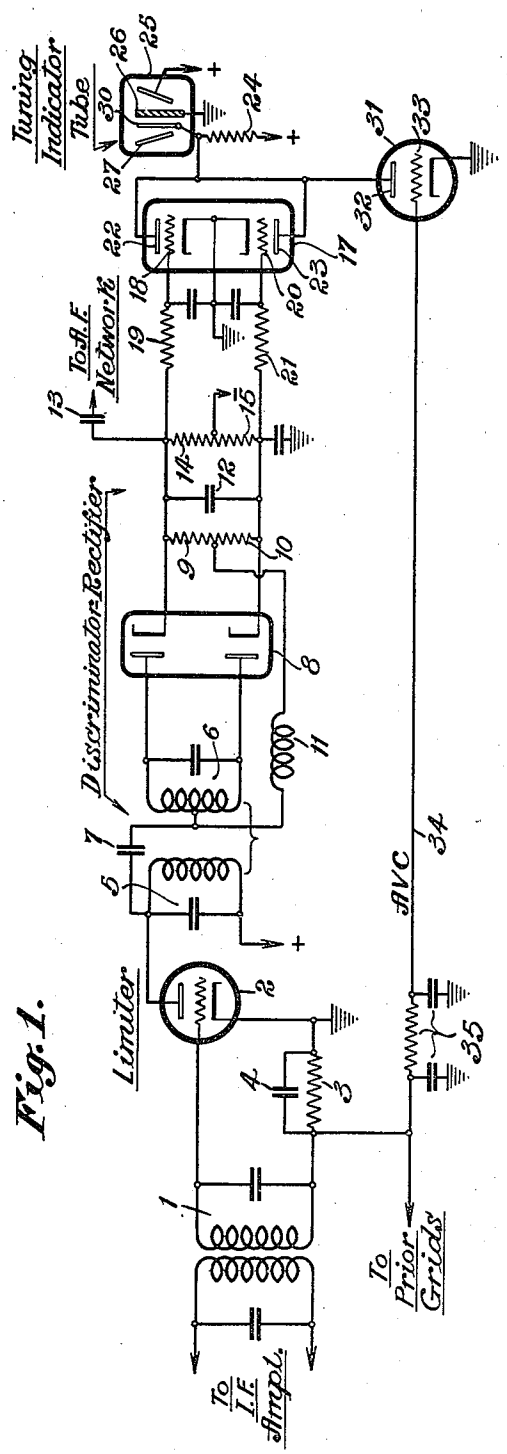


Fig. 1.

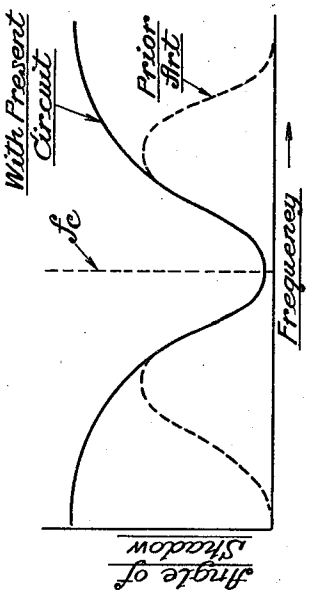


Fig. 2.

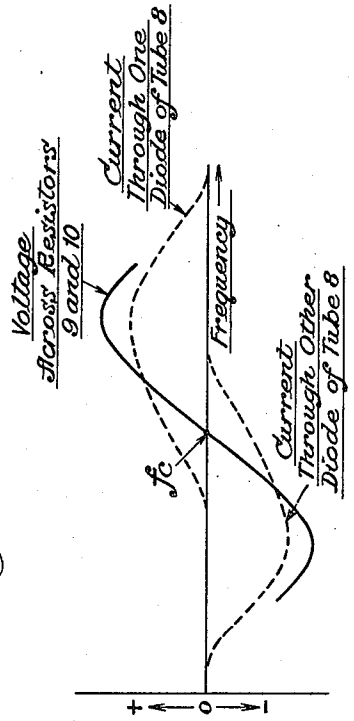


Fig. 1a.

INVENTOR
Edward W. Herold
BY H. S. Grover
ATTORNEY

June 16, 1942. E. W. HEROLD 2,286,412

FREQUENCY MODULATION RECEIVER TUNING INDICATOR

Filed March 25, 1941 2 Sheets-Sheet 2

Fig. 3.

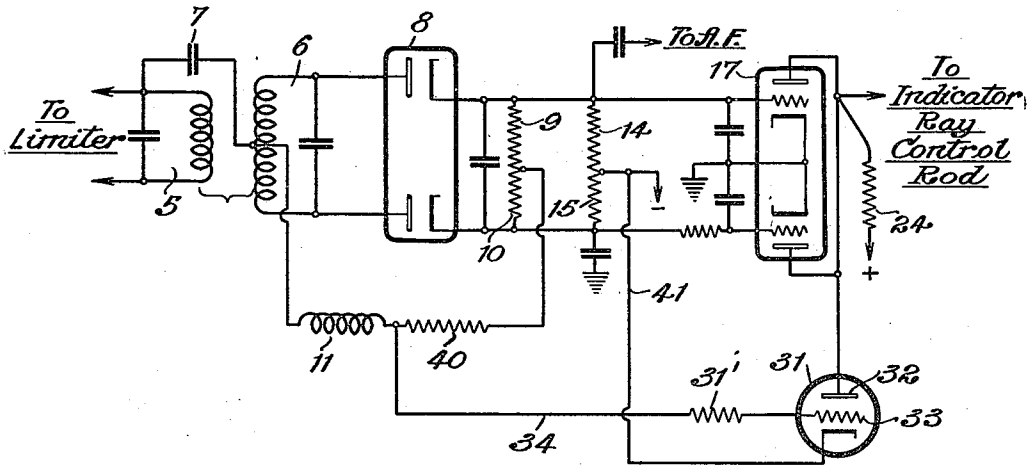


Fig. 4.

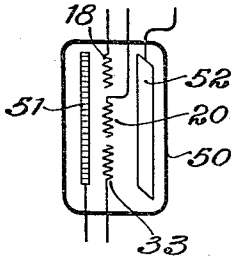
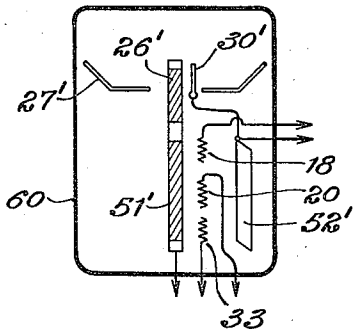


Fig. 5.



INVENTOR
Edward W. Herold
BY H. S. Grover
ATTORNEY

Patented June 16, 1942 2,286,412

UNITED STATES PATENT OFFICE

2,286,412

FREQUENCY MODULATION RECEIVER TUNING INDICATOR

Edward W. Herold, Verona, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application March 25, 1941, Serial No. 385,083

12 Claims. (Cl. 250—40)

My present invention relates to tuning indicator circuits for receivers of frequency modulated carrier waves, and more particularly to a method of, and means for, accurately tuning to the center frequency of a desired frequency modulated carrier wave in a receiver designed for such reception.

It is well known in the art of receiving frequency modulated (referred to as FM) carrier waves, to tune accurately to the center frequency of such waves in order to improve the signal to noise ratio and reduce distortion. In the commonly used FM receivers, the FM wave is converted to a wave which is both amplitude and frequency modulated, the converted wave then being rectified. In other words, the frequency modulations on the transmitted carrier wave, which appear as frequency deviations of the center frequency, are converted to an audio frequency signal corresponding to the original modulating signal, the audio frequency signal being amplified and converted to sound by a loud speaker. As is well known, a discriminator network is used which usually embodies a pair of cascaded reactively coupled resonant circuits each tuned to the center frequency of the applied frequency modulated waves. The high potential side of the first tuned circuit is capacity coupled to the midpoint of the second tuned circuit. Opposed rectifiers are used in such a manner that when the applied FM waves have a center frequency equal to the center frequency of the cascaded resonant circuits, then across the common load of the opposed rectifiers zero rectified voltage is produced. When the center frequency of the applied waves departs from the center frequency of the discriminator circuits, then direct current voltage is produced of a polarity and magnitude dependent upon the direction and extent of the frequency deviation from the center frequency of the discriminator circuits.

In the past there has been utilized a visual tuning indicator for enabling the set operator to tune the receiver so that the center frequency of the frequency modulated waves would be exactly equal to the center frequency of the tuned circuits of the discriminator network. The point of accurate tuning occurs at the center of the discriminator characteristic, and, as is well known, the mean carrier frequency of the applied waves must be held at this point for best signal to noise ratio. However, when using an indicator of the well known electronic shadow type it has been found that a false reading will be secured when signals are not present, or when the signal is far off tune. Since the shadow type of indicator tube depends upon a minimum angle of shadow to indicate accurate tuning, the production of such minimum angle, when weak or no FM waves are received, is confusing and misleading to the person tuning the receiver.

Accordingly, it may be stated that it is one of the main objects of this invention to eliminate the aforesaid defect, and to have the shadow angle attain its minimum value solely when the center frequency of the received FM waves is exactly equal to the center frequency of the discriminator tuned circuits, this being the condition for accurate tuning.

Another important object of this invention may be stated to reside in the provision of a visual current indicator of the electronic shadow type which has a predetermined shadow angle to indicate accuracy tuning when used with an FM receiver, and means being employed, which is responsive to the magnitude of the carrier amplitude, for exercising a control over the indicator tube in a sense such that the said desired shadow angle is secured solely for accurate tuning of the receiver.

Further objects of my invention are to improve tuning indicator means which are applicable equally to receivers of both frequency and amplitude modulated carrier waves, and to provide such tuning indicator means in a reliable and economical manner.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawings in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:

Fig. 1 shows a receiving system embodying the invention,

Fig. 1*a* graphically shows the discriminator characteristics,

Fig. 2 illustrates graphically the advantage of the present invention over the prior art,

Fig. 3 shows a modification of the invention,

Fig. 4 shows a tube construction that may be used in conjunction with the indicator circuit,

Fig. 5 shows a modified tube construction.

Referring to the accompanying drawings, wherein like reference characters in the different figures indicate similar circuit elements, the cir-

cuit arrangement in Fig. 1 represents that portion of an FM receiver of the superheterodyne type following the last intermediate frequency (I. F.) amplifier. It is not believed necessary to show the various circuits up to the limiter stage, since they are well known to those skilled in the art. In general, any desired type of signal collector may be used, and particularly one, such as a dipole, which is able to collect desired FM waves in the 42 to 50 megacycle (mc.) band. Following amplification at ultra-high frequency, the desired FM wave is converted in any desired type of converter network to an FM wave whose center frequency is at an I. F. value. For example, such I. F. value may be 4.2 mc., or, in general, any value chosen from a range of 2 to 5 mc.

Subsequent to amplification at I. F., the FM waves are applied to the tuned input circuit 1 of the limiter tube 2. The limiter tube may be constructed in the manner of a saturated amplifier, and usually is provided with a resistor 3 in its grid circuit shunted by an I. F. by-pass condenser 4. The network 3—4 is chosen, in addition to the constants of the plate circuit, so that the limiter functions to produce in its resonant output circuit 5 waves which have substantially no amplitude variation. In other words, the limiter stage has an input-output characteristic which rises up to a predetermined input amplitude, and then is substantially flat thereafter.

The output circuit 5 is tuned to the center frequency f_c of the FM waves, and, of course, f_c will be of the I. F. value, it being pointed out that the input circuit 1 is also tuned to the value f_c. The circuit 5 is connected to a mid-tap on the coil of the following resonant circuit 6 through a coupling capacity 7. The circuits 5 and 6 are also magnetically coupled. It is not believed necessary to describe in detail the manner in which the discriminator network 5—6 functions, since that has been disclosed and claimed by S. W. Seeley in U. S. Patent 2,121,103 granted June 21, 1938. It is sufficient for the purpose of this application to point out that the discriminator has a characteristic as depicted by the full line in Fig. 1*a*. The characteristic is an inclined, S-shaped curve which is a result of the currents flowing in the double diode rectifier tube 8. The latter may be of the 6H6 type. This tube has a pair of diodes disposed therein, and the anodes of the two diodes are connected to opposite sides of the resonant circuit 6. The cathodes of the diodes are connected to each other through a pair of series related load resistors 9 and 10, the junction of the resistors being connected to the midpoint on the coil of resonant circuit 6 through a radio frequency choke coil 11. The condenser 12 is shunted across resistive load 9—10 to by-pass I. F. currents, and audio voltage developed across resistive path 9—10 is transmitted through condenser 13 to the audio frequency amplifier network.

As shown by the characteristic of Fig. 1*a* when the applied FM waves have the center frequency located at f_c, which is the predetermined frequency of the discriminator circuits 5 and 6, then the rectified voltage produced across 9—10 will be an accurate reproduction of the modulation signal on the carrier wave. This occurs because at one side of the resonance frequency f_c one of the diodes is impressed with a higher carrier voltage than the other diode. At the other side of resonance the latter diode has a higher voltage than the first diode.

This behavior is due to the changed phase difference between the primary and secondary voltages existing across circuits 5 and 6 as the carrier frequency is deviated with respect to f_c. At exact resonance with f_c each diode has equal carrier voltage applied thereto. As shown by the dotted characteristic curves in Fig. 1*a*, first one diode then the other receives maximum voltage as the frequency of the carrier is varied relative to f_c. At the exact f_c value the two diode currents are equal, and the voltages produced across 9 and 10 exactly cancel. The periodic variations of the incoming frequency, as in frequency modulation reception, gives rise to a periodically varying output across 9—10 which corresponds to the original modulation. The modulation voltage developed across path 9—10 is, of course, the rectified voltage corresponding to the instantaneous deviations from f_c.

However, the direct current voltage produced across 9—10 is utilized for visual tuning indication. The direct current voltage represents the average, or mean, departure of the center frequency of the applied FM waves from the frequency of the discriminator circuits 5 and 6. Such a departure produces a direct current voltage across 9 and 10 whose polarity and magnitude depends upon the direction and extent respectively of departure of the center frequency from f_c.

In the past the direct current voltage so produced has been utilized for tuning indication by connecting in shunt with resistors 9 and 10 a second pair of resistors 14 and 15 whose junction is connected to a source of negative bias voltage. An audio by-pass condenser is connected between the lower end of resistor 15 and ground. A tube housing a pair of triodes acts as a direct current voltage amplifier of the direct current voltages developed across resistors 14 and 15. The cathodes of the triodes are connected to ground. The grid 18 of one triode is connected through filter resistor 19 to the upper end of resistor 14. The grid 20 is connected through filter resistor 21 to the lower end of resistor 15. Each of the grids of the pair of triodes is connected to ground through capacitance to by-pass audio frequency voltage components.

The plates 22 and 23 of tube 17 are connected in parallel to the positive terminal of a source of direct current through a resistor 24. The electronic shadow indicator tube is designated by numeral 25, and comprises an electron emission element 26 which is established at ground potential. The target, whose inner face is coated with fluorescent material, is designated by numeral 27, and it is connected to the aforementioned positive terminal of the direct current source which energizes the plates of tube 17. The shadow control rod is denoted by numeral 30, and has a direct current voltage connection to the plate end of resistor 24.

As is well known to those skilled in the art, the rod 30 deflects electrons from the adjacent portion of the fluorescent target to an extent dependent upon the potential difference between rod 30 and target 27. That is, if the rod 30 becomes less positive than the target 27 it deflects electrons, and, therefore, produces a shadow or dark area on the target portion in front of it. The shadow angle becomes wider depending upon the extent to which rod 30 becomes less positive. When the plate current of both of the triode sections of tube 17 are cut off by a sufficiently negative bias applied to each of grids 18 and 20,

the shadow produced on target 27 by rod 30 is of minimum angle. In that case the voltage drop across resistor 24 is substantially zero.

In normal operation grids 18 and 20 receive an initial bias from the aforementioned negative bias source through resistors 14 and 15 respectively. In other words, each of grids 18 and 20 is normally biased so as to prevent the flow of plate current through resistor 24. When the receiver is now tuned so that the applied FM waves have a center frequency exactly equal to f_c, each of the diodes of tube 8 have equal average currents so that the total direct current voltage drop across 9 and 10 is zero. The grids 18 and 20 are, therefore, at the same potential, and minimum shadow angle on the indicator is produced.

If, now, the receiver tuning is changed so that the mean carrier frequency of the applied FM waves is no longer of the value f_c, the average current of one diode of tube 8 exceeds that of the other, and a net direct current voltage exists across resistors 9 and 10 in series. This net voltage results in the grid of one triode section of tube 17 receiving a more negative bias, and the grid of the other triode section the less negative bias. The latter triode will then draw plate current, and the shadow angle on the target will become greater. On either side of the correct tuning position (f_c) the shadow angle will increase. It will, now, be noted that when no signal is present, or when the signal is very far off tune, the average current of each diode of tube 8 is very small and substantially equal to that of the other diode.

The shadow angle is, therefore, a minimum for this condition giving the same indication as for a correctly-tuned signal. This prior operation of the tuning indicator is more clearly brought out by means of the characteristic curve shown in Fig. 2. In this figure there is plotted graphically the angle of the shadow on the target of indicator tube 25 as a function of frequency to which the receiver is tuned. The dotted line curve labeled "Prior art" shows that as the actual carrier frequency is approached from the left, the angle of the shadow increases from zero, passes through a maximum, then decreases through zero, and then increases once more and passes through a positive maximum and finally decreases to zero. The point of accurate tuning is marked by the trough located at the center. It is seen that when no signal is present, that is, for example, when the receiver is very far off-tune, the shadow is of a minimum angle. This action is undesirable because it is confusing to the person who is tuning the receiver. The defect, or false reading, is caused by the fact that the grids of the two triode sections of tube 17 receive a fixed bias independent of the incoming signal.

According to my invention this false indication is eliminated by providing a third electron discharge tube, illustrated in Fig. 1 as a triode 31. The plate 32 is connected to the ray control electrode 30 along with the plates 22 and 23 of the other triode sections. The grid 33 of tube 31 is connected to a source of negative direct current voltage which is derived from, or controlled by, the incoming signal itself. For example, the grid 33 is shown connected through a lead 34 which may also be the automatic volume control (AVC) lead. The limiter resistor 3 develops direct current voltage, dependent upon carrier amplitude, which is sometimes used in FM receivers as a source of AVC bias to control the signal grids of prior ultra-high frequency, and I. F. amplifiers. The network 35 filters out pulsating voltage components from the AVC bias, and the filtered voltage is applied over lead 34 to grid 33. Lead 34 is connected to the grid end of resistor 3.

The operation of the indicator circuits differs now from prior art operation in the manner shown by the full line curve in Fig. 2 labeled "With present circuit.". When no signal is present the tube 31 has no negative bias on its grid 33, and its plate current, therefore, flows through resistor 24 thereby keeping the shadow angle on either side of f_c fairly wide. Since the cathode of tube 31 is grounded, the plate current of tube 31 necessarily flows through resistor 24 and develops a voltage which establishes control rod 30 at a negative potential with respect to target 27. However, when the receiver is tuned close to the desired value f_c, there is applied to grid 33 sufficient negative bias, from the limiter or AVC circuit, to cut off the plate current of tube 31. From this point the tuning is correctly done as before, but the false reading of the shadow angle is completely avoided, this being clearly shown by the full line curve in Fig. 2. Such a characteristic is substantially the same as is obtained in the usual amplitude modulated carrier wave receiver using a variable shadow indicator tube of the type shown in Fig. 1.

It will be noted that in receivers intended for the reception of either amplitude or frequency modulation, my invention continues to be operative without change in connection. In such receivers it is necessary, of course, to obtain the audio frequency signal from the carrier at some other point in the system when receiving amplitude modulated carrier waves. In other words, the FM discriminator cannot be used to receive amplitude modulated carrier waves. Alternatively, however, a switch in the connections of the discriminator may be made correctly to receive either type of signal.

It should be clear that the bias for the grid of tube 33 may be obtained by a variety of means which are apparent to those skilled in the art. The limiter grid current provides an automatic grid bias which is roughly proportional to the signal carrier, and, hence, provides a ready and convenient means to prevent the false minimizing of the shadow angle when no signals are received.

In Fig. 3 is shown a modified arrangement which shows the possibility of obtaining the control bias for tube 31 from the discriminator itself. In this circuit, which is exactly similar to that shown in Fig. 1 except for the details to be hereinafter explained, the resistor 40 has developed across it a direct current voltage which depends on the sum of the two diode currents of tube 8. The resistor 40 is arranged in series with the choke coil 11, and is in the common path of both diodes. The voltage developed across resistor 40 is, therefore, dependent upon the signal carrier amplitude, but does not vary with tuning when the latter is close to the correct adjustment. The grid 33 is connected through filter resistor 31' to the junction of choke coil 11 and resistor 40. If the cathode of tube 31 were connected to ground and the lead 41 were eliminated, then the tube 31 would have to be a tube of lower amplification factor than the triode sections of tube 17.

This can be avoided by connecting the cathode of tube 31 through lead 41 to the junction of re-

sistors 14 and 15. It will now be seen that in the case of the circuit of Fig. 3, and in the absence of received signals, the plate current of tube 31 flows through resistor 24 and provides the increased extremities of the full line curve of Fig. 2. As signals are received the carrier amplitude results in an increased voltage being produced across resistor 40. This ultimately cuts off the plate current of tube 31, and then the indicator tube is responsive solely to the direct current voltage developed across resistors 9 and 10.

Since there are tubes commercially available which include a triode and a tuning indicator section of the type herein considered in a single envelope, it will be apparent that the most economical application of the circuits of Figs. 1 and 2 will make use of such a tube. In this case the triode 31 will be in the same envelope as the tuning indicator tube. The cathode of tube 31 may be a portion of the cathode 26 of the ray-control tube.

From the standpoint of economy, it may be desirable to combine the triode sections of tube 17 and the triode section of tube 31 in one tube envelope using a common cathode and a common plate as shown in Fig. 4. In this latter figure the tube 50 has a cathode 51 which would provide the electrons flowing to the plate 52. In axial alignment between the common cathode 51 and common plate 52 would be arranged the control grid 18, the control grid 20 and the control grid 33. It will be seen that this tube can be used in the circuit of Fig. 1, because the three plates of tube 17 and tube 31 are connected to a common point on resistor 24, and the three cathodes are all at ground potential.

In Fig. 5 there is shown another tube construction which may be used. Commercially available tubes can be had which include a single triode and a variable shadow indicator section. Such a tube may be made to include all three control grids necessary to my invention. Hence, the tube 60 of Fig. 5 may have a cathode section 51' emitting electrons to a common plate 52', the control grids 18, 20 and 33 being arranged in axial alignment between the cathode 51 and plate 52'. The cathode section 51' may have a second emission section 26' corresponding to the cathode 26 of Fig. 1, a target section 27' and a ray control rod 30'. It is believed that it will be obvious to those skilled in the art how the various electrodes of Fig. 5 are to be connected to the different portions of the circuit of Fig. 1 or Fig. 3.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims. The expression "timing modulated carrier wave" used in the claims is to be understood as generically covering frequency, or phase, modulated carrier waves.

What I claim is:

1. In combination with a timing modulated carrier wave detector having an input circuit upon which are impressed timing modulated carrier waves, said detector having an output circuit across which is developed direct current voltage whose polarity and magnitude depend upon frequency departure of the center frequency of the applied modulated waves from an assigned center frequency value of said detector input circuit, an electronic shadow indicator tube provided with a shadow control electrode, means for varying the potential of said shadow control electrode in response to said detector direct current voltage output whereby the shadow angle of the indicator tube indicates the said frequency departure, means for controlling the potential of said shadow control electrode in the absence of modulated waves of a predetermined amplitude at said input circuit for maintaining the shadow of said indicator tube at maximum width, and additional means responsive to carrier amplitude increase for rendering said last-named means ineffective.

2. In combination with a detector having an input circuit upon which are impressed timing modulated carrier waves, said detector having an output circuit across which is developed direct current voltage whose polarity and magnitude depend upon the frequency departure of the center frequency of the applied modulated waves from an assigned center frequency value of said detector input circuit, an electronic shadow indicator tube provided with a ray control electrode, means for varying the potential of said control electrode in response to said detector direct current voltage output whereby the shadow angle of the indicator tube indicates the said frequency departure, means for controlling the potential of said control electrode in the absence of modulated waves at said input circuit for maintaining the shadow of said indicator tube at maximum width, additional means, responsive to carrier amplitude increase, for rendering said last named means ineffective, said last named means consisting of an electron discharge tube, means for deriving a second direct current voltage from received modulated waves, and means for applying said second direct current voltage to said last tube in a sense to prevent plate current flow thereof.

3. In a frequency modulation receiver provided with a detection network of the type comprising a pair of rectifiers having a common input circuit tuned to a predetermined center frequency, an output circuit across which is developed a direct current voltage whose polarity and magnitude are a function of the frequency departure of applied modulated waves from said center frequency, a direct current voltage amplifier for amplifying said direct current voltage, an indicator tube provided with an emission electrode, a fluorescent target, and an electron ray control electrode, means for applying the direct current voltage output of said amplifier to said ray control electrode thereby to control the width of angle of the shadow produced on the target, and means responsive to a decrease of modulated carrier amplitude below a desired value for maintaining the shadow on said target at a relatively wide angle.

4. In a receiver for frequency-modulated waves including a selective amplifier and a balanced detector whose rectified output is substantially proportional, over the normal operating range, to the departure in frequency of a selectively amplified incoming signal from its mean value, a tuning indicator means of the electronic, shadow-indicating type which operates from the output of said balanced detector and which indicates a correct adjustment of tuning of said receiver by a definite shape of shadow, and carrier-operated means connected to said indicator means in such a manner that said definite shape of shadow appears only when a signal is present in the output of the selective amplifier.

5. In a receiver for frequency-modulated waves including a selective amplifier and a balanced detector whose rectified output is substantially proportional, over the normal operating range, to the departure in frequency of a selectively amplified incoming signal from its mean value, a tuning indicator means of the electronic, shadow-indicating type which operates from the output of said balanced detector and which indicates a correct adjustment of tuning of said receiver by a definite shape of shadow, and carrier-operated means connected to said indicator means to control the latter whereby said definite shape of shadow appears only when a signal is present in the output of the selective amplifier, said carrier-operated means consisting of an electron discharge tube whose plate current flow is interrupted by a direct voltage derived from the magnitude of said signal independently of its frequency.

6. In a receiver for frequency-modulated waves including a selective amplifier and a balanced detector whose rectified output is substantially proportional, over the normal operating range, to the departure in frequency of a selectively amplified incoming signal from its mean value, a tuning indicator means of the electronic, shadow-indicating type which operates from the output of said balanced detector and which indicates a correct adjustment of tuning of said receiver by a definite shape of shadow, and additional means for operating said tuning indicator by a direct voltage derived from the amplitude of said signal independently of its frequency variations.

7. In combination with a frequency modulated carrier wave detector having an input circuit upon which are impressed frequency modulated carrier waves, said detector having an output circuit across which is developed direct current voltage whose polarity and magnitude depend upon the frequency departure of the center frequency of the applied modulated waves from an assigned center frequency value of said detector input circuit, an electronic shadow indicator tube provided with a shadow control electrode, means for varying the potential of said shadow control electrode in response to said detector direct current voltage output whereby the shadow angle of the indicator tube indicates the said frequency departure, tube means for controlling the potential of said shadow control electrode in the absence of frequency modulated waves at said input circuit for maintaining the shadow of said indicator tube at maximum width, and additional means, responsive to carrier amplitude increase, for rendering said tube means ineffective.

8. In a frequency modulation receiver provided with a detection network of the type comprising a pair of rectifiers having a common input circuit resonated to a predetermined center frequency, an output circuit across which is developed a direct current voltage whose polarity and magnitude are a function of the frequency departure of applied modulated waves from said center frequency, an amplifier for amplifying said direct current coltage, an indicator tube provided with an emission electrode, a fluorescent target, and an electron ray control electrode, means for applying the direct current voltage output of said amplifier to said ray control electrode thereby to control the width of angle of the shadow produced on the target, and means including a tube, and responsive to a decrease of modulated carrier amplitude below a desired value, for maintaining the shadow on said target at a relatively wide angle.

9. In combination with a variable frequency wave detector having an input circuit upon which are impressed variable frequency waves, said detector having an output circuit across which is developed a rectified voltage whose polarity and magnitude depend upon the frequency departure of the center frequency of the applied waves from an assigned center frequency value of said detector input circuit, an indicator tube of the fluorescent target type provided with a shadow control electrode, means for varying the potential of said shadow control electrode in response to said detector voltage output whereby the shadow angle of the indicator tube indicates the said frequency departure, a normally operative tube for controlling the potential of said shadow control electrode in the absence of waves at said input circuit for maintaining the shadow of said indicator tube at maximum width, and additional means responsive to carrier amplitude increase for rendering said last tube ineffective.

10. In combination with a variable frequency wave detector having an input circuit upon which are ipressed variable frequency waves, said detector having an output circuit across which is developed a rectified voltage whose polarity and magnitude depend upon the frequency departure of the center frequency of the applied waves from an assigned center frequency value of said detector input circuit, an indicator tube of the fluorescent target type provided with a shadow control electrode, means for varying the potential of said shadow control electrode in response to said detector voltage output whereby the shadow angle of the indictor tube indicates the said frequency departure, a normally operative tube for controlling the potential of said shadow control electrode in the absence of waves at said input circuit for maintaining the shadow of said indicator tube at maximum width, and additional means responsive to carrier amplitude increase for rendering said last tube ineffective, said additional means consisting of a direct current voltage connection between said normally operative tube and a point on said detector output circuit whose voltage varies with carrier amplitude change.

11. In a frequency modulation receiver provided with a detection network of the type comprising a pair of rectifiers having a common input circuit resonated to a predetermined center frequency, an output circuit across which is developed a direct current voltage whose polarity and magnitude are a function of the frequency departure of applied modulated waves from said center frequency, an amplifier for amplifying said direct current voltage, an indicator tube provided with an emission electrode, a fluorescent target, and an electron ray control electrode, means for applying the direct current voltage output of said amplifier to said ray control electrode thereby to control the width of angle of the shadow produced on the target, and means including a tube, and responsive to a decrease of modulated carrier amplitude below a desired value, for maintaining the shadow on said target at a relatively wide angle, and the electrodes of said amplifier being located in tube envelope of said last mentioned tube.

12. In a receiver for frequency-modulated waves including a selective amplifier and a balanced detector whose rectified output is substantially proportional, over the normal operating

range, to the departure in frequency of a selectively amplified incoming signal from its mean value, a tuning indicator means of the electronic, shadow-indicating type which operates from the output of said balanced detector and which indicates a correct adjustment of tuning of said receiver by a definite shape of shadow, and additional means for operating said tuning indicator by a direct voltage derived from the amplitude of said signal independently of its frequency variations, said additional means including an electron discharge device having an output connection to said indicator means, and means for applying said derived direct current voltage to said device from a point of the receiver preceding said detector.

EDWARD W. HEROLD.