

Sept. 15, 1942.

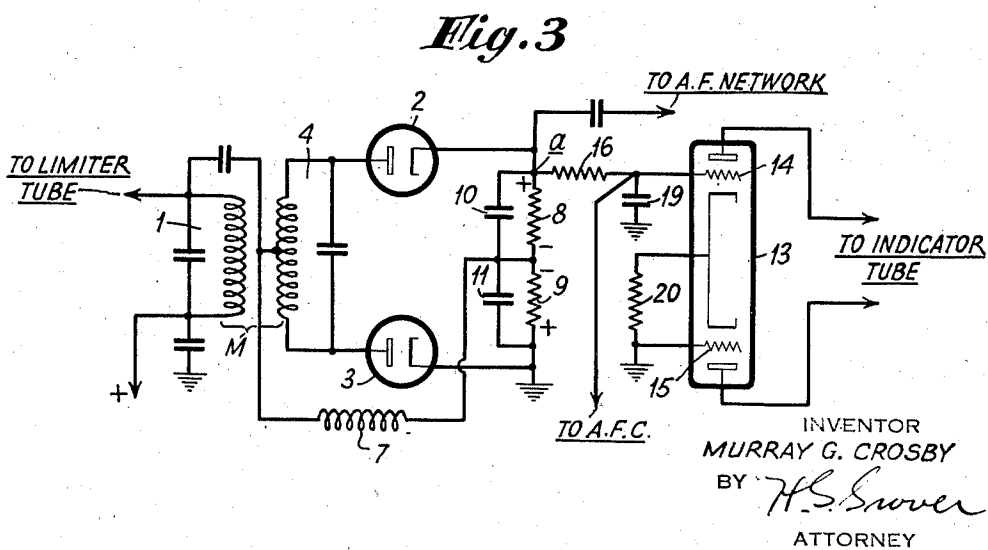
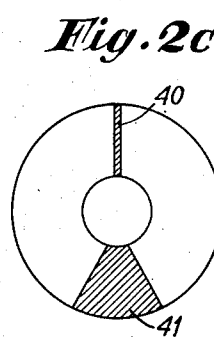
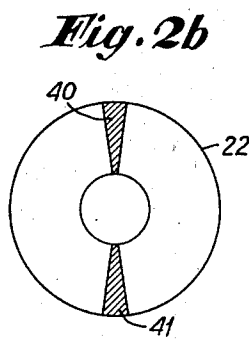
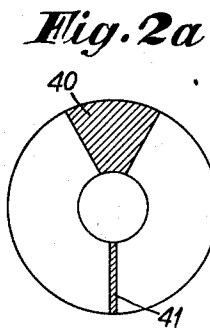
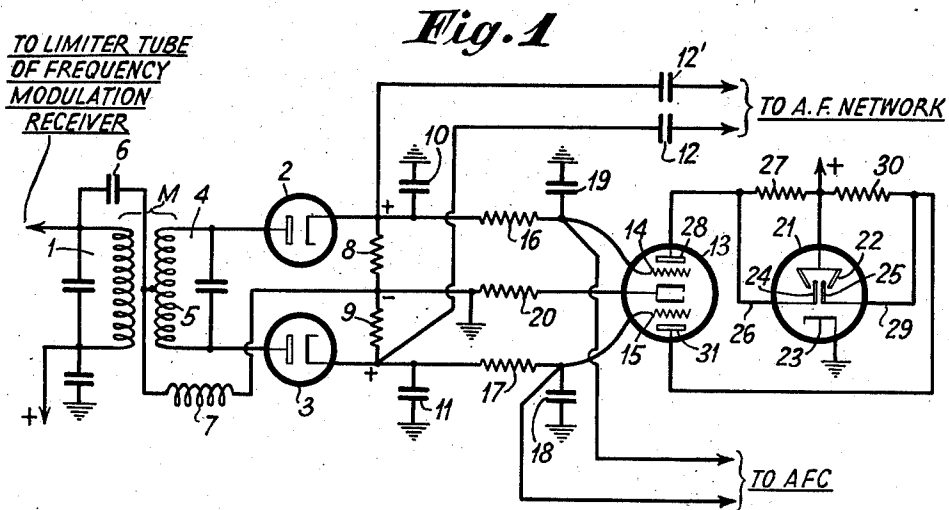
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2,296,089

FREQUENCY MODULATION RECEIVER TUNING INDICATOR

Filed Feb. 20, 1940

2 Sheets-Sheet 1



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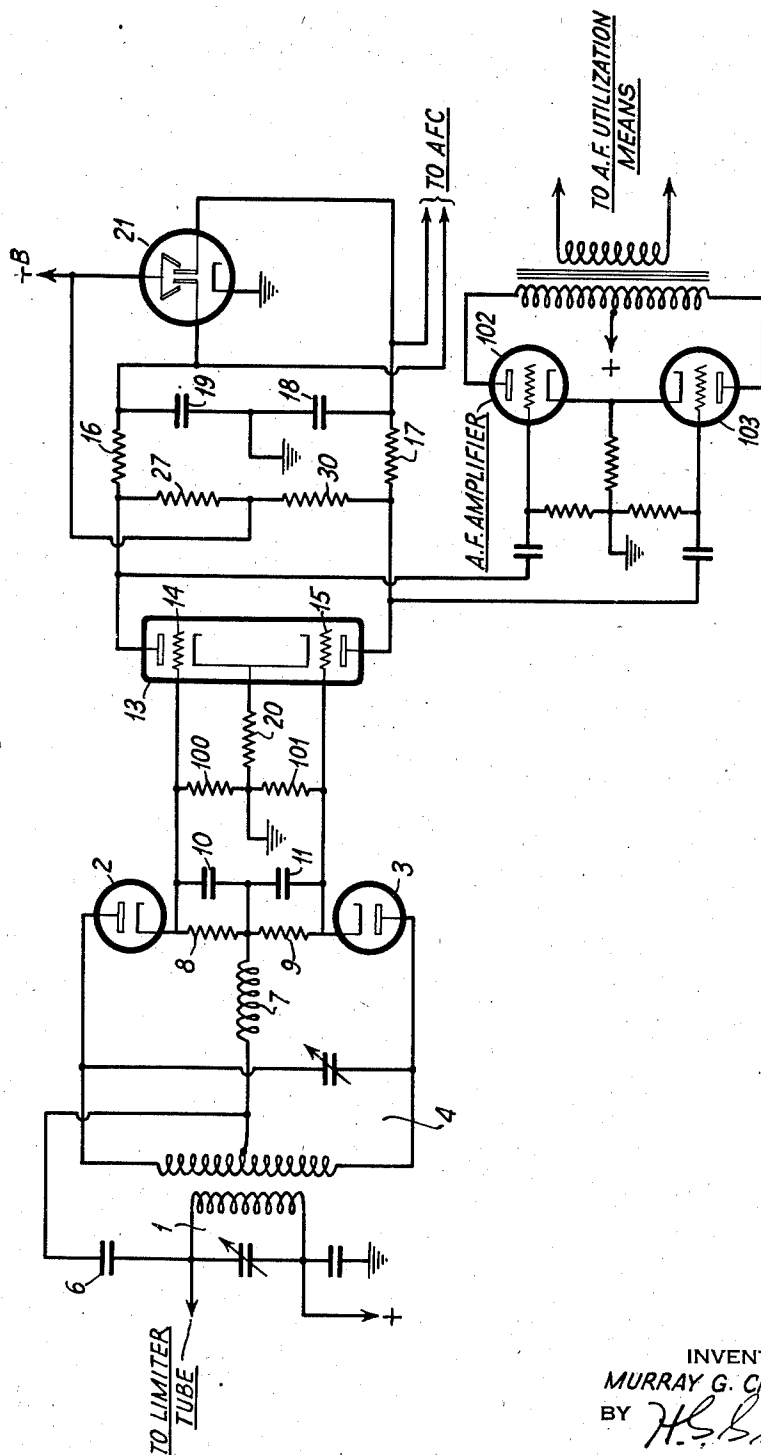
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FREQUENCY MODULATION RECEIVER TUNING INDICATOR

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Fig. 4



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FREQUENCY MODULATION RECEIVER
TUNING INDICATORMurray G. Crosby, Riverhead, N. Y., assignor to
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Delaware

Application February 20, 1940, Serial No. 319,828

2 Claims. (Cl. 250—20)

My present invention relates to tuning indicators for frequency modulation receivers, and more particularly to an electronic indicating arrangement adapted for use in a frequency modulation receiver to indicate the proper tuning point.

In the reception of frequency modulated carrier waves in a superheterodyne receiver it is important that the receiver tunable circuits be adjusted during the tuning process so that the modulated intermediate frequency carrier energy has a mean carrier frequency value which accurately corresponds to the middle of the frequency discriminator characteristic. As is well known, the latter characteristic has the general appearance of an inclined S curve wherein the section of the curve connecting the two spaced peaks is substantially linear. The center of the linear portion of the characteristic, insofar as frequency is concerned, corresponds to the mean carrier frequency value of the modulated carrier wave. Unless the applied frequency modulated energy has its mean carrier frequency value equal to the frequency at the middle of the discriminator characteristic a type of distortion is encountered which is analogous to the mal-adjustment of bias on an audio frequency amplifier tube in amplitude modulation practice. In general, it is difficult accurately to tune a frequency modulation receiver.

It is, therefore, one of the main objects of this invention to provide a visual indicator device which is adapted to indicate to the operator of a frequency modulation receiver when the receiver is in proper tune so that distortion due to frequency mis-alignment between the applied modulated carrier energy and the frequency discriminator is avoided.

Another important object of my invention is to provide a tuning indicator device for a frequency modulation receiver wherein an electron ray indicator tube of the dual shadow type is arranged to give balanced shadow angles for the "in-tune" position, and oppositely "off balance" shadow angles for the two directions of mistuning.

Still another object of my invention is to utilize, in a frequency modulation receiver, a pair of amplifiers arranged to drive simultaneously audio amplifiers and a visual indicator for aiding in accurately tuning the receiver.

Other objects of the invention are to improve generally the simplicity and efficiency of tuning arrangements for frequency modulation receivers, and more particularly to provide arrange-

ments of the aforesaid type which are not only reliable in operation, but are economically constructed and assembled for frequency modulation receivers.

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 is a circuit diagram of the detector of a frequency modulation receiver employing the invention,

Figs. 2a, 2b, 2c illustrate respectively different appearances of the tuning indicator tube,

Fig. 3 shows a modification of the invention,

Fig. 4 shows still another modification.

Referring now to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, in Fig. 1 there is shown the entire detector network of a frequency modulation receiver, as well as those circuits which are essential to a proper understanding of this invention. While those skilled in the art are fully aware of the manner of designing a receiver of that type, a general review thereof will be given in order to provide an adequate background for the present disclosure. For a frequency range of say 40 to 44 megacycles which employs some 5 modulation channels, there would be employed an intermediate frequency (I. F.) of about 3 megacycles. Such a superheterodyne receiver would employ at least one radio frequency amplifier tunable over the signal frequency range; a converter stage having a similarly tunable circuit; one or more I. F. amplifiers each fixedly tuned to the operating I. F. value of 3 megacycles. The signal output of the last I. F. amplifier would feed a limiter stage functioning to attenuate all amplitude components of noise and modulation. Such a stage employs usually a sharp cut-off tube having input and output circuits resonated to the operating I. F. value. The resonant circuit *1*, then, is to be understood as being connected in the plate circuit of the limiter tube, and the circuit *1* is tuned to the I. F. value.

As is well known, the I. F. signal energy in a frequency modulation receiver comprises a wide band of radio frequencies whose mid-band fre-

quency has the selected I. F. value. The audio modulation components are represented in the band as different carrier frequency components of the same amplitude. In other words, the rate at which the mid-band carrier is varied corresponds to the frequency of the impressed audio wave, while the extent of the mid-band frequency variation is proportional to the amplitude of the audio components employed.

The detection of a frequency modulated wave is carried out by a network which is capable of producing a uni-directional voltage varying at an audio rate, and which voltage depends in magnitude on the deviation of the I. F. energy from the predetermined mid-band frequency. The polarity of the detected voltage depends on the direction of deviation of the I. F. signal energy. Such a detector network is shown in Fig. 1 as comprising a pair of diode rectifiers 2 and 3, the anodes of the two rectifiers being connected to opposite sides of the resonant circuit 4 which is tuned to the mid-band I. F. value. Circuits 1 and 4 are magnetically coupled, as at M, while the mid-point of the coil 5 is connected to the high potential side of circuit 1 by a direct current blocking condenser 6. The cathodes of the diodes 2 and 3 are connected by a resistor whose mid-point is connected to the mid-point tap on coil 5 through a radio frequency choke coil 7. The mid-point tap on the output resistor of diodes 2 and 3 divides the resistor into the resistive sections 8 and 9.

The junction of resistive sections 8 and 9 is established at ground potential, and the cathode end of each of resistive sections 8 and 9 is bypassed to ground for intermediate frequency currents by condensers 10 and 11 respectively. Connections through audio coupling condensers 12 and 12' from the cathode ends of resistor sections 9 and 8 respectively provide the coupling to the audio frequency utilization network. However, direct current voltage connections to the cathode ends of each of resistor sections 8 and 9 provide means for feeding detected direct current voltages to a visual tuning indicator device.

It is not believed necessary to describe in detail the detection network disclosed herein. Reference is made to U. S. Patent 2,121,103, granted to S. W. Seeley on June 21, 1938, for a detailed description of the electrical functioning of the detection network shown herein. It is believed sufficient to point out for the purposes of this application that frequency deviations of the I. F. energy from the predetermined mid-band I. F. value are converted into voltages which depend in magnitude and polarity upon the extent and direction of deviation respectively. As long as the I. F. value of the applied I. F. energy is equal to the predetermined I. F. value the unidirectional voltages produced across sections 8 and 9 are of opposite polarity and of equal magnitude.

A double triode tube, which may be of the 6SC7 type, is designated by numeral 13, and is used to provide direct current voltage amplification for the direct current voltages applied to the control grids 14 and 15. The grid 14 is connected through filter resistor 16 to the cathode end of resistor section 8, while grid 15 is connected through filter resistor 17 to the cathode end of resistor section 9. In order to eliminate the audio voltage fluctuations from the voltages impressed on grid 15 and grid 14, condensers 18 and 19 are connected between the grid end of each of resistors 17 and 16 to ground. The cathodes of the two triode sections of tube 13 are

connected in common to ground through a common bias resistor 20.

The indicator tube itself is denoted by numeral 21, and may be a twin shadow indicator tube of the 6AF6G type. This type of tube is well known to those skilled in the art and is similar in construction to the type of tuning indicator tube shown by H. M. Wagner in U. S. Patent 2,051,189, granted August 18, 1936, except that the triode section of the tube is omitted, and two opposite shadow rods are employed. In general, the tube is provided with an envelope in which is included a fluorescent target, which actually has the shape of a conical anode 22 whose interior surface is coated with a fluorescent material. The cathode 23, which is established at ground potential, is positioned to bombard the interior surface of anode 22 with electrons, and, therefore, the entire interior surface of anode 22 becomes luminous as electrons from cathode 23 impinge thereupon. The control rods 24 and 25 are spaced from cathode 23, but are arranged in parallel on opposite sides of cathode 23 so that there are provided two diametrically opposite shadow areas on the fluorescent target. As is well known to those skilled in the art, each of rods 24 and 25 is connected to potential points such that normally each shadow-producing rod deflects a maximum amount of electrons from that portion of the fluorescent surface which is in alignment with each shadow rod.

Thus, the shadow rod 24 is connected by lead 26 to the plate end of resistor 27, the latter being connected between the plate 28 of tube 13 and the positive potential supply lead of the target 22 of indicator tube 21. Similarly, the shadow rod 25 is connected by lead 29 to the plate end of resistor 30, which latter resistor is located between the plate 31 of tube 13 and the positive potential supply lead of target 22. It will, therefore, be seen that a common positive voltage supply lead is employed for the plates of amplifier 13 and for the target 22. As a result of these connections, in the absence of received signal energy there will be no voltage developed across each of resistors 8 and 9. Hence, each of grids 14 and 15 will have a normal negative bias with respect to the cathodes of tube 13 which is equal to the direct current voltage drop across cathode resistor 20. In this case the rods 24 and 25 will be at a minimum potential difference with respect to cathode 23 of the indicator tube.

This means that there will be provided on the fluorescent target opposed shadow areas of minimum width, since the rods 24 and 25 will repel practically very few electrons from the portion of the fluorescent target directly in front of each rod. However, assuming that signal energy is received and that the impressed I. F. signal energy has an I. F. value equal to the predetermined mid-band I. F. value, then there will be impressed on each of grids 14 and 15 direct current voltages which are of positive polarity, but of equal magnitude. It follows, then, that the plate current flow in each of the triode sections of tube 13 will be increased, and, therefore, the plate ends of each of resistors 27 and 30 will assume a less positive potential than in the normal no-signal state. As a result the electron-repelling rods 24 and 25 will become less positive in potential with respect to cathode 23. In this "in-tune" state the shadow areas on the inner face of the target 22 will appear as shown in Fig. 2b. In that latter figure numeral 22 designates the

target, whereas the shadow areas are indicated by numerals 40 and 41. It will be understood that the shadow patterns shown in Figs. 2a, 2b and 2c are the appearances of the shadows on the fluorescent target inner face as observed by the operator of a radio receiver.

When the applied I. F. signal energy is off-tune with the predetermined mid-band I. F. value then the patterns indicated in Figs. 2a and 2c show the appearances of the shadow areas depending on the sense of detuning of the carrier. For example, let it be assumed that shadow area 40 is produced by rod 24, and that the receiver tuning means has been adjusted in such manner that the I. F. signal energy is shifted in frequency to that side of the predetermined I. F. value such that the voltage across resistor 8 is greater than the voltage produced across resistor 9. In such case the grid 14 will become more positive than grid 15, and the amplifier voltages appearing across resistors 27 and 30 will likewise be out of balance. As a result of this action the shadow rod 24 produces a greater diversion of electrons from its associated target area 40. The shadow area widens out, whereas the shadow area 41 actually becomes narrower than the shadow area shown in Fig. 2b. In Fig. 2c is shown the reverse case wherein the receiver tuning is to the opposite side of the predetermined I. F. carrier value. In other words, in Fig. 2c is shown the situation when the voltage drop across resistor 9 exceeds that across resistor 8.

It will be noted that the width of the shadow areas 40 and 41 in Figs. 2a and 2c respectively are of less width than their respective areas in Fig. 2b. This follows from the fact that when the receiver is off the correct tuning position, on either side of the predetermined I. F. value, one of the grids of tube 13 has applied to it a positive direct current voltage from the detector which is less than the "in-tune" value, while the other grid has a positive voltage applied thereto which is greater than the last named value. Hence, the operator can tell at once that the receiver is off-tune to that side of the predetermined I. F. value which gives rise to the wide shadow area. Of course, the indicator can be calibrated in advance so that the operator can tell whether the receiver has been tuned below or above the predetermined mean I. F. value. When the receiver is adjusted in tune so that each shadow pattern is as shown in Fig. 2b then the receiver is correctly tuned.

In this accurate tuning position the I. F. signal energy applied to the discriminator circuit (that is, the network between the limiter plate and the two diodes) has a mid-band carrier frequency which is equal to the selected common frequency of circuits 1 and 4. No distortion effects will be observed in this case. Since the characteristic of the discriminator network, as defined previously, is that of an S curve, it is essential to adjust the discriminator to operate at the central portion of the linear section of the discriminator curve, that is to say, centrally between the spaced peaks of the curve. At this central position, which corresponds to the predetermined I. F. value, the frequency swings of the carrier, representative of the audio modulation, are symmetrical and distortion effects cannot be produced. However, should the receiver be tuned at the tunable circuits ahead of the converter so that the I. F. signal energy applied to the discriminator circuit has its mid-band

frequency different substantially from the mean frequency value of the circuits 1 and 4, then it will readily be seen that the frequency swings of the I. F. energy will extend into one of the peak curvature areas of the discriminator curve. This gives rise to distortion effects very similar to the type of distortion which arises when a class A audio amplifier has its bias adjusted to a point of its characteristic other than the central portion of the linear part of the amplifier characteristic curve.

It is, also, pointed out that the common bias resistor 20 provides the advantageous function of increasing the sensitivity of the indicator. For example, when an increase of positive voltage is applied to grid 14 the current flow through resistor 20 increases. This results in an increased negative bias applied to both grids. However, in the case of grid 15 the effective bias thereof is increasingly negative, and, hence, results in a more pronounced narrowing, or an over-lapping, of the shadow area 41. It is, therefore, seen that the application of positive voltage to one grid of tube 13 causes a simultaneous augmented application of negative voltage to the opposite grid. In this way the degree of unbalance caused by a mean applied voltage is increased. The time constant filters 16-19 and 17-18 function to remove the fast variations of the detected frequency modulation waves so that only slow variations of the balance are indicated and the indicator is not responsive to the applied frequency modulation envelope.

The voltage appearing on diode resistors 8 and 9 consists of the detected audio frequency potentials and a permanent direct current component. The permanent direct current component is zero when the carrier is properly tuned to the discriminator, but varies to positive or negative values as the frequency of the carrier drifts to one side or the other. In the circuits of Fig. 1 the audio frequency potentials are filtered from the indicator circuit by means of time constant circuits 16, 19 and 17, 18. These resistance and condenser filters allow slow variations to pass and operate the indicator tube, but attenuate the fast audio frequency variations. Thus the carrier is deviating from the mid-band frequency value by two variations, one an audio frequency variation and the other a drift variation, and by means of the resistance filters the two components are separated at the receiver.

In Fig. 3 there is shown a modification of the invention wherein instead of grounding the junction of resistor sections 8 and 9, the cathode end of resistor section 9 is grounded. The grid 14 of tube 13 is connected to the cathode end of resistor section 8 through the time constant filter resistor 16. The grid 15 is connected to the cathode junction of tube 13 through the common bias resistor 20, but the junction of resistor 20 and the grid 15 is grounded. The remainder of the connections of the circuit are exactly as those in Fig. 1. In this circuit arrangement of Fig. 3 advantage is taken of the common cathode resistor coupling 20 from one tube to the other to allow control by voltage with one side grounded. Since the common cathode resistor 20 causes an automatic application of negative voltage to one grid when positive voltage is applied to the other, the grid 15 may be grounded and the control voltage may then be applied to the opposite grid 14. The control voltage is developed at the cathode end of resistor section 8, and is applied to grid 14 through

the time constant filter 16—19. For the in-tune condition zero voltage appears between point *a* and ground.

This is clearly seen from the fact that since the voltages produced across sections 8 and 9 are of opposite polarity and of like magnitude for the in-tune position; then the resultant voltage appearing at point *a* is zero. Accordingly, grids 14 and 15 will each have the negative bias developed across resistor 20 and, as in the case of Fig. 1, the shadow areas 40 and 41 will be of the minimum width, and may be chosen to be equal to about the width of the shadow rod itself. Now, as the applied I. F. carrier drifts in one direction away from the assigned I. F. value let it be assumed a positive voltage appears at point *a*, and that when it drifts in the opposite direction point *a* assumes a negative polarity. In the case of point *a* assuming a positive polarity the shadow pattern shown in Fig. 2*a* will result, it again being pointed out that the increased voltage produced across resistor 20 causes grid 15 to become increasingly negative. On the other hand, when point *a* assumes a negative polarity the shadow pattern of Fig. 2*c* will result.

Automatic frequency control voltage (AFC) may be tapped off from the grid end of filter resistor 16 in Fig. 3. In the circuit of Fig. 1 connections for AFC are made to the grid ends of filter resistors 16 and 17. There is no need to describe these AFC connections in further detail, since the manner of applying the AFC voltage to an electronic reactance tube operatively associated with the local oscillator tunable tank circuit is too well known. The AFC would act to "pull-in" the desired frequency modulated wave thereby simplifying the tuning process.

In Fig. 4, the amplifier 13 is given a double function. It will be noted that the resistance-condenser filters 16, 19, and 17, 18 are placed in the leads to the ray-control tube 21. This allows amplifier 13 to amplify both the detected audio frequency potentials to be fed to power output tubes 102 and 103 so as to use tube 13 for two functions. The second feature different from the other circuits is the manner in which the detector circuit is grounded by means of resistors 100 and 101. It will be noted that these resistors form the only grounding means for the detected output. By using this type of connection the voltages on the diode resistors 8 and 9 do not provide permanent bias on the grids 14 and 15. In the balanced condition of the voltages on 8 and 9 there will be no current flow through resistors 100 and 101 so that grids 14 and 15 will have no bias fed to them from the detector circuit. When the voltages across 8 and 9 are out of balance a current will flow through resistors 100 and 101 which will produce a positive bias on one grid and a negative bias on the other. Thus, grids 14 and 15 receive voltage from the detecting network only when the frequency deviates from the "in-tune" position by virtue of a frequency modulation or a frequency drift. That is to say, there will be no permanent bias fed from the detector to tube 13 in the absence of frequency modulation or off-tune drift. It will be noted that this feature is lacking in the circuit of Fig. 1 since the latter allows the voltage across the diode resistors to provide permanent bias on the grids of amplifier tube 13. The circuit of Fig. 3 has the same characteristic in this

respect as the circuit of Fig. 4. In Fig. 3 the connection of the diode resistors causes their permanent voltage to cancel so that an output voltage is only present when the carrier frequency deviates in frequency from the mid-band position.

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.

What I claim is:

1. In a frequency modulated carrier wave receiver of the type provided with an indicator tube having a cathode, a positive fluorescent anode surrounding the cathode, and at least two control electrodes disposed at separated points in the electron stream from the cathode to the anode, and a detection network comprising opposed rectifiers responsive to carrier frequency deviations in opposite directions from an assigned frequency value for producing a pair of direct current potentials variable in magnitude in opposite senses; the improvement which comprises a pair of electron discharge devices each having at least a cathode, an output electrode and an input electrode, means applying each of said potentials to a respective input electrode of one of said devices, means applying the amplified potential output of each device to a respective one of said control electrodes whereby a pair of independent electrical shadows are produced on said anode, a pair of series resistors connected between the input electrodes of said devices, said resistors being arranged in the space current paths of said rectifiers, means for grounding the junction of said resistors, and a third resistor connected between the cathodes of said devices and said grounded junction to provide common bias for said input electrodes, and an audio amplifier network provided with input terminals connected to said output electrodes of said devices for deriving therefrom amplified potentials whose magnitude varies at an audio rate.

2. In a frequency modulated carrier wave receiver of the type provided with an indicator tube having a cathode, a positive fluorescent anode surrounding the cathode, and at least two control electrodes disposed at separated points in the electron stream from the cathode to the anode, and opposed rectifiers responsive to carrier frequency deviations in opposite directions from an assigned frequency value for producing a pair of potentials variable in magnitude in opposite senses; the improvement which comprises a pair of electron discharge devices each having at least a cathode, an output electrode and an input electrode, means applying each of said potentials to a respective input electrode of one of said devices, means applying the amplified potential output of each device to a respective one of said control electrodes whereby a pair of independent electrical shadows are produced on said anode, and a resistor common to the space current paths of both said devices and being connected between the cathodes thereof and each of said input electrodes whereby the differential variation of said shadows is rendered highly sensitive.

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