

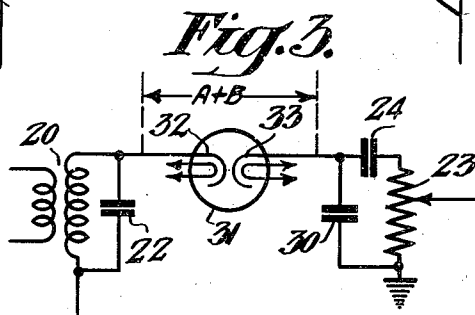
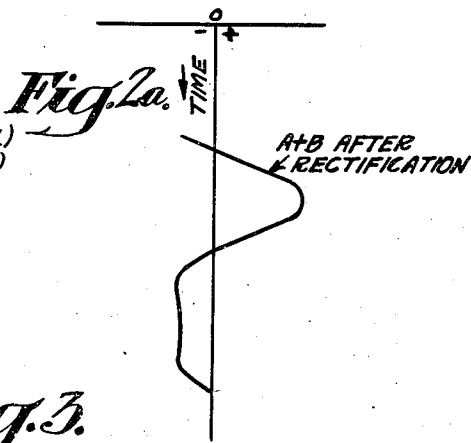
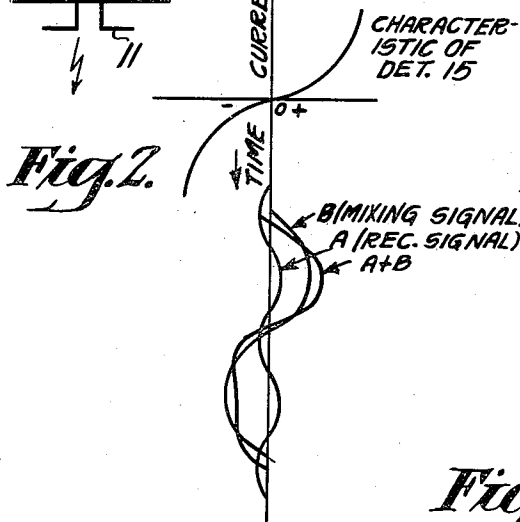
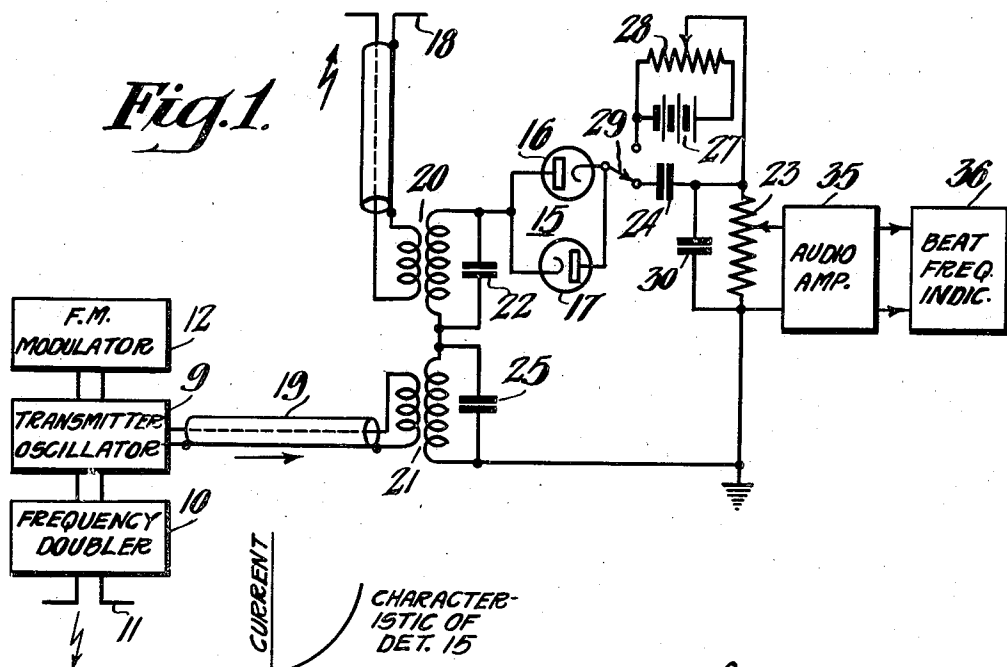
June 10, 1947.

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2,422,079

FREQUENCY MODULATED ALTIMETER OR DISTANCE INDICATOR

Filed Nov. 21, 1942



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UNITED STATES PATENT OFFICE

2,422,079

FREQUENCY MODULATED ALTIMETER OR
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Application November 21, 1942, Serial No. 466,402

12 Claims. (Cl. 250—1.68)

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Our invention relates to radio systems such as radio altimeters for indicating distance or height and will be described particularly with respect to systems wherein the radiated wave is frequency modulated.

Systems of this character are described in Bentley Patent 2,011,392 and Espenschied Patent 2,045,071. In these systems, the radiated frequency modulated wave is reflected from the earth's surface or other object and the reflected wave is received in a heterodyne receiver located in the vicinity of the transmitter. The heterodyning or mixing signal for the receiver is obtained directly from the transmitter whereby the receiver output includes a signal of "beat frequency" which frequency is a function of the time required for the radiated signal to reach the reflecting object and return to the receiver.

It has been found that one of the things that limits the full use of the sensitivity of the receiver is the interfering signal resulting from the amplitude modulation normally present on the mixing signal that is applied to the heterodyne detector. When the optimum mixing voltage, i. e., optimum with respect to noise ratio, is introduced on the heterodyne detector, the amplitude modulated signal in the output of the receiver is still ten to fifty times the noise level when the transmitter signal is swept through a twenty megacycle bandwidth, for example.

It might be expected that there would be no amplitude modulation on the mixing signal. This would be true if it were not for the difficulty of transmitting a wide frequency band signal over a line with uniform attenuation at all frequencies. In actual practice there are reflections on the line to the transmitter antenna and on the line between the transmitter and the receiver because of practically unavoidable imperfect line terminations, for example.

While amplitude modulation on the mixing signal causes the greater part of the above mentioned interference, there also may be some interference, usually almost negligible, caused by amplitude modulation on the received reflected signal. The latter modulation is introduced because of such factors as imperfect termination of the line from the transmitter to the transmitter antenna and possibly because of frequency selective reflection of the signal.

An object of our invention is to provide an improved method of and means for reducing the interfering amplitude modulation signal appearing in the output of a receiver in a frequency modulated distance determining system. A fur-

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ther object of the invention is to provide an improved system of the above-described type.

In practicing a preferred embodiment of the invention, the transmitter radiates to the earth or other reflecting surface a frequency modulated carrier wave having a carrier frequency twice that of the frequency modulated carrier wave which is supplied directly, i. e., without reflection, to the receiver as a mixing signal. The radiated carrier wave, after travelling from the transmitter to the reflecting surface and back to the receiver, is also applied to the receiver.

The detector in the receiver may comprise two similar diodes connected in "parallel opposition." This results in a detector having a symmetrical characteristic curve of volts input vs. current output. Any amplitude modulation that may be present on either of the two applied carrier waves is balanced out since the amplitude modulating outputs from the two diodes are of opposite polarity and feed into a common output resistor. Likewise, any interfering or jamming signal may be balanced out.

The operation of the detector in producing a beat frequency by the use of a double frequency signal is based upon the method described in Carlson Patent 1,734,894, issued November 5, 1929.

The invention will be better understood from the following description taken in connection with the accompanying drawing in which

Figure 1 is a circuit diagram of a radio altimeter designed in accordance with one embodiment of our invention, Figures 2 and 2a are graphs which are referred to in explaining the operation of the apparatus, and Figure 3 is a diagram illustrating the use of a different detector in the receiver. In the several figures like parts are indicated by similar reference characters.

Referring to Fig. 1, the altimeter comprises a frequency modulated radio-frequency oscillator 9 which has its output doubled in frequency by a frequency doubler 10. The output of the doubler 10 is supplied to a dipole 11 whereby a frequency modulated signal is radiated toward the earth. Such a signal is produced by sweeping the frequency of the carrier wave of the oscillator 9 through a frequency band periodically, i. e., by cyclically frequency modulating the carrier wave. This may be done by means of a suitable frequency modulator 12, which may be, for example, a motor driven capacitor or a vibrating capacitor (not shown) for varying the tuning of the transmitter oscillator 9.

The receiver includes a detector 15 comprising

two diodes 16 and 17 which are connected in parallel opposition. The reflected signal is picked up by a dipole 18 and applied to the input circuit of the detector through a transformer 20. The mixing signal is of a large amplitude compared with the reflected signal and is applied directly from the oscillator 9 over a line 19 to the input circuit of the detector 15 through a transformer 21. Transformers 20 and 21 may be tuned to the mean frequency of the carrier wave of the reflected signal and of the mixing signal, respectively, by means of capacitors 22 and 25 connected across the transformer secondaries. It will be noted that the secondaries of transformers 20 and 21 are in series with each other and in series with the detector 15 whereby the reflected signal and the mixing signal are applied to the detector in additive relation.

The outputs of diodes 16 and 17 flow through a common output resistor 23 which is connected in series with the detector 15 and the transformer secondaries and which is shunted by a carrier-frequency bypass capacitor 30. In the circuit as illustrated, a capacitor 24 is connected in series with the detector 15 and output resistor 23 to apply a balancing bias to the diodes 16 and 17, as explained below, which ensures equal direct current in the diodes. This also ensures equal alternating current through the diodes 16 and 17 since a diode's A.-C. characteristic is similar to its D.-C. characteristic. If the two diodes are reasonably well matched, the desired balance is thus obtained automatically without requiring any adjustments, and any amplitude modulation that may be present is balanced out in the output resistor 23 since the amplitude modulation outputs of the two diodes are in phase opposition. The desired beat frequency signal will appear in the detector output, however, as explained later in connection with Figs. 2 and 2a, and it is supplied through an audio amplifier 35 to a beat frequency indicator or counter 36.

The action of capacitor 24 in providing automatic balancing of the circuit is as follows: If the current flow for a given applied voltage is the same through diode 16 as through diode 17, then the charge received by capacitor 24 due to the positive half cycles of R.-F. current flowing through diode 16 will be completely removed by an equal current flow through diode 16 during the negative half cycles. However, assume for example that with a given applied voltage the current flow through diode 16 is greater than that through diode 17. Then a charge will build up on capacitor 24, and the side of capacitor 24 connected to the cathode of diode 16 and to the plate of diode 17 will be positive. Thus current flow through diode 16 will be reduced by the bias and that through diode 17 will be increased until an equilibrium condition is reached where the current flow is the same in the two diodes.

While the capacitor 24 causes the circuit to balance automatically and is desirable for this reason, it may be omitted and the amplitude modulation will still be balanced out satisfactorily provided the diodes 16 and 17 are closely matched. However, if capacitor 24 is omitted, it usually is desirable to provide an adjustable biasing source such as a battery 27 shunted by a potentiometer 28. The polarity of battery 27 depends upon which one of the diodes tends to pass the more current at a given applied voltage. A switch 29 connects the diodes either to capacitor 24 or to the battery 27.

The manner in which the desired beat fre-

quency is produced will be seen by referring to Figs 2 and 2a. When the received signal A and the mixing signal B have the phase relation shown in Fig. 2, the negative half cycle of the added signal A+B is flattened and the rectified output flowing through output resistor 23 will have the wave shape shown in Fig. 2a. It is evident that the current shown in Fig. 2a has a D.-C. component. This component reverses at the beat frequency as the relative phase of the received signal A and the mixing signal B changes, and the resulting audio beat signal is supplied to the indicator 36.

It should be understood that the invention is not limited to the particular circuit shown in Fig. 1. For example, the detector 15 may be replaced by a vacuum tube having one or more grids as described in the above-mentioned Carlson patent, but its characteristic curve should, like the detector 15 be substantially symmetrical with respect to the A.-C. axis of the applied signals.

Fig. 3 shows another type of detector that may be used in place of the double diode detector of Fig. 1. It comprises a vacuum tube 31 having two indirectly heated cathodes 32 and 33 across which the voltage A+B is applied. The direction of current flow through the tube 31 depends upon the polarity of the applied voltage. The voltage vs. current characteristic of tube 31 is similar to the characteristic shown in Fig. 2 for detector 15. The operation with the detector 31 is the same as that described in connection with Fig. 1.

From the foregoing it will be apparent that our improved circuit has the important advantage that no critical adjustments are required to balance out any amplitude modulation that may be present. If the capacitor 24 is utilized, the condition of balance is reached automatically. If, instead, the biasing source 27 is utilized, the circuit may be adjusted to balance by the adjustment of a single bias voltage value. Another advantage of the present invention is that one side of the circuit may be grounded, thus avoiding the difficulty of obtaining an exact balance with respect to a grounded center point required in some circuits.

We claim as our invention:

1. A distance determining system comprising means for transmitting to a reflecting object a radio carrier wave which is cyclically frequency modulated, a detector, means for receiving the signal reflected from said object and for applying it to said detector, means for also applying to said detector a mixing signal that is obtained directly from said transmitting means and which has a frequency equal to one-half the frequency of the frequency modulated wave that is transmitted to said object whereby the detector output includes a beat frequency signal which is a measure of the distance from said transmitting means to said object and whereby any amplitude modulation that may be present is substantially balanced out.

2. The invention according to claim 1 wherein the detector characteristic is substantially symmetrical with respect to the alternating current axis of the applied signals.

3. A distance determining system comprising means for transmitting to a reflecting object a radio carrier wave which is cyclically frequency modulated, a detector, an output impedance element for said detector, means for receiving the signal reflected from said object and for applying it to said detector, means for also applying to said detector a mixing signal that is obtained

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directly from said transmitting means and which has a frequency equal to one-half the frequency of the frequency modulated wave that is transmitted to said object whereby the detector output includes a beat frequency signal which is a measure of the distance from said transmitting means to said object and whereby any amplitude modulation that may be present is substantially balanced out, and a capacitor connected in series with the detector and the output impedance element whereby a bias voltage will appear across said capacitor to correct any unbalance due to lack of symmetry of the detector characteristic about the alternating current axis of the applied signals.

4. A distance determining system comprising means for transmitting to a reflecting object a radio carrier wave which is cyclically frequency modulated, a detector comprising means for conducting direct current in either direction non-linearly with respect to the applied voltage and with the current flow in the two directions symmetrical with respect to the A.-C. axis of the applied voltage, an output impedance element for said detector, means for receiving the signal reflected from said object and for applying it to the input of said detector, means for also applying to the input of said detector a mixing signal that is obtained directly from said transmitting means and which has a frequency equal to one-half the frequency of the frequency modulated wave that is transmitted to said object whereby the detector output appearing across said output impedance element includes a beat frequency signal that is a measure of the distance from said transmitting means to said object and whereby any amplitude modulation that may be present is substantially balanced out.

5. The invention according to claim 4 wherein a capacitor is included in series with the detector and the output impedance element whereby a bias voltage will appear across said capacitor to correct for any unbalance due to any lack of symmetry of the detector characteristic with respect to said A.-C. axis.

6. A distance determining system comprising means for transmitting to a reflecting object a radio carrier wave which is cyclically frequency modulated, a detector, an output impedance element for said detector, means for receiving the signal reflected from said object and for applying it to said detector, means for also applying to said detector a mixing signal that is obtained directly from said transmitting means and which has a frequency equal to one-half the frequency of the frequency modulated wave that is transmitted to said object whereby the detector output includes a beat frequency signal which is a measure of the distance from said transmitting means to said object and whereby any amplitude modulation that may be present is substantially balanced out, said detector comprising a pair of diodes connected in parallel with each other and in series with said output impedance element and said receiving means, said diodes being connected for current conduction in opposite directions.

7. The invention according to claim 4 wherein

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a capacitor is included in series with the detector and the output impedance element whereby a bias voltage will appear across said capacitor to correct any unbalance due to a difference between the characteristics of the two diodes.

8. A distance determining system comprising means for producing a radio carrier wave which is cyclically frequency modulated, means for doubling the frequency of said modulated wave and for then transmitting it to a reflecting object, a detector, means for receiving the signal reflected from said object and for applying it to said detector, means for also applying to said detector as a mixing signal a portion of said modulated carrier wave before its frequency is doubled whereby the detector output includes a beat frequency signal that is a measure of the distance from said transmitting means to said object and whereby any amplitude modulation that may be present is substantially balanced out.

9. The invention according to claim 6 wherein the detector characteristic is substantially symmetrical with respect to the alternating current axis of the applied signal.

10. A distance determining system comprising means for producing a radio carrier wave which is cyclically frequency modulated, means for doubling the frequency of said modulated wave and for then transmitting it to a reflecting object, a detector comprising means for conducting direct current in either direction non-linearly with respect to the applied voltage and with the current flow in the two directions symmetrical with respect to the A.-C. axis of the applied voltage, an output impedance element for said detector, means for receiving the signal reflected from said object and for applying it to said detector, means for also applying to said detector as a mixing signal a portion of said modulated carrier wave before its frequency is doubled whereby the detector output appearing across said output impedance element includes a beat frequency signal that is a measure of the distance from said transmitting means to said object and whereby any amplitude modulation that may be present is substantially balanced out.

11. The invention according to claim 10 wherein a capacitor is included in series with the detector and the output impedance element whereby a bias voltage will appear across said capacitor to correct for any unbalance due to any lack of symmetry of the detector characteristic with respect to said A.-C. axis.

12. In combination, means for transmitting to a reflecting object a radio carrier wave, a symmetrical non-linear detector, means for receiving the signal reflected from said object and for applying it to the input of said detector, means for also applying to the input of said detector a mixing signal that is obtained directly from said transmitting means and which has a frequency equal to one-half the frequency of the wave that is transmitted to said object whereby any amplitude modulation that may be present is substantially balanced out.

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