June 16, 1942. W. A. HARRIS 2,286,410

FREQUENCY MODULATION RECEIVER TUNING INDICATOR

Filed April 9, 1941 2 Sheets-Sheet 1

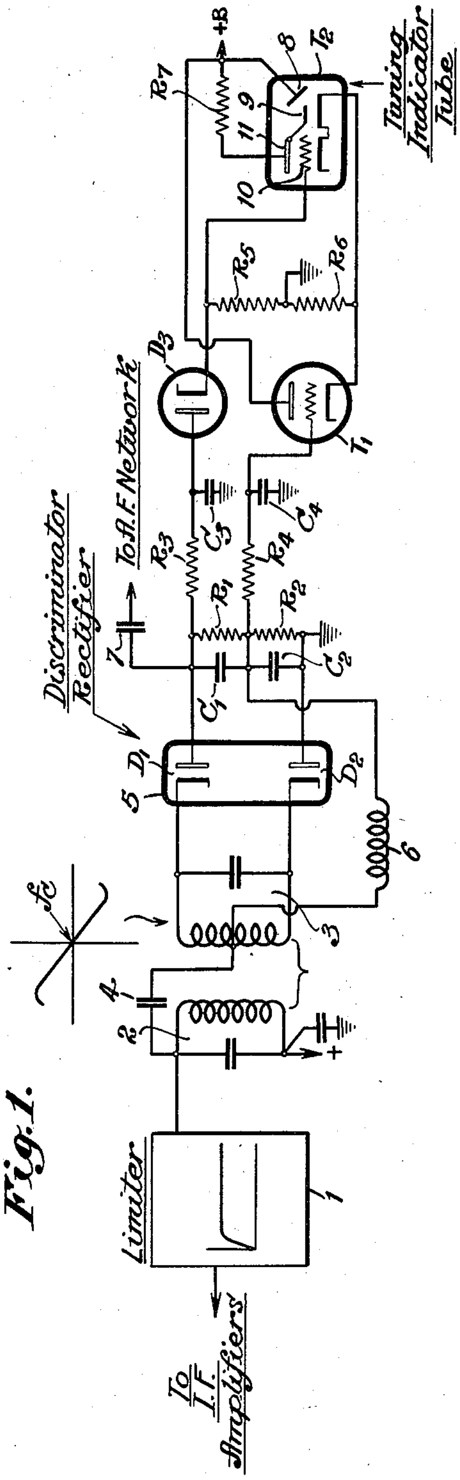

Fig. 1.

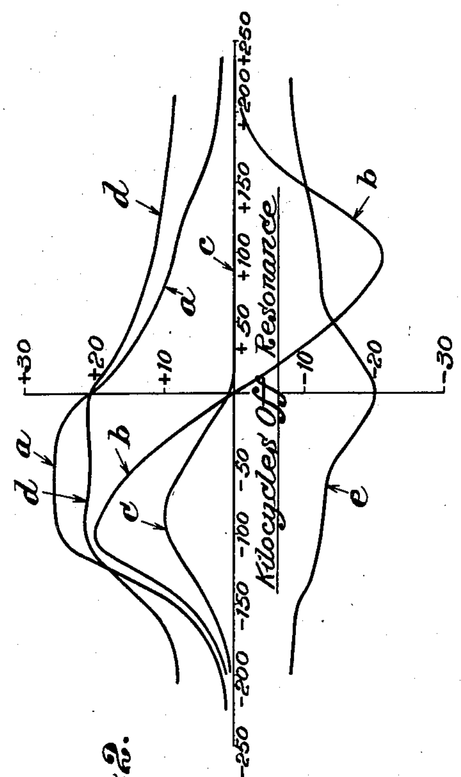

Fig. 2.

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Filed April 9, 1941 2 Sheets-Sheet 2

Fig. 3.

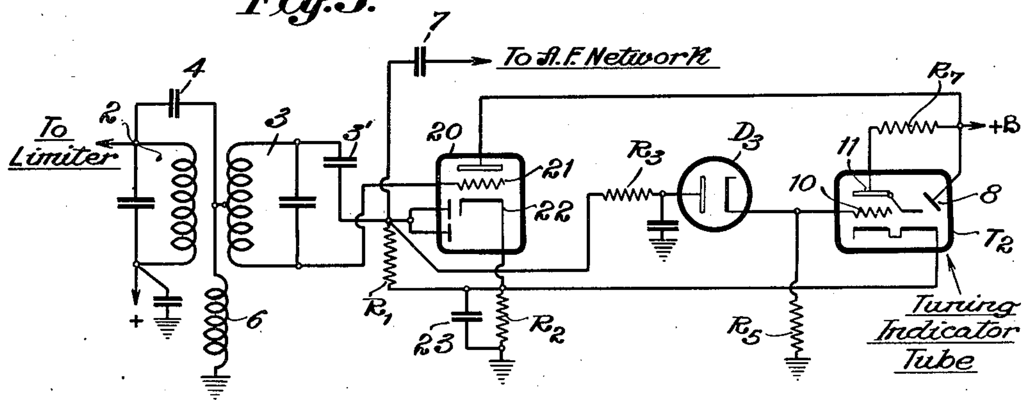
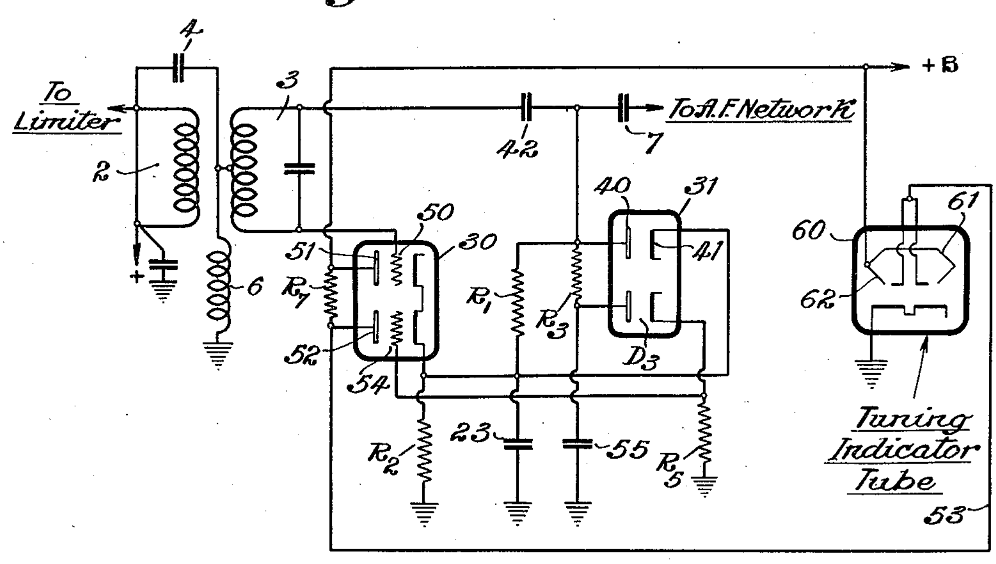


Fig. 4.



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2,286,410

FREQUENCY MODULATION RECEIVER TUNING INDICATOR

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Application April 9, 1941, Serial No. 387,571

14 Claims. (Cl. 250—40)

My present invention relates to tuning indicator circuits for frequency, or phase, modulated carrier wave receiving systems, and more particularly to improved circuits of the type disclosed by John D. Reid in application Serial No. 362,910, filed October 26, 1940 and patented on February 3, 1942 as U. S. Patent No. 2,272,052.

In the last-mentioned application there has been disclosed, and claimed, a system for deriving two control potentials from the balanced detector circuit of a frequency modulation (designated FM hereinafter) receiver. These control potentials vary in the same sense, but at different rates, when tuning through the center frequency of a received modulated carrier wave. The potential difference of the control potentials is a maximum at resonance with the center frequency. The specific apparatus employed in that system required a special tube construction to make use of the aforesaid potential difference.

It is one of the important objects of my invention to improve the aforesaid Reid system, and to provide a simplified and effective means for obtaining visual tuning indication for FM receivers; accurate tuning of the receiver to the center frequency of a desired FM channel being indicated by minimum shadow angle on an electron-ray type of indicator tube.

Another important object, stated in terms of results sought to be secured, is to provide indicators free of false indications, possessing better sensitivity while using simple, standard tube types.

Still other objects of my invention are to improve generally the efficiency and reliability of FM receiver tuning indicators, and more especially to provide tuning indicators which are economically manufactured and assembled.

The novel features which I have 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 circuit embodying the invention;

Fig. 2 graphically depicts the operation of the system of Fig 1;

Fig. 3 shows a modification; and

Fig. 4 illustrates another modification.

Referring now to the accompanying drawings, wherein like reference characters in the figures represent similar circuit elements, there is shown in Fig. 1 that portion of an FM receiver between the pre-limiter network and the audio amplifier. While those skilled in the art are very familiar at the present time with the construction of an FM receiver of the superheterodyne type, the following general description is given for the purpose of clarity. The FM band covers, at the present time, a range of 43 to 50 megacycles (designated mc., hereinafter). Each FM channel in the band has a width of 200 kilocycles (referred to as kc.). That is, the carrier center frequency may be deviated a maximum of 100 kc. to each side. Any desired type of signal collector (such as a dipole, grounded antenna, loop or distribution line) may be used to feed the desired frequency modulated carrier waves to one or more tunable radio frequency amplifier stages. The amplified waves are then converted to an intermediate frequency (I. F.) by any of the well known types of converter networks. The center frequency (f_c) of the converted waves is generally chosen from a range of 2 to 10 mc., and, by way of example, let it be assumed that f_c for the intermediate frequency waves is 4.3 mc.

The I. F. waves are amplified in one or more I. F. amplifiers, and then applied to a "limiter" stage. This is designated as 1 in Fig. 1. The rectangle schematically represents such a limiter, the curve within the rectangle showing the relation between input voltage and output voltage. As is well known the limiter acts in the manner of a saturated amplifier tube. It insures that solely frequency-variable waves will reach the discriminator network of the second detector stage. Amplitude variation may be produced in the modulated carrier waves by noise impulses, fading and the prior resonant circuits. Since at the transmitter the modulation voltage amplitude appears in the carrier wave as a corresponding deviation of the carrier from the value f_c, while the modulation frequencies themselves correspond to the rate of deviation of the carrier, it follows that no spurious amplitude variation can be permitted in the modulated carrier waves when applied to the detector.

The limited I. F. waves are now applied to the FM detector circuit. The latter may be of the type shown by S. W. Seeley in U. S. Patent No. 2,121,203, granted June 21, 1938. It is not believed necessary to describe the circuit in detail. In general, numeral **2** denotes the resonant primary circuit which is tuned to f_c, and is in the plate circuit of the limiter tube. The resonant secondary circuit **3**, reactively coupled to circuit **2**, is tuned to f_c. The high potential side of circuit **2** is connected to the mid-point of the coil of circuit **3** by the direct current blocking condenser **4**. The tube **5** is a rectifier of the 6H6 type, and houses the diodes D_1 and D_2. The cathodes of the diodes are connected to opposite sides of the circuit **3**. The anodes of the diodes are connected to the opposite ends of the series-connected load resistors R_1 and R_2. The anode end of resistor R_2 is at ground potential. Each of the resistors is by-passed for I. F. currents, C_1 shunting R_1 and C_2 shunting R_1. The junction of R_1 and R_2 is connected to the midpoint of the coil of circuit **3** by choke coil **6**.

Above the detection stage is shown the typical S-shaped characteristic curve of the circuit. The curve shows the relation between rectified output voltage (ordinates) and frequency swing from f_c. At the center frequency of the applied waves the rectified voltage across R_1 is exactly equal to that across R_2, but the voltages are in polarity opposition. Hence, the total voltage across R_1—R_2 is zero at f_c. As the carrier frequency swings from f_c to either side there will be produced across the load R_1—R_2 a rectified voltage whose magnitude and polarity depend upon the extent and direction of carrier shift respectively. The modulation voltage component of rectified waves is tapped off by condenser **7**, and the modulation voltage is fed to one or more audio amplifiers followed by a reproducer.

As shown in the characteristic curve of the detector it is desirable that the applied I. F. waves have a center frequency equal to f_c; that is, the operating I. F. value. If the receiver be tuned so as to have the center frequency of the collected waves to one side of f_c, then considerable and annoying distortion is had. A visual tuning indicator is employed to facilitate tuning so as to enable the set operator to adjust the station selector accurately. In the aforesaid Reid patent it has been shown how a variable shadow indicator tube of the fluorescent target type may be employed as a tuning indicator for an FM receiver, there being secured a minimum shadow angle for solely accurate tuning of the receiver. Previous attempts to use such indicator tubes were unsatisfactory by virtue of false minimum shadow angle for the case when no carrier whatever was being received.

To operate the indicator tube T_2, there is utilized the direct current voltage component of the rectified voltage across R_1—R_2. The tube T_2 may be a 6U5 type tube, if desired. Such a tube has a triode direct current voltage amplifier section, a fluorescent target electrode **8** and the electron ray control electrode **9** which is connected to the plate of the amplifier section. As those skilled in the art will know, both target and plate are supplied from the +B terminal of a direct current source. Resistor R_7 reduces the voltage applied to the plate of the amplifier section. Hence, control electrode **9** will adjust the angular width of the electronic shadow produced on the target **8**. When the electrode **9** is at a minimum potential difference relative to the target **8**, then the shadow angle will be a minimum.

There will now be explained the manner of controlling tube T_2. The anode end of R_1 is connected to the anode of diode D_3 by resistor R_3. The cathode of D_3 is connected to the control grid **10** of the amplifier section of tube T_2. D_3 can be a 6H6 tube or a 6J5 tube; in either case, the electrodes are connected to provide a single diode. The junction of R_1 and R_2 is connected to the grid of tube T_1, say one of the 6J5 type, by resistor R_4. Each of resistors R_3 and R_4 acts as an audio voltage filter, and they may be by-passed to ground by condensers C_3 and C_4 respectively each of low impedance to audio voltages.

The plate of tube T_1 is connected to the positive end of R_7, while the cathode of tube T_1 is connected, in common with the cathode of tube T_2, to the ungrounded end of resistor R_6. Resistors R_5 and R_6 are arranged in series between the cathode of diode D_3 and the cathode of T_1. The junction of R_5 and R_6 is grounded. Merely by way of illustration, and in no way restrictive, the following constants are given:

R_1; R_2=0.1 megohm
R_3; R_4; R_5; R_7=1.5 megohms
R_6=1000 ohms
C_1; C_2=50 micro-microfarads (mmf.)
C_3; C_4=0.01 microfarad (mf.)

Considering, now, the operation of the system the voltage between the grid of tube T_1 and ground is the direct current component of the rectified voltage across R_2. The voltage between the grid **10** of tube T_2 and ground is a fraction of the total voltage across R_1 and R_2 when this voltage is positive. It is zero when the total voltage is negative. The voltage at the cathodes of T_1 and T_2 is positive, because of the currents of tubes T_1 and T_2. The voltage increases when a positive voltage is applied to the grid of T_1. The shadow angle of tube T_2 depends on the difference between the voltages on the grid and cathode of this tube. The shadow angle will be a minimum when the grid **10** is most negative with respect to cathode. In such case the potential difference between electrodes **8** and **9** is a minimum.

In Fig. 2 there are plotted various curves to show the relation between frequency deviation of the carrier from f_c and the rectified output voltages at different points in the circuit. The voltage across R_2 varies with frequency in the manner shown by curve (*a*). The total voltage across resistors R_1—R_2 varies in the manner shown by curve (*b*). The voltage developed across resistor R_5, and due to the action of diode D_3 and resistors R_3 and R_5, is shown by curve (*c*). The curve (*d*) depicts the voltage at the cathode of the tuning indicator tube T_2, and it will be noted that this curve is rather similar in shape to curve (*a*). The voltage between the grid **10** and the cathode of tube T_2 is shown by curve (*e*). Since grid **10** is always less positive than the cathode the voltage between grid **10** and cathode is always negative.

It will be observed that the maximum negative voltage on grid **10** occurs at the frequency f_c which gives zero voltage on curve (*b*). This is the desired and accurate tuning point. In general, then, when a diode is used to obtain a voltage corresponding to one half of curve (*b*) (that is, diode D_3) the difference between this voltage and the voltage of curve (*a*) is a maximum at the desired frequency. In the present circuit means is provided by which voltages proportional to curve (*a*) and the positive portion of curve (*b*) may be impressed on the cathode and grid respectively of a tuning indicator tube thereby obtaining the effect of the desired voltage difference.

In the circuit of Fig. 1 a voltage is developed across resistor R_6 even when no signal is being received. This voltage biases the triode section of tube T_2, and thus causes the shadow on the target to remain partially closed. A wider opening can be obtained by applying a negative potential to that end of R_6 which is shown connected to ground. When this is done there may be used an indicator tube of the 6E5 type, the latter being more sensitive to variations in voltage between grid and cathode. If a separate triode is used to operate the tuning indicator (as for example type 6SF5 with type 6AF6G) the target current of the tuning indicator does not have to pass through the resistor R_6. In such cases R_6 may be increased thereby providing better sensitivity. Furthermore, the initial bias applied to the tuning indicator triode can be smaller. For such a circuit arrangement a double triode of the 6SC7 type can be used to perform the functions of the triode T_1 and the triode section of the tube T_2.

In the arrangement of Fig. 1 the function of the tube T_1 is to produce a voltage across the resistance R_6 which is proportional to the voltage across the relatively high resistance R_2; the resistance R_6 having a relatively lower value. A frequency modulation detector circuit in which the voltage corresponding to curve (*a*) of Fig. 2 can be developed initially across a low resistance is shown in Fig. 3. The numeral **20** denotes a tube of the duplex diode-triode type. The diode anodes are strapped together, and function as a single diode anode. The diode anode is connected to one side of the tuned circuit **3**, a direct current blocking condenser **3'** being inserted in the connection. The control grid **21** of the triode section of tube **20** is connected to the opposite side of tuned circuit **3**. The cathode **22** is connected to ground through resistor R_2, the by-pass condenser **23** being connected in shunt with the resistor R_2. The second load resistor R_1 is connected in series with R_2. It will be understood that resistors R_1 and R_2 of Fig. 3 correspond to the resistors R_1 and R_2 of Fig. 1.

The grid and diode anode of tube **20** receive signals which have their maxima at different frequencies. The signal applied to the grid **21** causes a corresponding positive voltage to be developed across resistor R_2, and the signal applied to the diode anode produces a negative voltage across resistor R_1. The voltage across resistor R_2 will vary with frequency in the manner shown by curve (*a*) of Fig. 2, and the voltage between the diode anode of tube **20** and ground will vary in the same manner as curve (*b*) of Fig. 2. In this way the desired output characteristic is secured. The connections to the tuning indicator tube T_2 are also somewhat different in the case of Fig. 3. Resistors R_3 and diode D_3 are arranged in series between the upper end of resistor R_1 and grid **10** of the indicator tube. The cathodes of the indicator tube are directly connected to the cathode end of resistor R_2, while grid **10** is connected to ground through resistor R_5. In this circuit arrangement the resistor R_6 is not employed. The grid **21**, cathode **22**, resistor-condenser R_2 and **23**, the lower half of the input coil and choke **6** provide a detection circuit. Choke **6** is grounded for this result.

In Fig. 4 a further modification is shown wherein the upper triode section of tube **30**, which may be a 6SC7 type tube, and the upper diode of tube **31** (which may be a 6H6 type tube) act conjointly as the frequency modulation detector. The other sections of these two tubes are the diode and the control tube for the tuning indicator circuit. Thus, the diode anode **40** is connected through condenser **41** to one side of the secondary circuit **3**. The grid **50** of the upper triode of tube **30** is connected to the low potential side of circuit **3**. The load resistors R_1 and R_2 are in series between diode anode **40** and ground. The modulation voltage is taken off by condenser **7**. The lower triode section of tube **30** acts as the direct current voltage amplifier for indicator tube **60**. The latter is of the 6AF6G type, and has a pair of spaced shadows produced on independent targets **61** and **62**. Each target has its own cathode and ray control electrode.

As in Fig. 3, the +B terminal of the current source is connected to the plate **51** associated with detector grid **50**. The plate **51** is connected directly to the plate **52** by resistor R_7. The grid **54** associated with plate **52** is connected to the diode D_3 and R_3. The grid **54** is connected to ground through R_5. Condenser **55** by-passes R_3 to ground. The cathodes of indicator tube **60** are at ground potential, while cathode **41** of the detection diode is connected to the junction of R_1 and R_2. It will, therefore, be seen that the circuit arrangement of Fig. 4 is quite similar to that of Fig. 3.

Generically it will be seen that in each of the circuits the discriminator-rectifier operates the tuning indicator tube. The latter uses the combined output of the rectifiers with one of the individual outputs.

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 receiver of angular velocity-modulated carrier waves including a discriminator network, rectifier means connected with said network to provide a balanced output circuit and means for indicating resonance at the center frequency of said waves; the improvement comprising a rectifier device connected between the balanced output circuit and indicating means to apply to the latter a variable control potential developed across the entire output circuit, and a direct current voltage connection to apply a portion of the said control potential to said indicating means in opposition to said entire circuit potential.

2. In combination with a source of frequency-variable direct current voltage, an indicator tube having input electrodes, a connection including a rectifier for applying said voltage between said input electrodes, and a direct current voltage connection between one of the input electrodes and a point on said source such that a portion of the said voltage is applied to said input electrodes in opposition to said first voltage.

3. In a frequency modulated carrier wave receiver, a detection network having an output circuit across which is produced a direct current voltage whose magnitude and polarity vary with the extent and sense of shift of the center frequency of applied waves, a visual resonance indicator tube of the type having a fluorescent target and a control electrode for controlling the

fluorescence on said target, said output circuit comprising a pair of series-connected resistors, an auxiliary electron discharge tube having input and output electrodes, said control electrode being connected to said output electrodes, a series path in shunt with said pair of resistors, said series path comprising a rectifier in series with a third resistor, said auxiliary discharge tube input electrodes being connected across said third resistor, and a direct current voltage connection between one of the said input electrodes and the junction of said pair of series resistors.

4. In a frequency modulated carrier wave receiver, a detection network having an output circuit across which is produced voltage whose magnitude and polarity varies with the extent and sense of shift of the center frequency of applied waves, an indicator tube of the type having a fluorescent target and an electrode for controlling the fluorescent on said target, said output circuit comprising a pair of series-connected resistors, an auxiliary tube having input and output electrodes, said control electrode being connected to said output electrodes, a path in shunt with said pair of resistors, said path comprising a rectifier in series with a third resistor, said auxiliary tube input electrodes being connected across said third resistor, and a voltage connection between one of the said input electrodes and the junction of said pair of series resistors, the electrodes of said auxiliary tube being included in same tube envelope as said indicator tube electrodes.

5. In a frequency modulated carrier wave receiver, a detector having an output circuit across which is produced a direct current voltage whose magnitude varies with the extent of shift of the center frequency of applied waves, a visual resonance indicator tube having an electrode for controlling the indications of said tube, said output circuit comprising a pair of series-connected resistors, an auxiliary tube having input and output electrodes, said control electrode being connected to said output electrodes, a path in shunt with said pair of resistors, said path comprising a rectifier in series with a third resistor, said tube input electrodes being connected across said third resistor, a voltage connection between one of the said input electrodes and the junction of said pair of series resistors, and a common tube envelope housing the electrodes of the auxiliary tube and the electrodes of a rectifier of said detection network.

6. In combination with a frequency modulation detector of the type having a common input circuit, a pair of rectifiers and a pair of series-arranged resistors; a series path in shunt with said series resistors comprising a third rectifier in series with a third resistor, an indicator tube having a control electrode, means for applying to said control electrode the voltage difference existing between the junction point of said series resistors and the junction of said third rectifier and third resistor.

7. In a receiver of angular velocity-modulated carrier waves including a rectifier means connected to provide a balanced output circuit and means for indicating resonance at the center frequency of said waves; the improvement comprising a diode connected between the balanced output circuit and indicating means to apply to the latter a variable direct current control potential developed across the entire output circuit, and a direct current voltage path including an electron discharge tube to apply a portion of the said control potential to said indicating means in opposition to said entire circuit potential.

8. In combination with a source of frequency-variable direct current voltage, an indicator tube having input electrodes, a direct current voltage path including a diode for applying said voltage between said input electrodes, and a second direct current voltage path including a tube between one of the input electrodes and a point on said source such that a portion of the said voltage is applied to said input electrodes in opposition to said first voltage.

9. In a frequency modulated carrier wave receiver, a detection network having an output circuit across which is produced a direct current voltage whose magnitude and polarity vary with the extent and sense of shift of the center frequency of applied waves, a tube of the type having a fluorescent target and a control electrode for controlling the fluorescence on said target, said output circuit comprising a pair of series-connected resistors, an auxiliary electron discharge tube having input and output electrodes, said control electrode being connected to said output electrodes, a series path in shunt with said pair of resistors, said series path comprising a diode in series with a third resistor, said auxiliary discharge tube input electrodes being connected across said third resistor, and a direct current voltage connection including a tube between the junction of said pair of series resistors and said auxiliary tube.

10. In a frequency modulated carrier wave receiver, a detection network having an output circuit across which is produced voltage whose magnitude and polarity varies with the extent and sense of shift of the center frequency of applied waves, a tube of the type having a fluorescent target and an electrode for controlling the fluorescent on said target, said output circuit comprising a resistive path, an auxiliary tube having input and output electrodes, said control electrode being connected to said output electrodes, a second path, in shunt with said first path, comprising a rectifier in series with a resistor, said auxiliary tube input electrodes being connected across said resistor, and a connection betweeen one of the said input electrodes and a point of said resistive path, the electrodes of said auxiliary tube being included in same tube envelope as said indicator tube electrodes.

11. In a frequency modulated carrier wave receiver, a detector having an output circuit across which is produced a direct current voltage whose magnitude varies with the extent of shift of the center frequency of applied waves, an indicator tube having an electrode for controlling the indications of said tube, said output circuit comprising a resistive path, an auxiliary tube having input and output electrodes, said control electrode being connected to said output electrodes, a second path, in shunt with said first path, comprising a rectifier in series with a resistor, said tube input electrodes being connected across said resistor, a voltage connection betweeen one of the said input electrodes and a point on said resistive path, and a common tube envelope housing the electrodes of the auxiliary tube and the electrodes of a rectifier of said detection network.

12. In combination with a detector of angular velocity-modulated carrier waves having a common input circuit, a pair of rectifiers and a resistive path; a second path in shunt with said resistive path comprising a third rectifier in series with a resistor, an indicator tube having a

control electrode, means for applying to said control electrode the voltage difference existing between a predetermined point of said first path and the junction of said third rectifier and resistor.

13. In a receiver of angular velocity-modulated carrier waves, a discriminator input circuit for converting frequency-variable waves into amplitude variable waves, a first tube embodying at least two electron sections, a second tube embodying at least two diodes, means connecting one of said electron sections and one of said diodes to said input circuit to provide a rectifier network for the said amplitude variable waves, a resistive path in circuit with said rectifier network to provide a source of rectified voltage, an indicator device including a control electrode, means connecting the output electrodes of the second electron section of the first tube to the said indicator control electrode, a second path comprising the second diode of the second tube, connected in shunt with said resistive path, and a control connection between said second diode and the input electrode of said second electron section.

14. In a receiving system of frequency modulated carrier waves, a network for transforming the frequency-variable carrier waves into amplitude-variable carrier waves, a rectifier network for the amplitude-variable waves comprising a tube having at least two electron sections, said sections being in circuit with said transforming network to provide rectified carrier voltage across a resistive path, a second path, in shunt with the first path, comprising a device of unidirectional conductivity and a resistive impedance, an electronic indicator device provided with an electron control element, means, responsive to voltage variation across said resistive impedance, for controlling the potential of the control element.

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