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M. G. CROSBY

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FREQUENCY MODULATION RECEIVER TUNING INDICATOR

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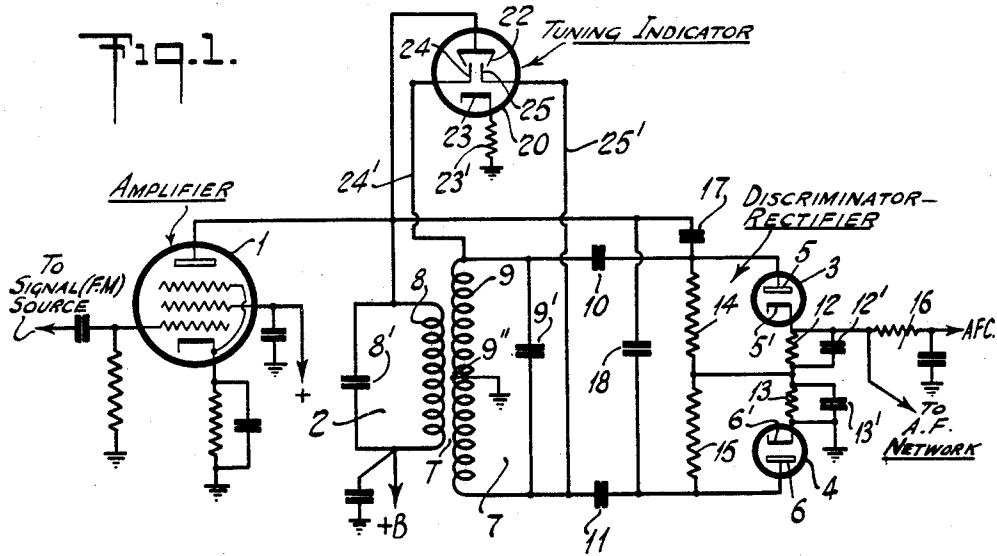


Fig. 2a.

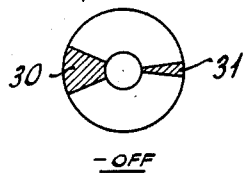


Fig. 2b.

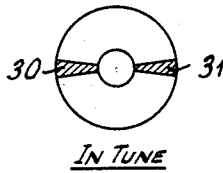


Fig. 2c.

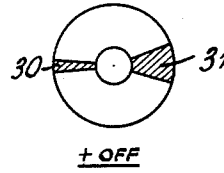


Fig. 3b.

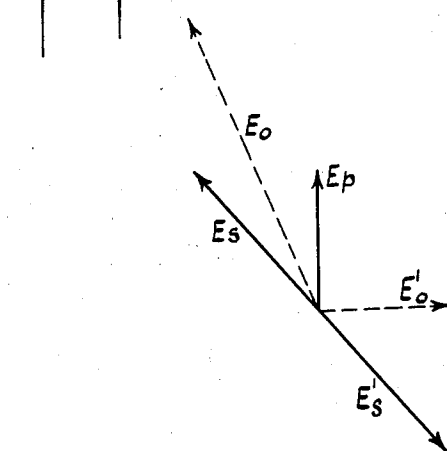
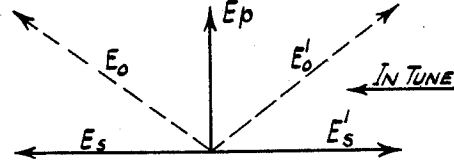


Fig. 3a.



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UNITED STATES PATENT OFFICE

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

Application March 27, 1943, Serial No. 480,762

18 Claims. (Cl. 250—40)

My present invention relates generally to resonance indicators for angle modulated carrier wave energy receivers, and more particularly to a tuning indicator circuit adapted for use in a frequency modulation receiver to indicate the proper tuning point.

In the reception of angle modulated carrier wave energy, it is generally desirable to provide a visual indication of accurate resonance of the receiving system with applied modulated wave energy. By the term "angle modulated carrier wave energy" is generically meant either frequency modulated (FM) carrier wave energy or phase modulated (PM) carrier wave energy. In the reception of FM carrier wave energy with a superheterodyne receiver it is important that the receiver tuning circuits be adjusted during the tuning process so that the modulated intermediate frequency (I. F.) energy has a mean frequency value accurately corresponding to the frequency midpoint of the frequency discriminator characteristic. The latter characteristic generally has the appearance of an inclined S-shaped curve, wherein the section of the curve connecting the two spaced peaks is substantially linear. The center of the linear portion of the characteristic corresponds to the mean frequency value of the applied modulated carrier energy. Unless the applied FM energy has its mean frequency value equal to the frequency at the middle of the aforesaid discriminator characteristic, there is produced a type of distortion which is analogous to the inaccurate adjustment of bias on an audio frequency amplifier tube in amplitude modulation reception. In general, then, it can be said that it is difficult accurately to tune an FM receiver.

In my U. S. Patent No. 2,296,089, patented September 15, 1942, I have disclosed an electronic indicating device for indicating to the operator of an FM receiver when the receiver is in proper tune so that distortion due to frequency misalignment is avoided. In that patent the electronic indicator device was an electron ray indicator tube of the dual shadow type. The tube was so connected with the frequency discriminator as to provide balanced shadow angles for the "in tune" position, and oppositely off-balance shadow angles for the two directions of mistuning. More specifically, the patented circuits utilized direct current voltage amplifier stages for operating the tuning indicator device from the output circuit of the frequency discriminator rectifiers. These prior arrangements required additional

circuit elements, and, hence, were more expensive to use.

It may, therefore, be stated that it is one of the main objects of my present invention to eliminate the need for direct current voltage amplifiers in connection with the tuning indicator device, and to operate the latter directly from the discriminator circuit itself.

Another important object of this invention is to provide a tuning indicator circuit of the dual shadow type, wherein the electron ray control elements may be energized by the modulated carrier energy instead of being energized solely by direct current voltages as in the past.

Another object of the invention is to provide a discriminator-rectifier network in a system for receiving angle modulated carrier wave energy, wherein the discriminator circuit has connected to it a tuning indicator device whose control is directly dependent upon the received angle modulated carrier energy.

Another object of my present invention is to provide a visual current indicator for FM receivers, wherein the indicator informs the operator whether or not the receiver is in tune and whether or not the received wave is modulated. Still other objects of my present invention are to improve generally the simplicity and efficiency of tuning indicator circuits for FM receivers, and more especially to provide a tuning indicator arrangement for an FM receiver which is not only reliable in operation, but is economically manufactured and assembled in the receiver.

The novel features which I believe to be characteristic of my invention are set forth with 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 I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows a circuit arrangement embodying the invention,

Figs. 2a, 2b and 2c show respectively different appearances of the indication shadows of the tuning indicator device,

Figs. 3a and 3b show respectively different vector relations at the discriminator circuit for respectively different tuning conditions.

Referring specifically to Fig. 1 of the drawing, there is shown the entire detector network of an FM receiver, as well as those circuits which are essential to a proper understanding of this in-

vention. While those skilled in the art are fully aware of the manner of designing a receiver of the FM type, a general review thereof will be given in order to provide an adequate background for the present invention. While the present invention is not limited to any specific frequency ranges, since the invention is equally applicable in the kilocycle (kc.) range or in the megacycle (mc.) range, by way of example let it be assumed that the present receiving system is to be employed in a frequency range of 40 to 50 mc. Let it, also, be assumed that the receiver is of the superheterodyne type, that it is capable of selectively receiving signals of a desired one of a plurality of modulation channels in the particular frequency range, and that an I. F. (intermediate frequency) value of about 3 mc. is utilized. It is, again, emphasized that the invention is entirely independent of these specific frequency values.

A superheterodyne receiver of this type would employ at least one ultra-high frequency amplifier which is tunable over the frequency range, a converter stage having a similarly tunable signal input circuit, and one or more I. F. amplifiers each fixedly tuned to the operating I. F. value of 3 mc. The signal output energy of the last I. F. amplifier would be fed to an amplitude limiter stage functioning to attenuate all amplitude components of noise and modulation. The invention is not limited to use of a limiter prior to the detector. The reference numeral 1 is to be understood as indicating an amplifier tube constructed to function as a limiter. The latter would usually employ a sharp cut-off tube having its input and output circuits resonated to the operating I. F. value. In other words, the resonant output circuit 2 of the limiter stage 1 is tuned to the mean frequency of the applied I. F. energy.

As is well known, the I. F. signal energy in an FM receiver comprises a wide band of radio frequencies whose midpoint frequency has the selected I. F. value. In other words, the received FM carrier energy has been reduced in mean frequency to the I. F. value. The audio modulation signal components are represented in the I. F. band as different carrier frequency components of the same amplitude. The rate at which the midband carrier frequency is varied corresponds to the frequency of the impressed audio wave, while the extent of the midband frequency variation is proportional to the amplitude of the audio signal components employed at the transmitter. One of the essential differences between a PM wave and an FM wave is the fact that the extent of deviation for the lower audio frequency components is less in the case of PM waves. Hence, it will be seen that the present invention is equally applicable for indicating accurate tuning in the case of PM reception.

The detection of an FM wave is carried out by a network which is capable of producing a unidirectional voltage varying at an audio rate. The unidirectional voltage depends in magnitude on the instantaneous frequency deviation of the applied I. F. energy from the predetermined midband frequency. The latter value is, of course, the resonant frequency of the circuit 2. The polarity of the detected voltage depends on the direction of frequency deviation of the applied I. F. signal energy from the aforesaid predetermined frequency. Such a detector network is shown in Fig. 1 as comprising a pair of diode rectifiers 3 and 4. The anodes 5 and 6 of diodes 3 and 4 respectively are connected to opposite sides of the resonant input circuit 7. The latter circuit is actu-

ally the tuned secondary circuit of the input transformer T. The primary winding of the transformer is indicated by reference numeral 8, while the secondary winding is indicated by reference numeral 9. Condenser 8' is connected in shunt with winding 8, and tunes the primary circuit 2 to the predetermined mean frequency F_c . The condenser 9' shunts secondary winding 9, and tunes the secondary circuit 7 to the same mean frequency F_c . This frequency F_c is, in the present instance, the I. F. value.

According to one feature of my present invention, the midpoint 9'' is established at a point of invariable potential, such as ground. Hence, there can be taken off from the opposite ends of winding 9 alternating potentials of equal magnitude and opposite polarity. The direct current blocking condenser 10 couples anode 5 to the upper end of winding 9. The direct current blocking condenser 11 couples the lower end of winding 9 to anode 6. The cathodes 5' and 6' of diodes 3 and 4 are connected together by the respective series-arranged load resistors 12 and 13. Load resistor 12 is shunted by the carrier bypass condenser 12', and the load resistor 13 is shunted by its carrier bypass condenser 13'. The cathode end of resistor 13 is established at ground potential. The junction of load resistors 12 and 13 is connected to the junction of the series resistors 14 and 15.

The upper end of resistor 14 is connected to anode 5 and to the condenser 10, while the resistor 15 is connected to the junction of anode 6 and condenser 11. From the cathode end of resistor 12 there is derived modulation signals corresponding to the original modulation signals which were applied to the carrier at the transmitter. There may, also, be taken off from the cathode end of resistor 12 automatic frequency control (AFC) voltage. The resistor-condenser filter network 16 is inserted in the AFC line in order to eliminate any pulsating voltage components. The AFC voltage is employed, of course, to regulate the frequency of the local oscillator.

The discriminator-rectifier circuit described up to this point is different from that disclosed in my aforementioned patent. In the latter the junction of the load resistors 12 and 13 was returned to the midpoint 9'' through a radio frequency choke coil, and the said midpoint was ungrounded. Furthermore, a coupling capacity was connected between the high potential side of winding 8 and midpoint 9''. Such a detection network has been disclosed and claimed by S. W. Seeley in U. S. Patent No. 2,121,103, granted June 21, 1938. In the present circuit, however, the primary circuit voltage is applied to the opposed rectifiers 3 and 4 by means of the parallel condensers 17 and 18. Condenser 17 is connected from the high potential side of winding 8 to the anode end of resistor 14, while condenser 18 is connected from the high potential side of the primary circuit 2 to the anode end of resistor 15.

Generally speaking, the functioning of the discriminator-rectifier network described herein is similar to that disclosed in the aforesaid Seeley patent. As long as the instantaneous frequency of the applied I. F. signal energy, that is the signal energy applied to the primary circuit 2, is equal to the predetermined frequency of circuit 2, then the vector relations shown in Fig. 3a will exist. In that figure the vector E_p designates the signal voltage existing across the primary circuit 2. This primary circuit voltage is applied in like polarity to each rectifier. Simultaneous-

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ly, and by virtue of the magnetic coupling between windings 8 and 9, there is developed across each half of winding 9 a secondary voltage. The secondary voltage developed across the upper half of winding 9 is assumed to be represented by the vector E_s . The vector E'_s represents the secondary voltage developed across the lower half of secondary winding 9. The voltages E_s and E'_s are respectively applied in opposite polarity through the respective coupling condensers 10 and 11 to respective rectifiers 3 and 4.

Hence, it is seen that each rectifier has applied to it in phase quadrature primary voltage E_p and a secondary voltage E_s . The secondary voltages applied to the opposed rectifiers are, however, in polarity opposition. The resultant vector E_o which is rectified by each of the rectifiers is also shown in Fig. 3a. The rectifiers 3 and 4 respectively rectify the resultant vectorial voltages E_o and E_o' . For the "in tune" condition of the receiver these vector quantities are equal in magnitude. Since the rectifiers are oppositely connected, it follows that the rectified voltages developed across resistors 12 and 13 will be of equal magnitude but of opposite polarity and will cancel out. Accordingly, for the "in tune" condition of the receiver there will be no AFC bias produced.

Assume, however, that the frequency of the signal energy applied to the primary circuit 2 deviates from the predetermined frequency F_o of circuits 2 and 7. The vector relations which now exist are those depicted in Fig. 3b. The primary voltage E_p is the same as the "in tune" case. However, the secondary voltages are shifted in phase with respect to the primary voltage. This shift in phase takes place due to the phase characteristic of the transformer. Hence, one of the resultant vectors exceeds the other in magnitude. It is assumed that the resultant vector E_o is of greater magnitude than the vector E_o' . In other words, the signal voltage applied to rectifier 3 exceeds the signal voltage applied to rectifier 4. In that case there will be rectified voltage developed for AFC bias.

Should the instantaneous frequency of the signal energy applied to circuit 2 now shift in the opposite direction relative to the mean frequency, then the vector E_o' will exceed the vector E_o in magnitude. The aforesaid explanation of the functioning of the discriminator-rectifier network to provide AFC voltage applies equally well to the production of modulation signal voltage. In the latter case the vector relations of Fig. 3a represent the instantaneous relations when the signal frequency is momentarily of mean frequency. Fig. 3b, then, represents relations for the relatively rapid instantaneous deviations from the said mean frequency. It will, therefore, be seen that there has been accomplished the same function as in the case of the aforesaid Seeley patent, but without utilizing the specific circuit connections thereof. Furthermore, by virtue of the grounding of the midpoint 9' a further feature of the present invention is made possible. According to this further feature of my invention, the changes in resonant condition of the receiver may be readily visualized by means of an electronic indicator device designated by numeral 20.

This device is shown by way of specific example as a twin shadow indicator tube of the 6AF6G type. This type of tube is well known to those skilled in the art. In general, the tube is provided with an envelope in which is included a

fluorescent target. The latter 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 through a resistor 23', is positioned to bombard the interior surface of the anode 22 with electrons. Therefore, the entire interior surface of anode 22 becomes luminous as electrons from cathode 23 impinge thereupon. The electron ray control electrodes, or rods, 24 and 25 are spaced from cathode 23, but are arranged in parallel on opposite sides of the cathode. Hence, there are provided a pair of diametrically opposite shadow areas on the fluorescent target. By the term "shadow area" is meant an area of the coated target surface which is non-luminous due to electron deflection.

As is well known to those skilled in the art, each of the rods 24 and 25 must be connected to potential points such that normally each ray control rod deflects a maximum amount of electrons from that portion of the fluorescent surface which is in alignment with each rod. In other words, the rods 24 and 25 act as shadow producing rods. The target 22 is connected to the plate voltage connection of tube 1. Accordingly, the plate voltage supply of amplifier 1 may be used as a source of positive target potential for target 22. The ray control electrode 24 is connected by lead 24' to the upper end of winding 9. The ray control rod 25 is connected by lead 25' to the opposite end of winding 9. It will be seen that each of the ray control rods 24 and 25 has applied to it secondary voltage E_s or E'_s . The target 22 has applied to it primary voltage E_p . In this regard the present feature of the invention differs entirely from the circuit of my aforementioned U. S. Patent No. 2,296,089. In the latter case the electrodes of the indicator tube were operated solely by direct current voltages.

In Figs. 2a, 2b and 2c I have shown the appearances of the shadow areas on the fluorescent target 22 for three different conditions of tuning. In Fig. 2a there are shown the patterns, or shapes, of the shadow areas on target 22 when the receiver is de-tuned to one side. Fig. 2b shows the "in tune" condition of receiver, while Fig. 2c shows mistuning of the receiver to the opposite side of mean frequency. It will be noted that the "in tune" condition has the shadow areas 30 and 31 produced by the control rods 24 and 25 of exactly the same shape and area. However, when the receiver is de-tuned to one side of resonance the shadow area 30 widens while the shadow area 31 narrows. The reverse is true for mistuning to the opposite side, as shown in Fig. 2c.

To explain the functioning of the tuning indicator in further detail, it is again pointed out that for the "in tune" condition the alternating voltage on the target 22 and the alternating voltages on each of the control rods 24 and 25 are balanced and 90 degrees apart in phase. In other words, the relation shown in Fig. 3a exists. This means that equal forces are applied to the electrodes of tube 20, and the shadow angles appear as shown in Fig. 2b. In the "off tune" condition the secondary voltage shifts in phase, as shown in Fig. 3b, so that the vector relations between the primary and secondary voltages changes. In the latter situation the alternating current voltage on the target 22 and on one of the control electrodes 24 or 25 tend to approach an "in phase" condition, while the same voltages on the target and the other control electrode tend to approach an "out-of-phase" condition. This is clearly

shown in Fig. 3b wherein the voltages E_p and E_s approach in-phase condition, while the voltages E_p and E_s approach out-of-phase condition. When the ray control electrode swings positive the shadow angle is reduced. When the target 22 is swung positive the shadow angle is increased to a small degree.

Hence, for the section of the indicator tube which has the two voltages near the in-phase condition the ray control voltage will oppose, and overcome, the effect of the target voltage variation. For the other section of the tube the ray control voltage will aid the effect of the target voltage variation. Hence, there is produced a differential effect which shows up as unsymmetrical shadow angles, as shown in Figs. 2a and 2c respectively.

It will now be appreciated that by grounding the midpoint of the secondary winding 9 it is a simple matter to provide the requisite secondary voltages for rods 24 and 25. Hence, the electronic indicator device 20 simply and effectively indicates the phase shift between the primary and secondary voltages of the input transformer T, and accurately and quickly indicates when the phase relations depart from the desirable quadrature relation of Fig. 3a. It will be clear that for resonance indication the indicator 20 indicates the average frequency deviation of the main frequency of the applied signal energy from the predetermined reference frequency of primary and secondary circuits 2 and 7. It, also, indicates the relatively rapid frequency deviations represented by the frequency modulation of the carrier. However, these rapid variations have a balanced effect on the operation of the indicator, and, therefore, do not destroy the indication since the "in tune" condition is indicated by a balance of the shadow angles. The rapid variation of the shadow angles shows up as a "fluttering" boundary, and furnishes an indication that modulation exists on the carrier. Hence, the present indicator additionally acts as a form of modulation indicator.

While I have indicated and described a system 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 organization 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 combination with a source of frequency-variable signal energy, a pair of opposed rectifiers having a common differential output circuit, a primary circuit tuned to a predetermined mean frequency, a secondary circuit coupled to the primary circuit and tuned to said mean frequency, means for establishing the midpoint of said secondary circuit at an invariable potential, means for applying signal voltage across said primary circuit to each of said rectifiers in like phase relation, and means for applying secondary signal voltage derived from opposite sides of said secondary midpoint to said rectifiers.

2. In combination with a source of frequency-variable signal energy, a pair of opposed rectifiers having a common differential output circuit, a primary circuit tuned to a predetermined mean frequency, a secondary circuit coupled to the primary circuit and tuned to said mean frequency, means for establishing the midpoint of said secondary circuit at an invariable potential, means for applying signal voltage across said primary

circuit to each of said rectifiers in like phase relation, means for applying signal voltage from said secondary circuit and on opposite sides of said midpoint to said rectifiers, an electronic indicator of the type comprising an electron emitter, a fluorescent target and a pair of electron deflection rods, means for connecting said target to said primary circuit, and separate connections from each of said electron deflection rods to said secondary circuit on opposite sides of said midpoint.

3. In combination with a source of angle modulated signal energy, a pair of opposed diode rectifiers having a common differential resistor output circuit, a primary circuit tuned to a predetermined mean frequency, a secondary circuit magnetically coupled to the primary circuit and tuned to said mean frequency, means for establishing the midpoint of said secondary circuit at ground potential, means for applying signal voltage across said primary circuit to each of said rectifiers in like phase relation, means for applying secondary signal voltage derived from said secondary circuit on opposite sides of said midpoint to said rectifiers.

4. In combination with a source of frequency-variable signal energy, a primary circuit tuned to a predetermined mean frequency, a secondary circuit reactively coupled to the primary circuit and tuned to said mean frequency, means for establishing the midpoint of said secondary circuit at an invariable potential, an electronic indicator of the type comprising an electron emitter, a fluorescent target and a pair of electron deflection rods, means for connecting said target to said primary circuit, and separate connections from each of said electron deflection rods to said secondary circuit on opposite sides of said midpoint.

5. In combination with a source of frequency modulated signal energy, a pair of opposed rectifiers having a common differential resistive output circuit, a primary circuit tuned to a predetermined mean frequency, a secondary circuit magnetically coupled to the primary circuit and tuned to said mean frequency, means for establishing the midpoint of said secondary circuit at an invariable potential, means for applying signal voltage across said primary circuit to each of said rectifiers in like phase relation, and means for applying signal voltage from said secondary circuit and on opposite sides of said midpoint to said rectifiers.

6. In combination with a source of angle modulated signal energy, a pair of opposed rectifiers having a common differential output circuit, a primary circuit tuned to a predetermined mean frequency, a secondary circuit coupled to the primary circuit and tuned to said mean frequency, means for establishing the midpoint of said secondary circuit at an invariable potential, means for applying signal voltage across said primary circuit to each of said rectifiers in like phase relation, means for applying signal voltage from said secondary circuit to said rectifiers in opposed polarity relation, an electronic indicator of the type comprising an electron emitter, a fluorescent target and a pair of electron deflection rods, means for connecting said target to said primary circuit, and individual energizing connections from each of said electron deflection rods to said secondary circuit on opposite sides of said midpoint.

7. In combination with a source of frequency-variable signal energy, a pair of opposed diode

rectifiers having a common differential resistive output circuit, a primary circuit tuned to a predetermined mean frequency, a secondary circuit reactively coupled to the primary circuit and tuned to said mean frequency, means for establishing the midpoint of said secondary circuit at an invariable potential, means for applying signal voltage across said primary circuit to each of said rectifiers in like phase relation, and means for applying signal voltage from said secondary circuit and on opposite sides of said midpoint to said rectifiers.

8. In combination with a source of angle modulated signal energy, a primary circuit tuned to a predetermined mean frequency, a secondary circuit coupled to the primary circuit and tuned to said mean frequency, means for establishing the midpoint of said secondary circuit at an invariable potential, means functioning as a resonance indicator and as a modulation indicator comprising an electronic device of the type comprising an electron emitter, a fluorescent target and a pair of electron deflection rods, means for connecting said target to said primary circuit, and separate connections from each of said electron deflection rods to said secondary circuit on opposite sides of said midpoint.

9. In combination with a source of frequency-variable signal energy, a pair of opposed rectifiers having a common differential output circuit, a primary circuit tuned to a predetermined mean frequency, a secondary circuit coupled to the primary circuit and tuned to said mean frequency, means for establishing the midpoint of said secondary circuit at an invariable potential, means for applying signal voltage across said primary circuit to each of said rectifiers in like phase relation, means for applying signal voltage from said secondary circuit and on opposite sides of said midpoint to said rectifiers, there being provided secondary signal voltages on either side of said midpoint which are in phase opposition, and each of said rectifiers having applied thereto a resultant of said primary voltage and a respective one of said secondary voltages.

10. In combination with a source of signal energy subject to departures in mean frequency from a predetermined reference frequency, a pair of coupled resonant circuits arranged in cascade and each tuned to said reference frequency, the second one of said coupled circuits comprising a coil shunted by a condenser, means for grounding the midpoint of said coil, an electronic resonance indicator comprising an electron emitter, a fluorescent target and a pair of ray control rods, means energizing said fluorescent target from the first of said coupled resonant circuits, separate connections from said ray control rods to respective ends of said coil whereby said control rods have secondary voltages applied thereto in opposite phase, but each secondary voltage being in phase quadrature with the primary voltage at said primary circuit in response to said mean frequency being equal to said reference frequency.

11. In combination with a source of frequency-variable signal energy, a pair of opposed rectifiers having a common differential output circuit, a primary circuit tuned to a predetermined mean frequency, a secondary circuit coupled to the primary circuit and tuned to said mean frequency, means for establishing the midpoint of said secondary circuit at an invariable potential, there being provided secondary signal voltages on either side of said midpoint which are in phase opposition, and means for applying to each of

said rectifiers a resultant of said primary voltage and a respective one of said secondary voltages.

12. In combination with a source of angle modulated signal energy subject to departures in mean frequency from a predetermined reference frequency, a pair of coupled resonant circuits arranged in cascade and each tuned to said reference frequency, the second one of said coupled circuits comprising a coil shunted by a condenser, means for grounding the midpoint of said coil, an electronic resonance indicator comprising an electron emitter, a fluorescent target and a pair of ray control rods, means energizing said fluorescent target from the first of said coupled resonant circuits, means coupling said source to said first resonant circuit, separate connections from said ray control rods to respective ends of said coil whereby said control rods have secondary voltages applied thereto in opposite phase, but each secondary voltage being in phase quadrature with the primary voltage at said primary circuit in response to said mean frequency being equal to said reference frequency.

13. In combination with a source of frequency modulated signal energy subject to departures in mean frequency from a predetermined reference frequency, a pair of magnetically coupled resonant circuits arranged in cascade and each tuned to said reference frequency, the second of said coupled circuits comprising a coil shunted by a condenser, means for grounding the midpoint of said coil, a resonance indicator comprising an electron emitter, a fluorescent target and a pair of ray control rods, means energizing said fluorescent target from the first of said coupled resonant circuits, said source being coupled to the first resonant circuit, separate connections from said ray control rods to respective ends of said coil whereby said control rods have secondary voltages applied thereto in opposite phase for energizing them, but each secondary voltage being in phase quadrature with the primary voltage at said primary circuit in response to said mean frequency being equal to said reference frequency.

14. In combination with a source of signal energy, a primary circuit coupled to said source and being tuned to a predetermined mean frequency, a secondary circuit reactively coupled to the primary circuit and being tuned to said mean frequency, means for establishing the midpoint of said secondary circuit at an invariable potential, an electronic indicator of the type comprising an electron emitter, a fluorescent target and at least one electron deflection rod, means for connecting said target to said primary circuit thereby to apply primary signal voltage thereto, and a separate connection from said electron deflection rod to a point on said secondary circuit such that secondary signal voltage is applied to said rod, and said primary and secondary voltages being in substantial phase quadrature in response to said signal frequency being equal to said mean frequency.

15. In combination with a source of signal energy subject to departures in mean frequency from a predetermined reference frequency, at least two resonant circuits coupled in cascade and each tuned to said reference frequency, the second one of said coupled circuits comprising a coil shunted by a condenser, means for grounding the midpoint of said coil, an electronic resonance indicator comprising an electron emitter, a fluorescent target and at least one ray control rod, means energizing said fluorescent target from the

first one of said coupled resonant circuits, a connection from said ray control rod to a point on said coil on one side of said midpoint whereby said control rod has secondary voltage applied thereto in substantial phase quadrature with the primary voltage at said primary circuit in response to said mean frequency being equal to said reference frequency.

16. In combination with a source of modulated signal energy subject to departures in mean frequency from a predetermined reference frequency, an electronic resonance indicator comprising an electron emitter, a fluorescent target and at least one ray control rod, means energizing said fluorescent target from said source of signal energy, means deriving from said source a signal voltage in phase quadrature with the source voltage in response to said mean frequency being equal to said reference frequency, and means for energizing said control rod with said quadrature voltage.

17. In combination with a visual indicator device of the type comprising an electron stream emission element, means responsive to electrons adapted to become luminous and means to control the electron stream to regulate the degree of luminosity of said means, a source of modulated carrier energy, a network constructed and arranged to derive from said source a pair of modulated carrier voltages in phase quadrature rela-

tion in response to said carrier frequency being equal to a desired reference frequency, means for applying one of said pair of voltages to said luminous means, and separate means for applying the second of said pair of voltages to said control means thereby to provide an indication of deviations of said carrier frequency from said reference frequency.

18. In a receiver of frequency modulated signal energy, a pair of opposed rectifiers having a common differential modulation output circuit, a primary circuit tuned to a predetermined frequency, means to apply signal energy to the primary circuit, a secondary circuit coupled to the primary circuit and tuned to said frequency, means for establishing the midpoint of said secondary circuit at an invariable potential, means for applying signal voltage across said primary circuit to each of said rectifiers in like phase relation, means for applying signal voltage from said secondary circuit to said rectifiers in opposed polarity relation, a tuning indicator of the type comprising an electron emitter, a fluorescent target and at least one electron deflection electrode, means for energizing said target with signal voltage from said primary circuit, and an energizing connection from said electron deflection electrode to said secondary circuit on one side of said midpoint.

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