June 16, 1942. E. W. HEROLD ET AL 2,286,413

FREQUENCY MODULATION RECEIVER TUNING INDICATOR CIRCUITS

Filed April 25, 1941

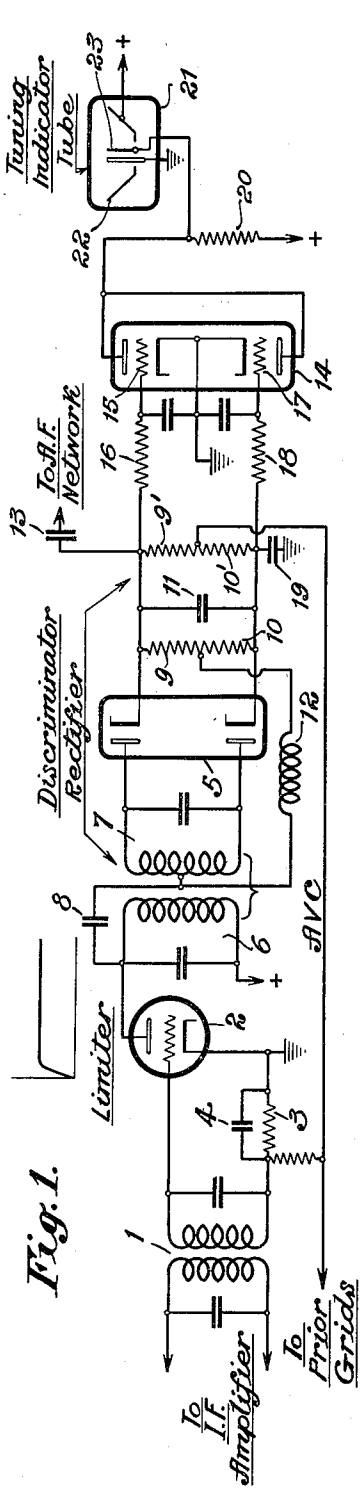


Fig. 1.

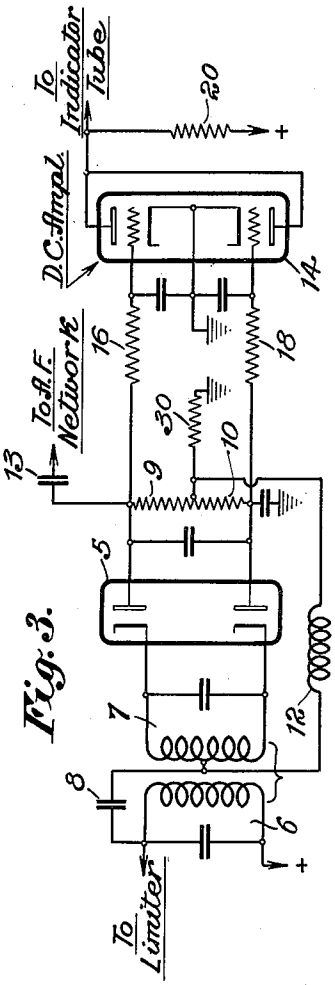


Fig. 3.

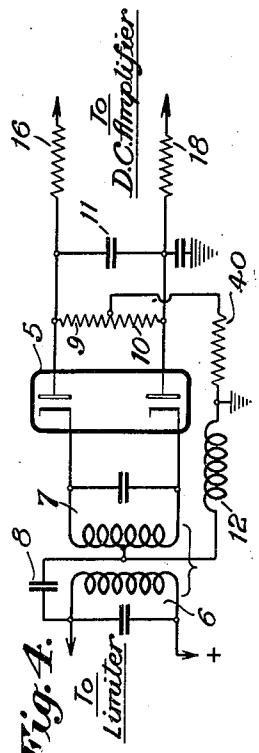


Fig. 4.

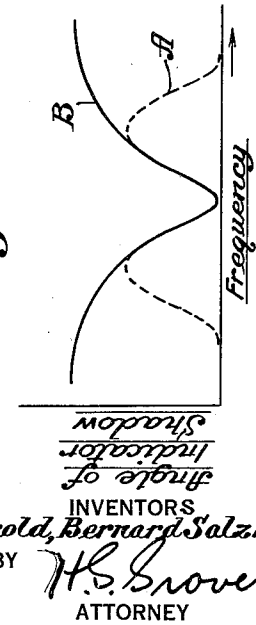


Fig. 2.

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FREQUENCY MODULATION RECEIVER TUNING INDICATOR CIRCUITS

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Application April 25, 1941, Serial No. 390,282

9 Claims. (Cl. 250—40)

Our present invention relates to improvements in tuning indicator circuits for frequency, or phase, modulated carrier wave receivers.

There has been disclosed by E. W. Herold in application Serial No. 385,083 filed March 25, 1941, a method of, and means for, accurately visually indicating the tuning of a frequency modulation receiver to the center frequency of a desired modulated carrier wave. In that method false indications supposedly representative of correct tuning were prevented by utilizing the absence of a carrier amplitude above a desired level to maintain off-tune, or no-signal, indications of the indicator device accurately representative of such latter condition of the receiver.

Accordingly, it may be stated that it is one of the main objects of our present invention to provide improved arrangements wherein false and misleading indications of an indicator tube of the variable shadow type may be prevented.

Another object of this invention is to provide in combination with the discriminator-rectifier of a frequency modulation receiver an indicator tube of the variable shadow type, wherein simplified and effective means are employed to prevent minimum shadow responses of the indicator tube when the receiver is adjusted out of resonance with a desired station, or when no signals are being received.

Still other objects of this invention are to improve indicator circuits of the type disclosed in the aforesaid Herold application, and which circuits are not only reliable and durable, but are economically manufactured and assembled in frequency modulation receivers.

The novel features which we believe to be characteristic of our 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 drawing in which we have indicated diagrammatically several circuit organizations whereby our invention may be carried into effect.

In the drawing:

Fig. 1 schematically shows a circuit diagram embodying one form of the invention,

Fig. 2 graphically illustrates the operation of the invention,

Fig. 3 shows a modified form of the invention, and

Fig. 4 illustrates still another modification.

Referring now to the accompanying drawing, wherein like reference characters in the different figures designate similar circuit elements, the arrangement in Fig. 1 is to be understood as showing the networks employed in a frequency modulation receiver between the last intermediate frequency (referred to hereinafter as I. F.) amplifier and the audio network. It is not believed necessary to describe the details of a superheterodyne receiver of this type, since the invention does not pertain to any of the networks save those immediately associated with the discriminator-rectifier network and the tuning indicator tube. It is merely necessary to point out that the receiver may be operated in the presently assigned frequency modulation (FM hereinafter) band of 42 to 50 megacycles (Mc.) and that each channel has a permissible center frequency deviation swing of 100 kilocycles (Kc.) on either side of the center frequency. The intermediate frequency value may be chosen from a range of 2 to 5 Mc., and may be, for example, 2.1 Mc.

The modulated I. F. carrier waves, after sufficient amplification, are impressed upon the input transformer 1 of the limiter tube 2. Each of the primary and secondary resonant circuits of transformer 1 is tuned to the center frequency whose value is the operating I. F. To secure accurate tuning the center frequency of the applied modulated carrier waves must, of course, have a value equal to the predetermined I. F. value. The limiter tube 2 is constructed so as to function as a saturated amplifier, and usually includes between the low potential side of its input circuit and the grounded cathode a resistor 3 shunted by a condenser 4. The network 3–4 acts to produce the limiting action, and develops direct current voltage in response to grid current flow of tube 2. Those skilled in the art are fully acquainted with the action of a limiter, and know that its characteristic is similar to that shown above the limiter 2 in Fig. 1. In other words the output rises with input voltage until a predetermined amplitude of input voltage is reached, and thereafter the output voltage is substantially constant for further increases in input voltage.

The second detector, or discriminator-rectifier, comprises a pair of diodes, and they are shown located within the common tube envelope 5. The circuit shown for deriving the modulation voltage from the frequency modulated carrier waves is that disclosed and claimed by S. W. Seeley in his U. S. Patent 2,121,103, granted June 21, 1938. Briefly, in that circuit the input transformer has a resonant primary circuit 6 which is tuned to

the I. F. value, and this primary circuit may be arranged in the plate circuit of the limiter tube. The primary circuit is magnetically coupled to the resonant secondary circuit 7 which is also tuned to the I. F. value. A condenser 8 acts as a direct current blocking condenser, and also couples the high potential side of circuit 6 to the midpoint of the coil of circuit 7. The anodes of the pair of diodes are connected to opposite sides of circuit 7, and the cathodes are connected together through series resistors 9 and 10, the resistors being shunted by I. F. by-pass condenser 11.

The junction of resistors 9 and 10 is connected through I. F. choke coil 12 to the midpoint of the coil of circuit 7. It is not believed necessary to point out in detail that audio modulation voltage developed across resistors 9 and 10 correspond to the frequency deviations of the center frequency of the FM waves applied to input circuit 6—7. It is well known at the present time that the discriminator-rectifier network shown herein produces across resistors 9 and 10 zero modulation and direct current voltages when the instantaneous frequency value of the FM waves applied to 6—7 is equal to the I. F. value. The instantaneous frequency swings of the center frequency of the FM waves appear across resistors 9 and 10 as modulation voltages, whereas the mean deviation of the center frequency of the FM waves from the I. F. value appears across resistors 9 and 10 as a variable direct current voltage. The modulation voltage is taken off for utilization in an audio frequency amplifier network by condenser 13.

The direct current voltage developed across resistors 9 and 10 is applied to the control grids of a tube 14. The latter may be a twin triode tube, and has the cathodes of the two triode sections connected to ground. The grid 15 is connected through the filter resistor 16 to the upper end of resistor 9, while the grid 17 is connected through audio filter resistor 18 to the lower end of resistor 10. The condenser 19 is an audio by-pass condenser, and an audio by-pass condenser is connected from the grid end of each of resistors 16 and 18 to ground. The plates of the triode sections of tube 14 are connected in common by a resistor 20 to the positive terminal of a direct current source. The visual tuning indicator tube may be of the well known type schematically represented by numeral 21.

This type of indicator tube is provided with a cathode which is connected to ground, a target 22 being provided around the electron emission electrode. The target is shaped as a frustum of a cone, and, as those skilled in the art know, the inner face thereof is coated with a fluorescent material. The numeral 23 indicates the electron deflection rod which is positioned between the cathode and the target. The rod functions to control the width of an electronic shadow produced on the inner face of the target. The target 22 is established at a positive potential, usually by connecting the target to the lower end of resistor 20. It will now be seen that when there is no voltage developed across resistor 20 the potential difference between the cathode of tube 21 and rod 23 is a minimum, and, hence, the shadow on the target is of a minimum width. That is to say, the rod 23 deflects few electrons. However, as the plate current flow through resistor 20 increases, the rod 23 is biased in a negative polarity sense relative to the cathode and the shadow on the target is increased in width.

In order to explain the problem which is sought to be solved by this invention, let it be assumed that the junction of series resistors 9' and 10', which resistors are connected in shunt across resistors 9 and 10, is connected to a source of negative voltage, and that this negative voltage source normally applies such bias to grids 15 and 17 that the plate current flow of tube 14 is cut off. This is the condition of minimum shadow width of tube 21. This type of circuit has been used in the past. When a signal is correctly tuned in, that is when the center frequency of the applied FM waves is exactly equal to the predetermined I. F. value of circuit 6—7 of the FM detector, the diodes of tube 5 have equal average currents so that the total direct current voltage drop across resistors 9 and 10 is zero. The grids 15 and 17 are, therefore, at the same potential, and the shadow width of tube 22 is a minimum.

If the receiver tuning is changed so that the mean carrier frequency is no longer at the proper accurate tuning point, the average current of one diode exceeds that of the other and a direct current voltage exists across resistors 9 and 10 in series. This voltage results in the grid of one triode receiving a more negative bias and the grid of the other triode a less negative bias. The latter triode will just draw plate current, and as a result the shadow width on tube 21 will be wider. On either side of the correct tuning position, therefore, the shadow will increase from the minimum width. It should be noted that when no signal is present, or when the receiver is off tune, the average current of each diode is very small and substantially equal to that of the other diode. The shadow width of the indicator tube is, therefore, a minimum for this condition, and thus gives a false indication as if the receiver were correctly tuned to the desired FM waves.

In Fig. 2 the dotted line curve A shows graphically the relation between the variation of the angle of indicator shadow and frequency, and it will be seen that as the actual center frequency of the desired FM waves is approached from the left, the angle of the shadow increases from zero and passes through a maximum. Thereafter it decreases passing through zero, and then increases once more and passes through a positive maximum and then decreases to zero. The point of accurate tuning is marked by the trough located at the center, that is, where the indicator shadow has minimum angular width. It is seen, therefore, that when no signal is present, or when the set is off tune, the shadow is of minimum angle. This action is undesirable, because it confuses the person who is tuning the receiver. The object of this invention is to provide improved circuits for eliminating this defect, and to have the shadow width attain its minimum value only when the receiver is correctly tuned to the desired FM waves.

According to our invention the false indication is eliminated by providing an automatic bias for grids 15 and 17 which is derived from the incoming signal itself. There is produced across resistor 3 of the limiter a direct current voltage whose amplitude varies with the carrier amplitude of the FM waves; such voltage is sometimes used for an automatic volume control action in FM receivers. Hence, this carrier-controlled bias may be applied to the junction of resistors 9' and 10', instead of using a fixed negative bias source. The full line curve B in Fig. 2 shows the angle of indicator shadow as a function of frequency, and illustrates how the false indi-

cation secured with characteristic A is eliminated.

When there is no signal, the shadow width remains at its maximum angle. As the signal is tuned in from the left, for example, the angle of the shadow decreases, passes through a minimum which marks the accurate tuning point, and then increases again. It will be seen that this is the case, because in the absence of signals the grids 15 and 17 are at the potential of the cathodes of tube 14. Therefore, current flows through resistor 20 with the result that rod 23 is biased so as to produce maximum shadow widths on either extremity of the tuning indicator shadow characteristic. Of course, the automatic bias for grids 15 and 17 may be derived from the FM carrier by means of any well known rectification network. The specific mode of securing carrier amplitude-dependent bias shown in Fig. 1 is merely illustrative. The simplest form of circuit to utilize for deriving the automatic negative bias for the grids of tube 14 is to employ the discriminator-rectifier itself.

This is not conveniently done with the circuit of Fig. 1 because the polarity of the direct current voltage of the diode circuits is incorrect. In Fig. 3 there is shown a circuit whereby this may be accomplished, and wherein the anodes and cathodes of each diode are interchanged. It will be noted that whereas in Fig. 1 the anodes of each of the diodes of tube 5 are connected to opposite sides of circuit 7, in Fig. 3 the cathodes of the diodes are connected to the opposite sides of circuit 7. The anodes of the diodes are connected to the opposite ends of the load resistors 9 and 10. The junction of resistors 9 and 10 is connected to ground by a resistor 30. Otherwise the circuit arrangement is to be understood as being similar to that disclosed in Fig. 1.

When no FM waves are received the triode sections of tube 14 will have no bias, and, hence, there will be maximum voltage drop across resistor 20 with the result that the shadow width of target 22 will be a maximum. When FM waves are received, and the receiver is correctly tuned to the center frequency of the waves, one grid of tube 14 will receive a negative bias from the voltage drop across resistor 9. The other grid will receive an equal negative bias from the voltage drop across resistor 10 so that the shadow on the target will be of minimum width. When the receiver is slightly off tune, however, the bias produced on one of the grids of tube 14 will be less and that on the other grid will be more. In this case that triode section whose grid is less biased will draw plate current, and the shadow width will be of a minimum value indicating an incorrect tuning adjustment. Accordingly, it will be seen that in Fig. 3 the false indication of the indicator tube is prevented effectively by merely utilizing a common resistor 30 connected between the junction of load resistors 9 and 10 and ground. In other words, it is merely necessary to add to the known circuit of the prior art a single resistor which provides the automatic negative bias for the grids of tube 14.

In Fig. 4 is shown still another simple circuit. In this form of the invention the resistor 40 is included in series with the radio frequency choke coil 12, and the junction of the coil 12 and resistor 40 is grounded. In other words, the resistor 40 is included in the common diode return lead. The direct current voltage drop across resistor 40 is substantially independent of tuning adjustment, but does vary with the presence of the signal. This variable voltage drop provides an additional negative bias to both grids of the triodes and this is necessary. The operation of this circuit is similar to that of Fig. 3. That is, when no signals are present there is no voltage produced across resistor 40, and consequently the grids are at the same potential as the cathodes of the tube 14, and the indicator shadow will be maximum.

It may be advantageous to combine the double triode of tube 14 in the same tube envelope with the indicator electrodes, using a common cathode and a common plate for the triodes. It is pointed out that the reception of an amplitude-modulated carrier wave will also operate the tuning indicator. It will be necessary in such case to provide a means for the detection of this type of signal, however.

While reference has been made to frequency modulated carrier waves, it is to be understood that phase modulated carrier waves are also included. The generic expression "timing modulated carrier waves" is employed in the claims to denote such frequency, or phase, modulated waves. Furthermore, the invention is not restricted to indicators of the variable shadow type, but is applicable to other tuning indicator devices.

While we have indicated and described several systems for carrying our invention into effect, it will be apparent to one skilled in the art that our 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 our invention, as set forth in the appended claims.

What we claim is:

1. In combination with a detector of the type comprising a pair of diodes having a common input circuit tuned to a predetermined center frequency of timing modulated carrier waves, each of said diodes having a respective output load element operatively associated therewith, the load elements of the two diodes being arranged in series relation in a closed circuit including said diodes, said input circuit being constructed and arranged to develop across said load elements a resultant direct current voltage which varies in magnitude and polarity in response to variation in extent and direction respectively of frequency departure of the modulated carrier waves from the aforesaid center frequency, means providing direct current voltage whose magnitude is a function of carrier amplitude of received modulated carrier waves, at least two electron discharge devices each including a cathode, a control electrode and an output electrode, a direct current voltage connection between opposite ends of said load elements and each control grid of said devices, means responsive to the combined space current flowing to each output electrode of said devices for operating a tuning indicator of the electronic, shadow-indicating type, and a direct current voltage connection between said direct current voltage producing means and the junction of said load elements.

2. In combination with a pair of diodes having a common input circuit tuned to the center frequency of applied frequency modulated carrier waves, the cathodes of the diodes being connected to opposite sides of said input circuit, a common resistive path connecting the anodes of said diodes, said input circuit being constructed and arranged to develop across said resistive

path a resultant direct current voltage whose magnitude and polarity are a function of the extent and sense respectively of frequency shift of said waves from said center frequency, a pair of electron discharge devices, each of said devices including at least a cathode, a control grid and an output electrode, means establishing the cathodes of said devices at a fixed potential, a direct current voltage connection between one of the control grids and one end of said resistive path, a second direct current voltage connection between the control grid of the second of said devices and the opposite end of said resistive path, a resistor connected between the midpoint of said resistive path and said fixed potential point whereby direct current voltage developed thereacross provides variable bias for said control grids, a visual indicator tube of the variable shadow type provided with an electron control electrode, and a common direct-current voltage connection between the output electrodes of said devices and said electron control electrode.

3. In combination with a pair of diodes having a common input circuit tuned to the center frequency of applied frequency modulated carrier waves, the cathodes of the diodes being connected to opposite sides of said input circuit, a common resistive path connecting the anodes of said diodes, said input circuit being constructed and arranged to develop across said resistive path a resultant direct current voltage whose magnitude and polarity are a function of the extent and sense respectively of frequency shift of said waves from said center frequency, a pair of electron discharge devices each of said dices including at least a cathode, a control grid and an output electrode, means establishing the cathodes of said devices at a fixed potential, a direct current voltage connection between one of the control grids and one end of said resistive path, a second direct current voltage connection between the control grid and the second of said devices and the opposite end of said resistive path, a resistor connected between the midpoint of said resistive path and said fixed potential point whereby direct current voltage developed thereacross provides variable bias for said control grids, a visual indicator tube of the variable shadow type provided with an electron control electrode, a common direct current voltage connection between the output electrodes of said devices and said electron control electrode, and a path between the electrical midpoint of said circuit and the midpoint of said resistive path which includes a resistor.

4. In a receiver for frequency modulated waves including 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, said detector being of the type having a pair of direct current output voltage sections, the output voltages across said sections being in polarity opposition, a tuning indicator means which shows correct tuning in a predetermined manner, means controlling said indicator comprising a direct current amplifier which consists of a first electron discharge tube whose control electrode is actuated by the direct-current voltage output of one section of said balanced detector, a second electron discharge tube whose control electrode is actuated by the opposing direct-current voltage output of the other section of said balanced detector, and means controlling both of said control electrodes in the same direction with another direct-current voltage in response to the presence of said amplified signal independently of its mean frequency, said tuning indicator being connected to the output electrodes of both said discharge tube to be actuated by the combined space currents thereof so as to cause the tuning indicator to show correct tuning only when said signal is actually present.

5. In a receiver for frequency-modulated waves including 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, said detector being of the type having a pair of direct current output voltage sections, the output voltages across said sections being in polarity opposition, a tuning indicator means which shows correct tuning in a predetermined manner, the improvement comprising means to operate said tuning indicator from the combined output of a direct current amplifier which consists of a first electron discharge tube whose control electrode is actuated by the direct-current voltage output of one section of said balanced detector, and a second electron discharge tube whose control electrode is actuated by the opposing direct-current voltage output of the other section of said balanced detector, and wherein both of said control electrodes are also actuated in the same direction by another direct current voltage which results from rectification of said amplified signal by a rectifying means separate from said balanced detector, and said last named direct current voltage being of such polarity as to permit the tuning indicator to show correct tuning only when said signal is actually present.

6. In a receiver for frequency-modulated waves including 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, said detector being of the type having a pair of direct current output voltage sections, the output voltages across said sections being in polarity opposition, a tuning indicator means which shows correct tuning in a predetermined manner, means for operating said tuning indicator comprising a direct current amplifier which consists of a first electron discharge tube, said tube having a control electrode actuated by the direct-current voltage output of one section of said balanced detector, a second electron discharge tube provided with a control electrode actuated by the opposing direct-current voltage output of the other section of said balanced detector, means for controlling both of said control electrodes in the same direction in response to a direct-current voltage which results from the flow of the combined currents of the two sections of said balanced detector through a common resistance and which varies only with the presence of the amplified signal irrespective of its mean frequency, said tuning indicator being connected to both said discharge tubes for energization by the combined space currents thereof, and said last-mentioned direct current voltage being of such polarity as to permit the tuning indicator to show correct tuning only when said signal is actually present.

7. In combination with a detector of the type comprising a pair of opposed rectifiers having a common input circuit tuned to a predetermined center frequency of timing modulated carrier

waves, each of said rectifiers having a respective output load element operatively associated therewith, the output load elements being in series relation in a closed circuit including said rectifiers, said input circuit being constructed and arranged to provide opposed rectified voltages across said load elements whose resultant has a magnitude and polarity dependent upon the extent and direction respectively of the frequency departure of said waves from said predetermined tuned frequency, means providing direct current voltage whose magnitude is a function of the carrier amplitude of said modulated carrier waves, at least two electron discharge devices each including a cathode, a control electrode and an output electrode, a direct current voltage connection between opposite ends of said load elements and each control grid of said devices, means responsive to the combined space current flowing to each output electrode of said devices for producing a resonance indication, and a direct current voltage connection between said direct current voltage producing means and the junction of said load elements.

8. In combination with a pair of diodes having a common input circuit tuned to the center frequency of applied frequency modulated carrier waves, the cathodes of the diodes being connected to opposite sides of said input circuit, a common resistive path connecting the anodes of said diodes, said input circuit being constructed and arranged to develop across said resistive path a resultant direct current voltage whose magnitude and polarity are a function of the extent and sense respectively of frequency shift of said waves from said center frequency, a pair of electron discharge devices, each of said devices including at least a cathode, a control grid and an electrode, means establishing the cathodes of said devices at a fixed potential, a direct current voltage connection between one of the control grids and one end of said resistive path, a second direct current voltage connection between the control grid of the second of said devices and the opposite end of said resistive path, a resistor connected between the midpoint of said resistive path and said fixed potential point whereby direct current voltage developed thereacross provides variable bias for said control grids, a voltage indication device, and a common direct current voltage connection between the output electrodes of said devices and said indication device.

9. In combination with a pair of diodes having a common input circuit tuned to the center frequency of applied timing modulated carrier waves, the cathodes of the diodes being connected to opposite sides of said input circuit, a resistor connecting the anodes of said diodes, said input circuit being constructed and arranged to develop across said resistive path a resultant direct current voltage whose magnitude and polarity are a function of the extent and sense respectively of frequency shift of said waves from said center frequency, a pair of electron discharge devices, each of said devices including at least a cathode, a control grid and an output electrode, means establishing the cathodes of said devices at a fixed potential, a direct current voltage connection between one of the control grids and one end of said resistor, a second direct current voltage connection between the control grid of the second of said devices and the opposite end of said resistor, a second resistor connected between the midpoint of said first resistor and said fixed potential point whereby direct current voltage developed thereacross provides variable bias for said control grids, a visual indicator tube of the variable shadow type provided with an electron control electrode, a common direct current voltage connection between the output electrodes of said devices and said electron control electrode, and a third resistor connected between the electrical midpoint of said circuit and the midpoint of said first resistor.

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