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INVERSE MODULATION DETECTOR

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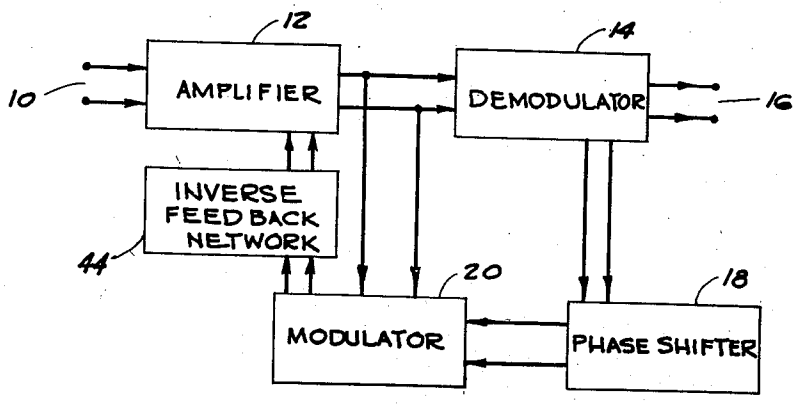


FIG. 1

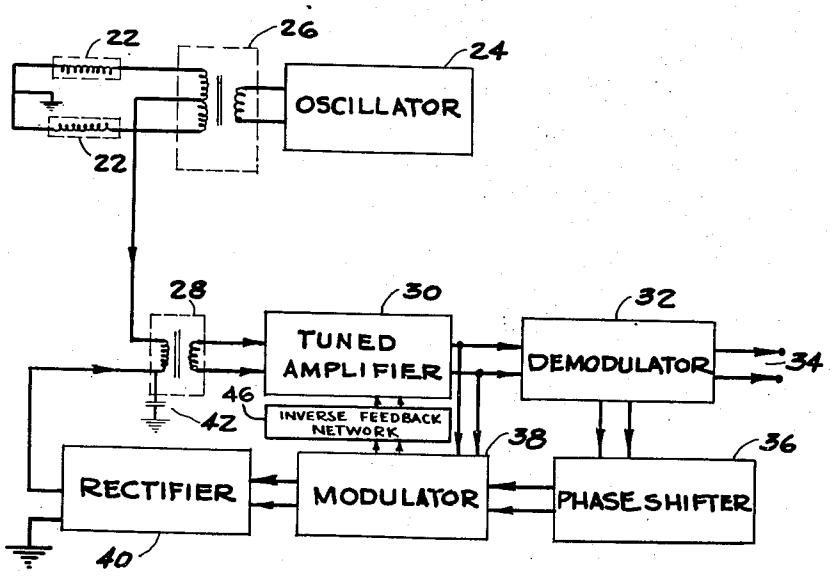


FIG. 2

Inventor

DONALD G.C. HARE

By F. J. Schmitt

Attorney

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INVERSE MODULATION DETECTOR

Donald G. C. Hare, Roslyn, N. Y., assignor to the United States of America as represented by the Secretary of the Navy

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9 Claims. (Cl. 177—351)

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This invention relates to detectors, and more particularly to detectors and methods of detection of the type arranged to derive intelligence from an amplitude-modulated carrier signal.

This invention also relates to detectors having linear response characteristics for signals of all amplitudes.

It is often desired in a detector of the type herein contemplated to obtain high sensitivity with a relatively large output for modulation signals falling within a chosen range of amplitude, and at the same time provide linear response for modulation signals having amplitudes much greater than those within the chosen ranges.

Linearity of response can be obtained by so adjusting the relative amplitudes of the modulation and of the carrier signals that a normal change in the amplitude of the modulated signal is represented by only a small change in the amplitude of the modulated carrier, this condition corresponding to operation at a low-modulation factor. Then, however, in order to obtain adequate demodulator output levels, it is necessary that the modulated carrier signal be amplified considerably before it is applied to the demodulator. The demodulator output level and the response linearity obtained by this method are dependent upon the plate voltage obtainable in the amplifier. An alternate method for obtaining the desired characteristics involves amplification of the output of the demodulator with several stages of modulation frequency amplification. This is often undesirable and is particularly so for low-modulation frequencies because of the instabilities introduced in conventional low-frequency amplifiers.

A primary object of this invention is to provide in a detector the desired output level without sacrificing either linear response or sensitivity at the modulation frequency, or requiring the use of high plate voltages in associated amplifiers.

A further object of this invention is to provide the requirements set forth in the primary object in a detector wherein the modulation factor of a signal applied is effectively increased.

Accordingly, there is provided a detector in which the modulated carrier signal is applied to a conventional demodulator, the output of which is applied both to a pair of output terminals and to a 180-degree phase shifter, the phase-shifted modulation being used to remodulate the modulated carrier input signal, and the resultant remodulated signal being fed back to the input of the detector in an inverse feedback circuit.

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For a more clear understanding of the invention, reference is made to the accompanying drawings, in which

Fig. 1 is a block diagram of a detector according to the invention; and

Fig. 2 is a block diagram illustrating one application of the detector of Fig. 1.

Referring to Fig. 1, a modulated carrier having a low-modulation factor in order to provide the desired linear response is applied through input terminals 10 to an amplifier 12 which is tuned to the carrier frequency and arranged to bring the modulated carrier to a convenient working level. The output of this amplifier is applied to a conventional demodulator 14, by means of which the modulation signal is recovered. This signal is applied to output terminals 16 and to a phase shifter 18, arranged to shift the phase of an applied signal through substantially 180 degrees.

The output of the phase shifter 18 is applied to a modulator 20, by which the phase-shifted modulation signal is caused to remodulate the modulated carrier signal appearing at the output of amplifier 12. The modulation signal is cancelled out by the remodulation process, and the output of the modulator 20 is, therefore, an unmodulated carrier having the same frequency as the original carrier and an amplitude proportional to the average amplitude of the original carrier. This signal is fed back to amplifier 12 in a standard inverse feedback circuit 44, and acts to partially cancel the average value of the carrier in the modulated carrier signal appearing at this point in the circuit. Since this feedback does not affect the amplitude of the modulation on the carrier, the modulation factor on the signal applied to the demodulator 14 is effectively increased.

As a result of the increased modulation factor made possible by this detector, considerably higher demodulator output levels may be obtained for a given plate voltage in the amplifier preceding the demodulator. In addition, since the feedback arrangement does not in any way alter the amplitude of the modulation signal, the response linearity of the system for greater-than-normal modulation signals is preserved.

The detector just described is of general application in systems in which intelligence is transmitted by means of an amplitude-modulated carrier. In one useful application, the detector is incorporated in a bridge-type saturated core magnetometer system as shown in Fig. 2, to which reference is now made. In this system a pair

of saturated-core magnetometer elements **22** is connected in a bridge and excited at some fundamental frequency by means of oscillator **24** through transformer **26**. The output of the bridge comprises a large number of harmonics of the excitation frequency, and the amplitude of any even harmonic is a function of any magnetic field acting at the magnetometer elements. Each of the even harmonics in the bridge output is effectively a carrier modulated by any ambient magnetic field at the location of the magnetometer elements, and any one of them may be used to obtain intelligence as to the field intensity at that location. Conveniently, and in the system to be described, the second harmonic component of the bridge output may be used for this purpose. The bridge output is, therefore, applied through input transformer **28** to amplifier **30**, tuned to the second harmonic of the excitation frequency. The output of this amplifier is a sine wave of twice the drive frequency modulated in accordance with changes in the applied magnetic field, and means are provided for deriving intelligence concerning the ambient magnetic field from this signal.

Often such magnetometer systems are employed to measure field changes of relatively low frequency, and the requirements of the detector are substantially those considered above in connection with the detector of Fig. 1. The output of amplifier **30** is therefore applied to a conventional demodulator **32**, and the output of this demodulator is applied both to output terminals **34** and through a 180-degree phase shifter **36** to a modulator **38**, by means of which the modulated-carrier output of amplifier **30** is remodulated to obtain a carrier signal of second harmonic frequency and of amplitude proportional to the average modulated carrier amplitude at the output of amplifier **30**. This signal is fed back in an inverse feedback system **46** to amplifier **30** to increase the modulation factor of the signal applied to demodulator **32**, thereby to increase the output level without sacrificing latitude of linear operation.

In magnetometer systems of this general type, the broadness and the linearity of response of the magnetometer elements may be somewhat improved by feeding back a bias current to the magnetometer-element bridge of the proper magnitude and polarity effectively to cancel out the effects of long-term variations in applied magnetic field. Various means have been proposed for this purpose, but these involve the use of a time-delay network or the equivalent thereof to prevent reduction of the signals to be detected as well as those due to long-time changes in the applied magnetic field. When the detector of the invention is employed, however, the desired cancellation of long-time variations can be effected without the use of delay circuits. For this purpose, a portion of the output of modulator **38** is rectified in rectifier **40** and fed back through the primary winding of transformer **28** to the magnetometer-element bridge, a blocking capacitor **42** being provided to prevent a short circuit in the direct-current feedback loop. The feedback voltage is proportional only to variations in the average amplitude of the carrier signal. It will be noted that this feedback to the magnetometer-element bridge is therefore instantaneous and yet in no way discriminates against those changes in applied magnetic field which it is desired to measure.

What is claimed is:

1. In an inverse modulation detector, comprising: amplifying means for amplifying an amplitude-modulated carrier input signal, including input terminals; a demodulator coupled to said amplifier for recovering the modulation signal from the utput of said amplifier, including output terminals; means coupled to said demodulator for shifting the phase substantially 180° of the modulation signal from a portion of the output of said demodulator; a modulator coupling said amplifier and phase shifter for remodulating the output of the amplifying means by the phase-shifted output of said phase shifting means; and means coupling said modulator and amplifier for applying the remodulated output signal from said modulator in inverse feedback relationship to said amplifying means.

2. The apparatus as set forth in claim 1 and a magnetometer having an associated exciting oscillator generating even harmonics modulated by any magnetic field ambient to said magnetometer; and a transformer coupling the output of said magnetometer to said amplifying means.

3. The apparatus as set forth in claim 1 and a magnetometer having an associated exciting oscillator generating even harmonics modulated by any magnetic field ambient to said magnetometer; a transformer, having a primary, coupling the output of said magnetometer to said amplifying means; and a rectifier receiving a portion of the output of said modulator and feeding it back through the primary of said transformer to the magnetometer for cancelling out any long-term variations in said ambient field.

4. The apparatus as set forth in claim 1 and a bridge-type saturated-core magnetometer having an associated exciting oscillator generating even harmonics modulated by any magnetic field ambient to said magnetometer; and a tuned transformer coupling the output of said magnetometer to said amplifying means.

5. The apparatus as set forth in claim 1 and a bridge-type saturated-core magnetometer having an associated exciting oscillator generating even harmonics modulated by any magnetic field ambient to said magnetometer; a tuned transformer, having a primary, coupling the output of said magnetometer to said amplifying means; and a rectifier receiving a portion of the output of said modulator and feeding it back through the primary of said transformer to the magnetometer for cancelling out any long-term variations in said ambient field.

6. An amplitude-modulated carrier signal detector comprising means for amplifying the signal, a demodulator coupled to said amplifying means for recovering the modulation signal, means coupled to said demodulator for shifting the phase of at least a portion of the modulation signal, a modulator coupled to said amplifying means and said phase shifting means for producing an unmodulated output carrier of substantially the same frequency as the original carrier, and means coupling said modulator and said amplifying means for applying said output carrier in inverse feedback relationship to said amplifying means.

7. A detector according to claim 6 wherein said phase shifting means comprises means for shifting the phase of the signal substantially 180°.

8. The method of increasing the modulation factor of an amplitude-modulated input signal comprising the steps of amplifying the signal, demodulating the amplified signal, shifting the

phase of the demodulated signal 180°, remodulating the input signal with the phase shifted signal, and degeneratively feeding back the remodulated signal.

9. In an amplitude-modulated signal detector system, the method of increasing the modulation factor of the signal, which comprises amplifying the signal, demodulating the amplified signal, shifting the phase of the demodulated signal substantially 180°, remodulating the amplified signal with the phase shifted signal, and applying the remodulated signal to the input of the system in inverse feedback relationship.

DONALD G. C. HARE.

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