Feb. 13, 1945. H. T. LYMAN 2,369,585

FREQUENCY MODULATION RECEIVER

Filed July 23, 1943

Fig. 1.

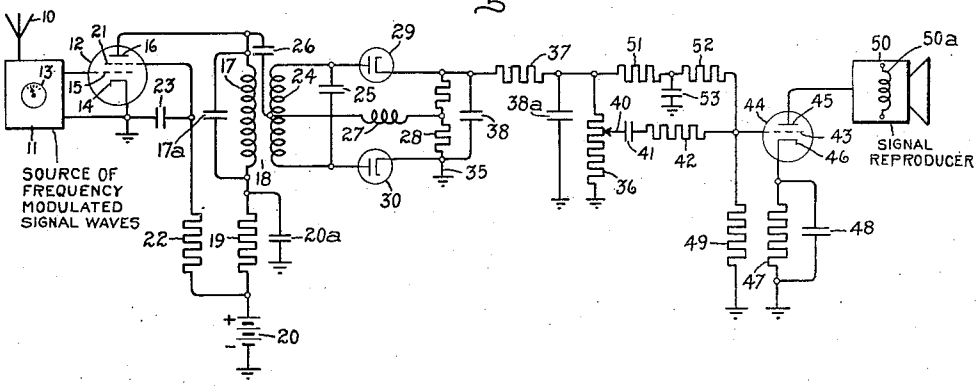


Fig. 2.

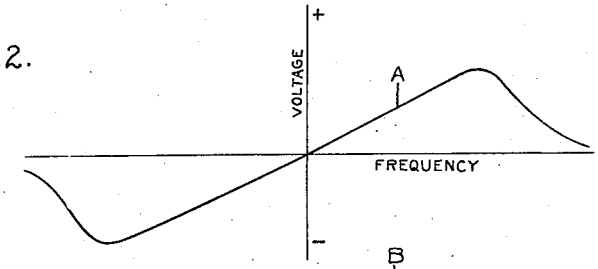


Fig. 3.

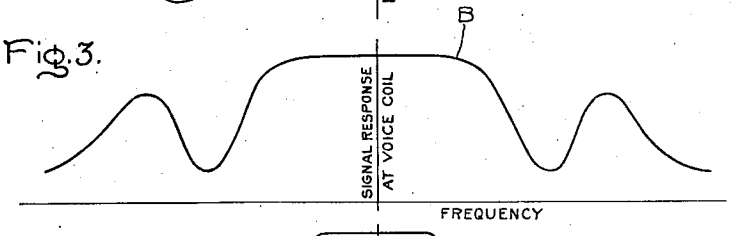
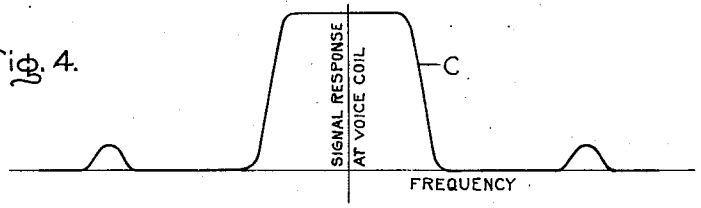


Fig. 4.



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2,369,585

FREQUENCY MODULATION RECEIVER

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4 Claims. (Cl. 250—20)

My invention relates to frequency modulation receivers, more particularly to improvements in detectors or demodulators for frequency modulated carrier waves, and has for its principal object the provision of new and improved signal selector circuits for indicating mistuning of the receiver with respect to a predetermined mid-band frequency.

In the tuning of amplitude modulation radio or television receivers it is a characteristic that, as the channel is tuned through, for example, in a superheterodyne receiver as the intermediate frequency approaches and then recedes from the resonant frequency of the intermediate frequency channel, the signal gradually increases in intensity to a maximum and then gradually decreases in intensity and fades out. This single maximum in the signal response is a highly desirable tuning characteristic, since it enables and unskilled operator readily to select the proper position of the tuning control for the reception of any desired broadcasting station.

It is equally well recognized, however, that detector or demodulator circuits which are currently in common use for the detection of frequency modulated carrier waves possess a tuning characteristic exhibiting three definitely distinguishable maxima of signal response; that is, as the channel is tuned through, a fairly strong signal having a poor signal-to-noise ratio is first observed, then a period of high distortion, then a range of good reception with high signal-to-noise ratio, then a second period of high distortion, and then a second period of fairly good reception with low signal-to-noise ratio as in the first condition, followed by a final fading out of the signal. While it is well known to those skilled in the art that the optimum tuning position is at the central, or mid-band, maximum of signal response, it is also well recognized that this triple response characteristic is confusing to unskilled operators who are not familiar with the cause of the three maxima and are therefore unable to select the proper tuning position. This tuning characteristic, whereby three maxima in signal response are presented, is a function of the relative values of the resonant frequency of the signal channel and the mean frequency of the frequency modulated carrier wave being transmitted through the channel. Accordingly, the characteristic will be observed as well in receivers where the resonant frequency of the channel is to be tuned to the mean frequency of the incoming carrier wave, such as tuned radio frequency receivers, as in superheterodyne receivers in which the mean intermediate frequency is adjustable to the fixed resonant frequency of the intermediate frequency channel.

Accordingly, it is a general object of my invention to provide new and improved selector circuits for indicating the proper tuning position of a frequency modulation carrier wave receiver.

It is a further object of my invention to provide a frequency discriminator or demodulator for frequency modulation receivers which shall be readily tunable to the desired coincidence of carrier mean frequency and channel resonant frequency without evidencing undesired tuning indications upon either side of the desired position.

It is still another object of my invention to provide new and improved means for positively indicating mistuning of a frequency modulation receiver by attenuation and distortion of undesired side band frequencies.

It is a specific object of my invention to provide means for controlling a signal frequency amplifier in response to mistuning of a balanced discriminator circuit to eliminate confusion on the part of an unskilled operator in selecting the optimum tuning position of the receiver.

In accordance with the present invention, a unidirectional bias potential of positive or negative polarity, derived from the output of a balanced discriminator circuit as a result of mistuning in one or the other direction, is utilized directly to control the grid of the signal amplifier in such a way that mistuning of the receiver to either side of the mid-band frequency is rendered highly undesirable. It is well known that a balanced discriminator as for example a discriminator of the type disclosed and claimed in U. S. Patent 2,121,103, issued to S. W. Seeley on June 21, 1938, includes in its output a unidirectional component of potential proportional in polarity and intensity to the direction and magnitude, respectively, of any deviation between the carrier mean frequency and the mid-band frequency of the discriminator. In accordance with the present invention the positive or negative unidirectional component of discriminator output voltage so derived upon mistuning is utilized to bias the signal amplifier either substantially to cutoff or into a region of very poor gain, depending upon whether the bias voltage is negative or positive, respectively. In this way the signal response upon either side of the desired mid-band frequency is so reduced by attenuation and distortion that the mistuning is

forcibly brought to the attention of even the most unskilled operator.

My invention itself will be more fully understood and its objects and advantages further appreciated by referring now to the following detailed specification, taken in conjunction with the accompanying drawing in which Fig. 1 is a schematic circuit diagram of a frequency modulation discriminator embodying my invention, and Figs. 2, 3, and 4 are graphical representations of certain frequency modulation receiver tuning characteristics illustrative of the invention.

Referring now to the drawing, and particularly to Fig. 1, I have shown a frequency modulation receiver including an antenna 10 for supplying frequency modulated signal waves at radio frequency to a signal channel 11. The signal channel 11 serves to supply to an electric discharge device 12 a carrier wave modulated in frequency about a mean frequency in accordance with desired signals representing voice, music, or the like. The signal channel 11 is provided with a suitable manually controllable tuning device 13. While it will be evident to those skilled in the art that the invention is equally applicable to a frequency modulation receiver in which the signal channel 11 comprises a plurality of stages of radio frequency amplification, it will also be understood that, in the typical case of a superheterodyne receiver, the channel 11 will ordinarily comprise a suitable number of stages of radio frequency amplification, an adjustable local oscillator, a mixer or converter for reducing the carrier frequency to a desired intermediate frequency by heterodyning the signal wave with the locally generated oscillations, and one or more stages of intermediate frequency amplification fixedly tuned to the desired intermediate frequency. In such a superheterodyne receiver, the tuning means 13 is ordinarily arranged to control the frequency determining circuits of the local oscillator. Tuning is then accomplished by adjustment of the mean frequency of the intermediate frequency carrier wave to equal the fixed resonant frequency of the intermediate frequency channel. Assuming for the purpose of illustration that the receiver is of the superheterodyne type, the discharge device 12 may be a limiter of the well known saturation type. The limiter 12 includes a cathode 14 and a control electrode or grid 15 connected to the intermediate frequency channel 11 and includes also an anode 16 connected to the cathode 14 through an output circuit including a tuned primary winding 17 of a discriminator input transformer 18. The primary winding 17 is tuned to resonance at the desired intermediate frequency by means of a shunt capacitor 17*a*. The output circuit of the discharge device 12 may be traced from the anode 16 through the primary winding 17 and a resistor 19 to the positive terminal of the battery 20, the negative terminal of which is connected through ground to the cathode 14. As shown, the limiting discharge device 12 also includes a screen grid 21 connected through a resistor 22 to the positive terminal of the battery 20 and through a capacitor 23 to the cathode 14. The lower terminal of the transformer winding 17 is maintained at ground potential for alternating currents of the intermediate frequency by a capacitor 20*a*.

The discriminator input transformer 18 includes also a secondary winding 24 magnetically coupled to the primary winding 17 and tuned to resonance at the predetermined intermediate frequency by a shunt capacitor 25. The high potential terminal of the primary winding 17 is coupled for intermediate frequency potentials to the midpoint of the secondary winding 24 through a coupling capacitor 26. The adjacent halves of the transformer secondary winding 24 on opposite sides of the midpoint are connected to supply signal modulated intermediate frequency waves for demodulation to a pair of rectifier circuits connected in balanced opposition.

The rectifier circuits include a common intermediate frequency choke coil 27 connected between the midpoint of the transformer secondary winding 24 and the midpoint of a load resistor 28. Opposite terminals of the load resistor 28 are connected through a pair of unidirectional conducting devices 29 and 30 to opposite terminals of the transformer secondary winding 24. As shown, the unidirectional conducting devices 29 and 30 are two-element electron discharge devices having their cathodes connected to opposite terminals of the load resistor 28 and their anodes connected to opposite terminals of the transformer winding 24. The lower terminal of the load resistor 28 is shown grounded at 35.

The discriminator circuit described in the foregoing paragraph is of a well known type and its operation is clearly explained in the Seeley patent referred to hereinbefore. Briefly, however, it may be noted that the tuned discriminator input transformer 18 supplies to the balanced rectifier circuits high frequency potentials which vary oppositely in intensity with frequency modulation of the received signal wave. The high frequency potential applied to each rectifier circuit is the vector sum of the induced voltage in one-half of the transformer secondary winding and the transformer primary winding voltage impressed upon the transformer secondary winding through the coupling capacitor 26. The induced voltages in opposite halves of the secondary winding are equal and opposite at all times and, by reason of the tuning of the transformer windings, they are displaced by 90° from the primary winding voltage when the instantaneous frequency of the carrier wave is equal to the resonant frequency of the transformer. The induced voltages are shifted oppositely in phase with respect to the primary winding voltage upon any deviation of the carrier frequency from the transformer resonant frequency, so that the net voltages applied to the rectifier circuits vary oppositely in intensity with frequency deviations. In this way the net voltages across the two halves of the transformer secondary winding 24 are modulated oppositely in amplitude in accordance with frequency modulation of the signal wave applied to the primary winding 17. Thus, the rectified currents, though flowing in opposite directions through the load resistor 28 on opposite sides of the midpoint, have the same average unidirectional component when the carrier mean frequency coincides with the resonant frequency of the transformer 18 and vary oppositely in instantaneous intensity with instantaneous frequency deviations of the carrier wave.

At Fig. 2 I have shown a curve A which represents the sum of the opposing instantaneous voltage drops between the terminals of the load resistor 28 as the frequency of the signal wave deviates to one side or the other of the transformer resonant frequency. The total signal voltage appearing across the terminals of the load resistor 28 is seen to comprise an alternating component at signal frequency and a unidirec-

tional component having a polarity depending upon the direction of departure of the carrier mean frequency from the transformer resonant frequency and a magnitude proportional to the magnitude of the departure.

In view of the foregoing explanation, it will be clear that when the carrier frequency is equal to the resonant frequency of the transformer and no signal modulation is present, no signal voltage appears across the terminals of the load resistor **28**. In the presence of signal modulation, a signal frequency voltage with a zero unidirectional component appears across the resistor **28**. If, however, the mean frequency of the carrier wave differs from the resonant frequency of the transformer **16**, the average voltage drop across one-half of the resistor **28** exceeds that across the other half so that the upper terminal of the resistor assumes a net positive or negative unidirectional potential with respect to ground independently of signal modulation, the polarity of the unidirectional potential depending upon the direction of departure of the carrier mean frequency from the transformer resonant frequency. Any alternating component of signal voltage developed from frequency modulation is superposed upon the unidirectional potential.

The signal voltage developed as above across the terminals of the load resistor **28** is placed across the volume control resistor **36** through an intermediate frequency rejection and high frequency de-emphasis filter comprising a resistor **37** and a pair of capacitors **38** and **38***a* connected between opposite ends of the resistor **37** and ground. By means of a suitable slider **40** on the volume control resistor **36**, the alternating component of signal voltage drop appearing across any desired portion of the volume control resistor is impressed through a blocking capacitor **41** and a demodulating resistor **42** upon a grid **43** of a signal frequency amplifier comprising an electric discharge device **44** having an anode **45** and a cathode **46**. The cathode **46** is connected to ground through a cathode bias resistor **47** which is by-passed for signal frequency currents by a condenser **48**. The control grid **43** of the discharge device **44** is connected to ground through a grid bias resistor **49**. The output circuit from the anode **45** of the amplifier **44** is connected in a well known manner to any suitable signal reproducing apparatus **50** which may include a signal output transformer, additional stages of amplification and a loud speaker, headphones, a picture tube, or the like. By way of illustration, I have shown a loud speaker having a voice coil **50***a*.

A discriminator, amplifier and reproducer of the type thus far described has a tuning characteristic such as represented in the curve B of Fig. 3. This curve shows signal response at the voice coil in terms of frequency departure of the carrier mean frequency from the transformer resonant frequency. As illustrated at Fig. 2, the signal response is a maximum and fairly constant in the region of the mid-band frequency, decreases to a minimum on each side where the signal is distorted by a zero rate of change of the curve A of Fig. 2, and then increases to an undesired maximum on either side before the signal fades out.

For the purpose of controlling the gain and fidelity of the signal amplifier **44** in accordance with mistuning of the receiver, I provide means for utilizing the unidirectional component of signal potential, appearing across the discriminator load resistor **28** in response to mistuning, to bias the signal amplifier control grid **43** positively or negatively into a region of poor gain or to cutoff, respectively. To provide such bias the unidirectional voltage across the volume control resistor **36** or a predetermined fixed portion thereof, is supplied to the grid **43** through a signal frequency rejection filter comprising a pair of serially connected resistors **51**, **52** and a capacitor **53** connected from the midpoint of the resistors to ground.

In operation, it will be understood that if the mean frequency of the carrier wave coincides with the resonant frequency of the discriminator transformer **18**, no unidirectional component of potential appears across the volume control resistor **36** so that no bias is impressed on the grid **43** through the signal rejection filter **51**, **52**, **53**. If now the receiver is mistuned in such a direction that the upper terminal of the discriminator load resistor **28** assumes a negative unidirectional component of potential with respect to ground, such negative potential will be impressed as a negative bias upon the signal amplifier grid **43** through the signal rejection filter **51**, **52**, **53**. Such negative grid potential will bias the signal amplifier **44** toward cutoff thereby sharply to reduce the amplification and the signal response. In the typical case of a radio receiving apparatus, it will become immediately obvious to the listener that a maximum of audio response has not been reached and that the receiver is mistuned. Stated in another way, the cutoff bias of the tube **44** suppresses the signal and eliminates the undesired maximum in audio response appearing at one side of the mid-band tuning position.

If, however, the receiver is mistuned in such a direction that the upper terminal of the volume control resistor **36** assumes a positive unidirectional potential with respect to ground, such positive potential, when impressed upon the grid **43** of the signal amplifier **44** through the signal rejection filter **51**, **52**, and **53**, drives the amplifier into a region of poor gain. In this region the amplification and fidelity of reproduction of the amplifier are both reduced so that the signal response is low. The amplification of the signal amplifier **44** is not reduced to the same extent by the positive bias as by the negative cutoff bias. However, in the positive bias region, the amplifier **44**, while still conducting, delivers such a severely distorted signal that the positive bias is equally as effective in reducing the signal response and apprising the operator of mistuning as is the negative cutoff bias. In the typical case of a radio receiver substantially no signal is heard when the receiver is mistuned to impress upon the audio amplifier a negative cutoff bias, while when the receiver is mistuned to impress upon the audio amplifier a positive bias, the output is so severely distorted that it is immediately obvious to the operator that the correct tuning position has not been reached.

At Fig. 4 I have shown a signal response curve of the type shown at Fig. 3, but for a receiver embodying my invention. It will be observed that due to attenuation of the side band signal response the curve C of Fig. 4 evidences a sharper maximum of response at the mid-band frequency and shows very appreciable reduction of the undesired maxima of signal response upon either side of the proper tuning position.

In view of the foreging description, it will now be evident that the whole purpose of my inven-

tion may be effectively carried out with very little apparatus additional to that conventionally required in a frequency modulation discriminating apparatus of the type described. It is only necessary to couple the high potential terminal of the discriminator load resistor to the control grid of the first signal amplifier through a signal frequency rejection filter. This coupling results in suppression of the signal response upon mistuning in one direction and in distortion and partial suppression of the signal response upon mistuning in the other direction. It is not necessary that the signal be made to fade out symmetrically upon both sides of the optimum tuning position, as in an amplitude modulation receiver. According to the present invention, mistuning is indicated by fading upon one side and, at least partially, by distortion upon the other side. The distortion, while unpleasant to the senses of the operator, is equally as effective as fading in carrying out the principal purpose of the invention namely, decreasing the signal response and indicating to the operator that the proper tuning position has not been reached.

While I have illustrated only a preferred embodiment of my invention by way of illustration, many modifications will doubtless occur to those skilled in the art and I therefore wish to have it understood that I intend in the appended claims to cover all such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, a source of carrier waves signal modulated in frequency about a mean frequency, a load resistor, means including a tuned circuit for deriving from said carrier waves and supplying across said resistor a signal potential having an alternating component at signal frequency and a unidirectional component proportional in polarity and intensity to the direction and magnitude respectively of any difference between said mean frequency and the resonant frequency of said tuned circuit, an electron discharge device having a control electrode, means for supplying a selectable portion of said alternating component of signal potential to said control electrode for amplification, and means for continuously supplying directly to said control electrode a fixed portion of said unidirectional component of signal potential thereby to reduce the amplification of said discharge device.

2. In combination, a source of carrier waves signal modulated in frequency about a mean frequency, a load resistor, means including a tuned circuit for deriving from said source of waves and supplying across the terminals of said load resistor a signal potential having an alternating component at signal frequency and a unidirectional component proportional in polarity and intensity to the direction and magnitude respectively of variations between said mean frequency and the resonant frequency of said tuned circuit, an electron discharge device having a control electrode, potentiometer means for supplying to said control electrode a selectable portion of said alternating component of signal potential for amplification by said discharge device, and means for continuously supplying directly to said control electrode a fixed portion of said unidirectional component of signal potential independently of the position of said potentiometer means thereby to control the amplification of said discharge device.

3. In combination, means including a tunable circuit for supplying a carrier wave signal modulated in frequency about a mean frequency, means including a load resistor for deriving from said carrier wave an alternating potential at signal frequency, said means including means for providing across the terminals of said load resistor a unidirectional potential of positive or negative polarity depending upon the direction of mistuning of said tunable circuit, an electron discharge device, means for supplying said alternating potential at signal frequency to said discharge device for amplification, and means including a signal frequency rejection filter for supplying said positive or negative unidirectional potential directly to said discharge device to reduce the amplification of said device.

4. In a tuning system for a receiver of the frequency modulation type the combination comprising, means for supplying a carrier wave signal modulated in frequency about a mean frequency subject to variation, means including a tuned circuit and a load resistor for deriving from said carrier wave an alternating potential at signal frequency, said means including means for providing across the terminals of said load resistor a unidirectional potential having a positive or negative polarity in accordance with the direction of a departure of said mean frequency from the resonant frequency of said tuned circuit, an electron discharge device having a control electrode, manually controllable means for supplying a selectable portion of said alternating potential to said control electrode for amplification, and means including signal frequency rejection means for supplying fixed portions of said positive or negative unidirectional potential directly to said control electrode to decrease the amplification of said discharge device upon the occurrence of a departure in either direction of the mean frequency from said resonant frequency.

HAROLD T. LYMAN.