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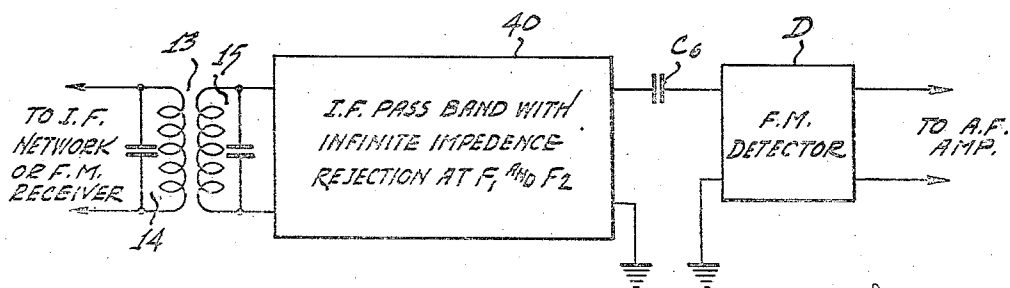
2,457,016

FREQUENCY MODULATION RECEIVER TUNING AID

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2 Sheets-Sheet 2

Fig. 4.



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FREQUENCY MODULATION RECEIVER
TUNING AIDBenjamin S. Vilkomerson, Camden, N. J., assignor
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My present invention relates generally to tuning aids for frequency modulation receivers, and more particularly to a novel and improved device for enabling a listener accurately to tune his receiver.

One of the main objects of this invention is to provide a novel arrangement for visually indicating in a frequency modulation receiver of the locked-in oscillator type whether or not frequency modulation (FM) signals are being received, and whether or not the receiver is accurately tuned to resonance with the center, or mid-channel, frequency of the desired FM station. In accordance with one aspect of the invention there is provided a visual indicator tube of the dual shadow type. One of the shadows has its angle or area controlled in accordance with the frequency of the locked-in oscillations, while the second shadow has its angle controlled in response to the magnitude of the received FM signal. In this way, observation of the dual shadow informs the listener whether FM signals are being received, and whether the receiver is accurately in tune.

Another important object of my present invention is to provide a novel method of preventing spurious detection along the slopes of the FM detection characteristic at frequencies below or above the peak response frequencies of the detection characteristic. Such method positively prevents the impression upon the detector input terminals of any frequency-variable energy outside of a restricted frequency range, such restricted frequency range being substantially less than the frequency difference between the peak response frequencies of the detector characteristic. My invention further provides a "one-spot" tuning system for receiving FM signals wherein a frequency change-responsive detector with opposite peak output response frequencies centered about the FM carrier frequency is preceded by a locked-in oscillator, or other network, of such frequency response characteristic that its pass band is centered on said FM carrier frequency and is completely within, and of negligible amplitude at and beyond the aforementioned opposite detector peak response frequencies.

Another object of this invention is to provide in an FM receiver of the type embodying a locked-in oscillator, whose lock-in range is substantially less than the frequency spacing between the peak frequencies of the FM detector, a tuning indicator tube which has a pair of electronic shadows, both shadows being of minimum angle or area

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when the FM signals impressed on the locked-in oscillator have a center frequency equal to the predetermined operating frequency of such oscillator.

Still other objects of my invention are to improve generally the efficiency and simplicity of tuning indicators for FM receivers, and more especially to provide tuning aids in such receivers in an economical manner.

Other objects and features of my invention will best be understood by reference to the following description, taken in connection with the drawings, in which I have indicated a circuit whereby my invention may be carried into effect.

In the drawing:

Fig. 1 is a circuit diagram of an embodiment of my invention;

Figs. 2a, 2b, and 2c show respective appearances of the indicator target for different conditions of reception;

Fig. 3 shows a typical FM detection characteristic; and

Fig. 4 is a circuit diagram of a modification of my invention.

In Fig. 1 I have shown a receiver circuit embodying my invention and including a locked-in oscillator acting as a frequency divider of FM signals. Such circuit is generally of the type disclosed by G. L. Beers in his U. S. Patent No. 2,356,201, granted August 22, 1944. More specifically, the locked-in oscillator circuit shown is that disclosed by M. C. Corrington in his application Serial No. 596,474, filed May 29, 1945. The locked-in oscillator functions concurrently to reduce, or divide, the mean frequency of the applied FM signal waves, and proportionately to reduce the extent of frequency deviation of the waves. It will be described herein by way of example, as dividing the intermediate frequency by a factor of 4. Assuming that the FM receiver is of the superheterodyne type, and that the networks prior to the locked-in oscillator tube are conventional in nature, the transformer 13 will have its primary circuit 14 and its secondary circuit 15 each tuned to the operating intermediate frequency (I. F.) of the system. I have assumed an I. F. value of 10.7 megacycles, but may use any other suitable intermediate frequency.

The received FM waves may be those which are transmitted in the present assigned FM band of 42 to 50 megacycles (mc.), or they may be in the recently assigned 88 to 108 mc. range. The invention is not limited to any particular fre-

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quency band or to the reception of FM waves, since it is generally applicable to angle modulated carrier waves. Those skilled in the art of radio communication are fully aware of the fact that in each channel the FM waves transmitted in the aforementioned assigned FM band are presently allotted a maximum frequency swing of 150 kc. (kilocycles). That is, a maximum deviation of ± 75 kc. in respect to the mean, or center, frequency. The frequency deviation at any instant is dependent upon the amplitude of the modulation signals at the transmitter, while the time for a cycle of the frequency deviation is equal to the period of the modulating signal per se. It is to be understood that my invention is not limited to the specific locked-in oscillators shown in the Beers patent and Corrington application.

The collected FM waves are usually selected in one or more stages of tunable radio frequency amplification, after which they are combined with locally-produced oscillations at the first detector network. The output of the first detector, or converter, is the I. F. (intermediate frequency) energy. In other words, the I. F. energy is the FM wave whose mean frequency has been reduced to a much lower frequency, but whose frequency deviation is unchanged. After amplification by one or more stages of I. F. amplification, the I. F. energy is applied to the locked-in oscillator for concurrent frequency division and reduction of the frequency deviation.

The FM signal energy, with its mean frequency at the operating I. F. value, is applied to the input grid 2 of tube 1. The latter may be, for example, a miniature tube of the pentagrid type. The input grid 2 is connected to the high alternating potential side of the secondary circuit 15. The low potential side of circuit 15 is returned to the grounded cathode 3 through resistor R_1 shunted by condenser C_9 , the latter comprising a network designated by the numeral 16. The function of the network 16 is to provide voltage across the resistor element R_1 in response to grid current flow through the signal input grid circuit. Such grid voltage developed across the resistor R_1 may be utilized for automatic volume control (AVC). The AVC voltage is employed automatically to bias the control grids of the preceding amplifier tubes in a manner well-known to those skilled in the art.

The plate circuit 5 in Fig. 1 has an operating band width of between 50 and 65 kc. while the mean frequency of the output voltage of the locked-in oscillator has a value of one-fourth of 10.7 mc., i. e. 2675 kc. This is appropriate since the effect of the locked-in oscillator network has been to divide the mean frequency of the FM wave energy by a factor of 4, and the overall frequency deviation range has, also, been divided by the same factor. The pass band width should be sufficiently above 37.5 kc. to provide suitable operating tolerances. Further, the plate current is substantially constant regardless of amplitude variations at the signal input grid.

The advantages of frequency division at this point of the FM receiving system have been explained in the Beers patent. The extension of the lock-in range of the oscillator accomplished by the circuit employed herein, and shown in the aforesaid Corrington application, enables reception of waves which are frequently modulated over a wider range, and guards against distortion which might otherwise occur by reason of "break-out" effect. Since the wave energy developed

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across the plate circuit 5 is modulated in strict accordance with the originally received FM signals save that the mean frequency and extent of frequency deviation have been proportionately reduced, the output of the locked-in oscillator may now be subjected to suitable frequency discrimination and rectification to reproduce the signals.

Further considering the specific construction and operation of the locked-in oscillator circuit, the oscillator grid 6 of tube 1 is connected by lead 6' to the high alternating potential side of tickler coil L_1 . The lower end of the coil is connected to ground through the parallel-connected combination of resistor R_3 and condenser C_{10} . Condenser C_2 shunts the tickler coil L_1 . The grid circuit 5' may be resonant to any frequency within a considerable range, and the capacity of C_2 is therefore not critical. In a practical circuit, the resonant frequency of L_1C_2 can be of the order of double the frequency of the tank circuit 5.

The screen grid 2' of tube 1 is connected to a source of positive potential $+S$, say $+30$ volts, and is bypassed to ground for I. F. currents by condenser C_1 . The plate 4 of tube 1 is connected to the $+B$ terminal, say at $+90$ volts, through the resonant circuit 5. The resonant tank circuit 5, tuned in the present illustration of my invention to 2675 kc., consists of the parallel-connected combination of coil L_2 , resistor R_4 and condenser C_4 . The resistor element may be made variable, as indicated by the arrow. Coils L_1 and L_2 are magnetically coupled to provide the proper amount of regenerative feedback in order continuously to produce oscillations at the desired frequency division ratio. Condenser C_5 bypasses the low end of resistor R_4 to ground for the oscillator current.

The auxiliary resonant network, concerning which reference may be made to the Corrington application for a more complete description, is designated 5'', and consists of the parallel-connected combination of condenser C_3 , resistor R_2 and coil L_3 . The coil L_3 is magnetically coupled to the plate coil L_2 , and this coupling is indicated by the dashed arrow through both coils. The resistor R_2 is preferably variable, as indicated. The degree of coupling between coils L_3 and L_2 predominantly determines the extent of the lock-in range of the oscillator. There are other factors which influence the lock-in range, but these factors are minor compared to the coupling between the aforesaid coils.

The auxiliary resonant network 5'' is tuned to the same resonant frequency as the plate circuit 5. For maximum lock-in range the auxiliary coupled circuit 5'' is slightly overcoupled (closer than critical coupling) with respect to tank circuit 5. It has been found possible to secure a lock-in range, through all prior radio frequency and I. F. selectivity, of ± 130 kc. or more in terms of the input to the locked-in oscillator.

Turning now to the FM detector D, I utilize a discriminator circuit, which may be of suitable known type, e. g., that shown in U. S. patent to S. W. Seeley, No. 2,121,103, granted June 21, 1938, or to J. D. Reid, 2,341,240 granted February 8, 1944. The high potential side of plate circuit 5 is coupled to the detector by condenser C_6 . In Fig. 3 I have depicted a typical detection characteristic for the detector schematically shown in Fig. 1. The frequencies F_1 and F_2 denote the detector input frequencies which give opposite peak direct current response. The resultant instan-

taneous output voltage of the detector is zero at the frequency F_c . It is highly desirable, of course, that the curve be highly linear between the peak response, or output frequencies. The detector circuit used in Fig. 1 should possess such a characteristic.

From Fig. 3 it can be seen that there is a distinct advantage in using a locked-in oscillator to feed an FM detector of the sloping filter type so far as prevention of so-called "three-spot" tuning is concerned. As is well known FM detection can occur, in the absence of a signal-swing restraining device, on the outer slopes of the peaks F_1 and F_2 , i. e., at a frequency below F_1 or above F_2 . Such detection produces distortion in the audio output system F , and is also very confusing to the listener in tuning an FM receiver. In my arrangement, the locked-in oscillator system functions positively to maintain the signal deviations with a range of approximately ± 25 to ± 32.5 kc. indicated by points x and y , Fig. 3, of the detection characteristic, thereby automatically providing "single spot" tuning. With such an overall lock-in range (x, y) of 50 to 65 kc., the maximum deviations of the FM signal applied to detector D cannot reach the response peaks F_1 and F_2 which I prefer to have 100 to 130 kc. apart.

A restricted lock-in range prevents detection beyond the peaks F_1 and F_2 , because the locked-in oscillator will follow the frequency deviations of the I. F. signal energy only as long as they are within the lock-in range. When the I. F. voltage applied to the locked-in oscillator is at some frequency below or above the lock-in range, the oscillator, instead of following that frequency, develops "break-out." That is, the oscillator snaps back to nearly its own center frequency. (There is some shift of the center frequency even in the absence of lock-in.) The FM detector gets its alternating current energy only from the locked-in oscillator. Since the locked-in oscillator supplies output energy either at its center frequency or at frequencies corresponding to one-fourth of the I. F. value within its lock-in range, all of the alternating current energy applied to the F. M. detector will fall well within the frequency range included between F_1 and F_2 . When the receiver is detuned so that the I. F. energy is of such frequency that one-fourth of it falls beyond points F_1 and F_2 , the alternating current energy fed to the FM detector will be at the center frequency of the locked-in oscillator, since the oscillator does not lock-in with I. F. energy so far removed from the normal operating value.

It may be pointed out that a network or pass-band 40 having indefinite impedance rejection characteristics such as to give zero response at frequencies F_1 and F_2 may be used, in place of the locked-in oscillator, between network 13 and the detector D as shown in Fig. 4. Here, again, the detector output would be zero below and above the lower and upper response peaks F_1 and F_2 respectively. For example, there may be substituted for box 40 of Fig. 4 the infinite impedance rejection network described by G. Mountjoy in U. S. Patent No. 2,137,475, granted November 22, 1938. Undesirable spurious responses beyond peaks F_1 and F_2 are, accordingly, readily prevented by restraining the signal deviation at the detector input terminals to prescribed limits (as x and y) well within the peaks F_1 and F_2 .

In an FM set, it is further desirable to indicate visually whether the receiver is tuned to one side of F_c , the degree of detuning from F_c , and whether or not signals are actually being received. These

conditions are readily visually indicated by my invention. In general, I utilize AVC voltage to indicate whether or not FM signals are being received, while I employ the frequency of the locked-in oscillator output energy to indicate the condition of resonance of the receiver. By observing both indications the receiver operator is enabled to tune the receiver to the desirable mid-frequency of the station channel.

The indications are provided by an electronic indicator tube of the dual shadow type. For example, there may be used the 6AF5 type of tube. I have designated the indicator tube by reference numeral 20. The tube 20 is schematically represented, since such tubes are well-known to those skilled in the art of radio communication. The tube 20 comprises the electron emission element, or cathode, 21 which may be returned to the ground —B terminal of the direct current source (not shown). The spaced electron ray control rods, or electrodes, A and B control the flow of electrons to respective adjacent areas of the fluorescent target 22.

Target 22 is usually an inverted frustum of a cone, the flared end being the viewing end. The inner face of the target is coated with fluorescent material which glows in response to electronic bombardment from cathode 21. The rods A and B are usually located on opposite sides of the cathode and in alignment therewith whereby they may cast "electronic shadows" on the target. That is, the electrodes A and B are electron deflection rods.

The target 22 is connected to the +B terminal (say at +250 volts), while rods A and B are energized from different points of the receiver system. Rod A is connected to the high potential side of a resonant circuit 23 which is sharply tuned to the mean operating frequency of the locked-in oscillator. In other words, circuit 23 with an I. F. of 10.7 mc. and a frequency division of 4 is sharply tuned to a frequency of 2675 kc. The circuit 23 is magnetically and loosely coupled to plate circuit 5. The low potential side of circuit 23 is connected preferably to a positive voltage point which may be chosen from a range of zero to approximately +40 volts. It can, therefore, be seen that normally the rod A is at a positive potential with respect to the grounded cathode 21.

The rod B is varied in voltage in response to variations in magnitude of the AVC voltage developed across resistor R_1 . As shown, the rod B is connected to the plate 30 of the direct current voltage amplifier tube 31. Tube 31 may be a tube of the 6J5 type, and has its cathode 32 grounded. Plate 30 is connected to the +B terminal of the direct current source through a resistor 33. Accordingly, when the space current of tube 31 is at maximum the voltage drop across resistor 33 is at maximum, and, therefore, the rod B will be at minimum positive potential with respect to the highly positive target 22.

The space current flow of tube 31 is regulated by the control grid 34 which is connected through the alternating current filter resistor 35 and lead 36 to the ungrounded end of resistor R_1 . The bypass condenser 35' may be inserted to bypass alternating current components from the lead 36. It will now be seen that when FM signals exist in circuit 45 the grid current flowing through resistor R_1 will develop a voltage which is negative with respect to ground. This negative voltage is applied to grid 34 with the result that the space current flowing through tube 31 is di-

minished, thus causing the voltage drop across resistor 33 to decrease. This means that rod B approaches in potential the voltage of target 22. Hence, rod B will deflect less and less electrons from the adjacent target area as the FM signal magnitude at circuit 15 approaches a maximum value. Conversely, when there is no FM signal at circuit 15 the grid 34 will have the same potential as the grounded cathode 32, and the rod B will have minimum positive potential relative to the highly positive target 22. This means that the rod B will deflect sufficient electrons to cause a shadow area on the adjacent surface of the target which is at maximum angular width.

So far as the action of rod A is concerned, that electrode will have minimum deflection effect on the electrons flowing in its vicinity towards the target either in the absence of signals or when the receiver is accurately tuned to mid-channel frequency, since in either of such cases, the locked-in oscillator delivers maximum output at the frequency to which circuit 23 is tuned. By choosing the correct value of positive bias for rod A, the shadow angle caused by rod A can be made to adjust to zero at the peak response of the resonant pickup circuit 23, which corresponds to correct tuning. That is, in the latter condition the local oscillator of the receiver is heterodyning the received FM carrier to the middle of the I. F. channel and the operating center frequency of the lock-in range of the locked-in oscillator. Positive bias applied to rod A, also, reduces the amount of radio frequency power required from the pickup circuit coil to reduce the corresponding shadow angle to zero. This permits looser coupling between circuit 23 and circuit 5, and, hence, provides sharper tuning to peak response.

In Figs. 2a, 2b and 2c I have depicted the relative appearances of the shadow angles A' and B' for different voltage conditions of the deflection voltages A and B respectively. Thus, each of these figures shows the flared end of the fluorescent target 22. The shadow angles A' and B' are produced by the respective rods A and B as the effective voltages thereof vary. Fig. 2a shows the shadow angle B' at maximum width when no FM signal is being received, while the shadow angle A' is of minimum or zero width, because the locked-in oscillator section is producing locked-in oscillations at the center frequency F_c . This means that maximum radio frequency voltage is applied to rod A thereby causing minimum electron deflection. Minimum electron deflection results from the fact that the rod A is effectively at maximum positive potential with respect to the target 22.

Referring to Fig. 2b the shadow angle A' has widened out, whereas shadow angle B' is diminished. This shows the condition for reception of FM signals with the receiver partially detuned. In that condition of off-resonance, the FM signal magnitude at circuit 15 is not at maximum. Hence, the shadow angle B' will have an intermediate value, while the shadow angle A' will be enlarged. This is due to the fact that the oscillator tube 1 is locked to a center frequency differing from the resonant frequency resonant circuit 23. Hence, rod A will have reduced positive peak potentials with respect to cathode 21. The magnitude of the oscillations provided by the locked-in oscillator are not significantly less when the receiver is off-tune. In fact, they might be slightly more, or slightly less, depending on whether the oscillator is being accelerated or

decelerated by the I. F. energy. What actuates ray control electrode A is resonant circuit 23, which, being sharply tuned to the oscillator center frequency, applies the maximum voltage to rod A when the oscillator is operating in the center of its lock-in range. The said voltage drops off rapidly in magnitude at frequencies removed above or below the oscillator center frequency (say by ± 10 kc.) due to the peaked amplitude-frequency response characteristic of resonant circuit 23. It will be noted that this occurs even though the oscillator voltage remains about the same.

In Fig. 2c both shadow areas A' and B' are substantially zero thereby indicating the in-tune condition of the locked-in oscillator, and maximum FM signal being applied to circuit 15. It will, therefore, be seen that tuning any desired station becomes a question of adjusting the station selector control until both shadow angles A' and B' are of minimum width, as shown in Fig. 2c.

It is to be clearly understood that the tube 31 need not be controlled from the grid circuit of the locked-in oscillator tube 1, but, in general, the grid 34 may be varied in voltage from any point in the receiving system which develops negative voltage whose magnitude is proportional to the magnitude of the received FM signals. Furthermore, where large variations in AVC voltage are encountered the tube 31 is preferably one of the remote cut-off type. In conjunction with the AVC voltage indication B', shadow angle A' may be replaced by an indication from the direct current voltage output of the FM detector.

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.

What I claim is:

1. In combination with the locked-in oscillator of a frequency modulation receiver, said oscillator continuously producing oscillations of a predetermined center frequency in the absence of received signals, an electronic indicator tube of the dual shadow type, means responsive to variations in center frequency of the lock-in oscillations for controlling one of the shadow areas of said indicator tube, and means responsive to the magnitude of received signals for controlling the second shadow area of said indicator tube.

2. In combination with the locked-in oscillator of a frequency modulation receiver, said oscillator continuously producing oscillations of a predetermined center frequency in the absence of received signals, an electronic indicator tube of the dual shadow type, means responsive to variations in center frequency of the locked-in oscillations for controlling one of the shadow areas of said indicator tube, means responsive to the magnitude of received signals for controlling the second shadow area of said indicator tube, both of said control means being so constructed and arranged that said two shadow areas are of minimum width when the center frequency of received signals is equal to the predetermined center frequency of the locked-in oscillations.

3. In a receiver of angle modulated carrier waves of the type including a locked-in oscillator having an input network upon which said carrier waves are applied and an output network feeding a detector whose characteristic is a sloping filter with spaced response peaks substantially exceed-

ing the lock-in range of said locked-in oscillator, said oscillator producing oscillations of a predetermined center frequency in the absence of received carrier waves, means responsive to the locked-in oscillator output network for indicating correct oscillator center frequency, and additional means responsive to the received angle modulated carrier waves for indicating maximum carrier magnitude.

4. In a receiver of angle modulated carrier waves of the type including a locked-in oscillator having an input network upon which said carrier waves are applied, and an output network feeding a detector whose characteristic is a sloping filter with spaced response peaks substantially exceeding the lock-in range of said locked-in oscillator, said oscillator producing oscillations of a predetermined center frequency in the absence of received carrier waves, means responsive to the locked-in oscillator output network for indicating correct oscillator center frequency, additional means responsive to the received angle modulated carrier waves for indicating maximum carrier magnitude, an electronic indicator tube of the fluorescent target type, a pair of spaced electron deflection rods, and said rods functioning as the respective responsive means.

5. In combination, a source of frequency modulation signals, a frequency modulation detector having a sloping characteristic between a pair of peak frequencies, said characteristic having a predetermined center frequency located at the middle of said sloping characteristic, means responsive to said source of frequency modulation signals for positively restricting signal frequency deviations at the detector input terminals to a frequency range substantially less than the frequency range between said peak frequencies whereby detection beyond the limits of said peak frequencies is effectively prevented, and said responsive means consisting of a locked-in oscillator.

6. In a one-spot tuning system for a frequency modulation receiver, a frequency responsive detector having a detection characteristic provided with spaced response peak frequencies centered about a predetermined center frequency, said peak frequencies differing by substantially more than the maximum modulation deviations of received signals, a signal transmission network preceding said detector and having output terminals coupled to the detector input terminals, said network having a frequency response characteristic which is centered on said center frequency, said response characteristic being completely within, and of negligible amplitude at and beyond, the aforementioned peak frequencies.

7. In a system as defined in claim 6, said signal transmission work consisting of a locked-in oscil-

lator, said oscillator having an input circuit upon which the frequency modulation signals are applied, and said oscillator having a restricted lock-in range equal to the band width of said frequency response characteristic.

8. In a receiver of frequency modulated carrier waves of the type including a locked-in oscillator having an input network upon which carrier waves are applied and an output network, a detector whose characteristic is a sloping filter with spaced response peaks substantially exceeding the lock-in range of said locked-in oscillator, said output network being coupled to the detector, selective means relatively loosely coupled to the locked-in oscillator output network, means connected to the selective means for indicating oscillator frequency variations from a predetermined normal frequency, said oscillator normally producing oscillations of said normal frequencies in the absence of received waves, and additional means responsive to the received modulated carrier waves for indicating maximum carrier magnitude.

9. In a receiver of frequency modulated carrier waves of the type including a locked-in oscillator having an input network upon which carrier waves are applied and an output network, a detector whose characteristic is a sloping filter with spaced response peaks substantially exceeding the lock-in range of said locked-in oscillator, said output network being coupled to said detector, selective means relatively loosely coupled to said locked-in oscillator output network, said oscillator normally producing oscillations of a predetermined normal frequency in the absence of received waves, additional means responsive to the magnitude of the received modulated carrier waves, and an electronic indicator tube of the fluorescent target type provided with a pair of spaced electron deflection rods, one of the rods being connected to said selective means for indicating oscillator frequency variations from said predetermined normal frequency, and the other rod being connected to said additional means for indicating maximum carrier magnitude.

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