

[54] **ELECTROMAGNETIC WAVE RECEIVER**

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[58] Field of Search **343/113 R, 895, 854**

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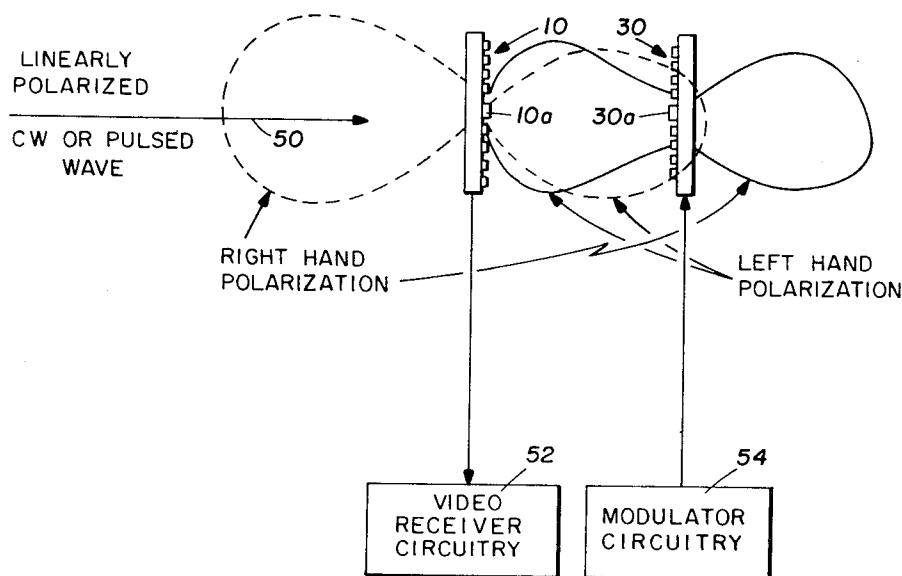
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[57] **ABSTRACT**

Video pulse radio frequency receivers are rendered sensitive to continuous waves by means of an amplitude modulation technique involving coupling between circularly polarized antennas. The circularly polarized antennas incorporate semiconductor diodes as an integral part of the antenna structure. Two circularly polarized antennas with diodes incorporated therein are mounted in tandem with counter rotating faces directed toward a source of linearly polarized electromagnetic wave. One circularly polarized component of the electromagnetic wave excites the first antenna, while the counter rotating component passes through the first antenna and excites the second antenna. The integral diode of the antennas acts respectively as a detector and modulator, with radio frequency coupling being provided by the tandem arrangement which locates the antenna faces of like polarization sense adjacent each other. By arranging a multiple of the pairs of tandem mounted antennas in a distributed pattern, direction finding capabilities are provided.

16 Claims, 9 Drawing Figures



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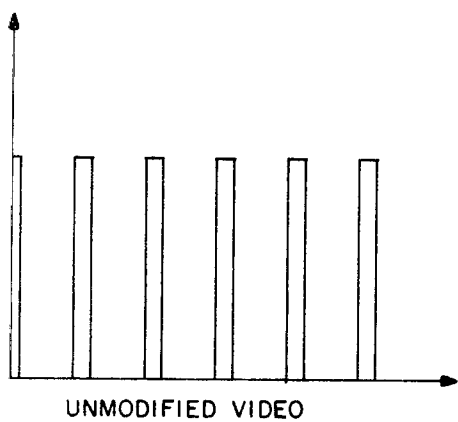
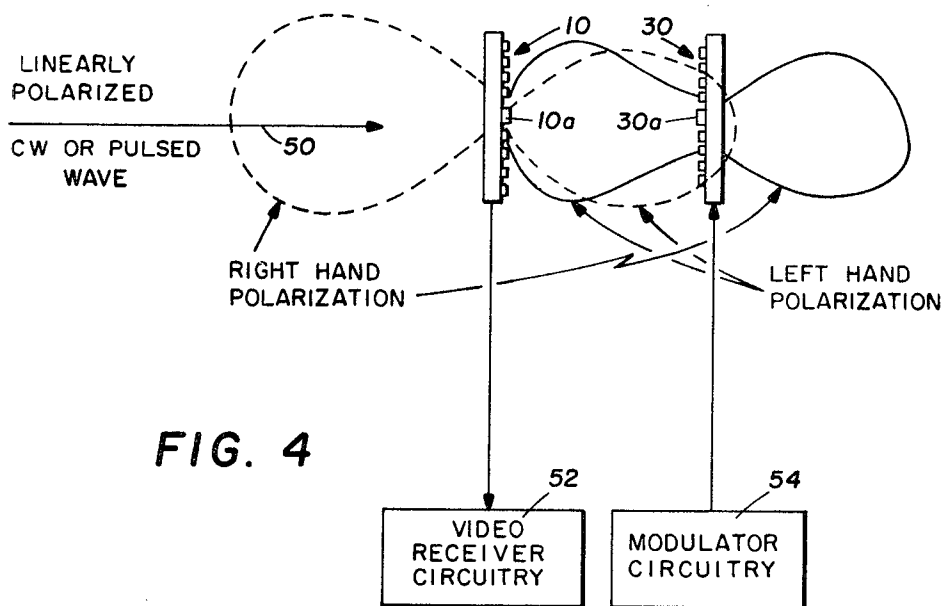


FIG. 5a

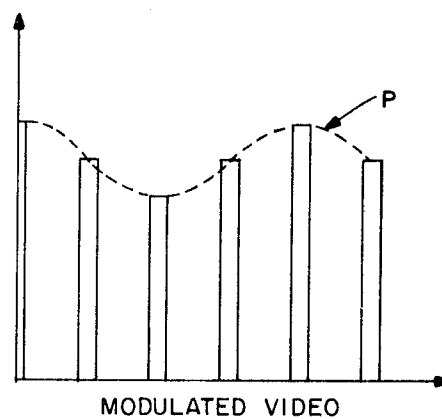


FIG. 5b

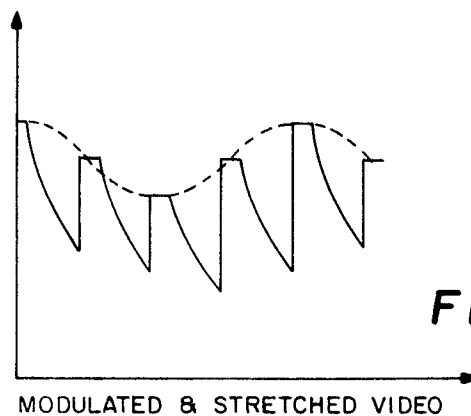


FIG. 5c

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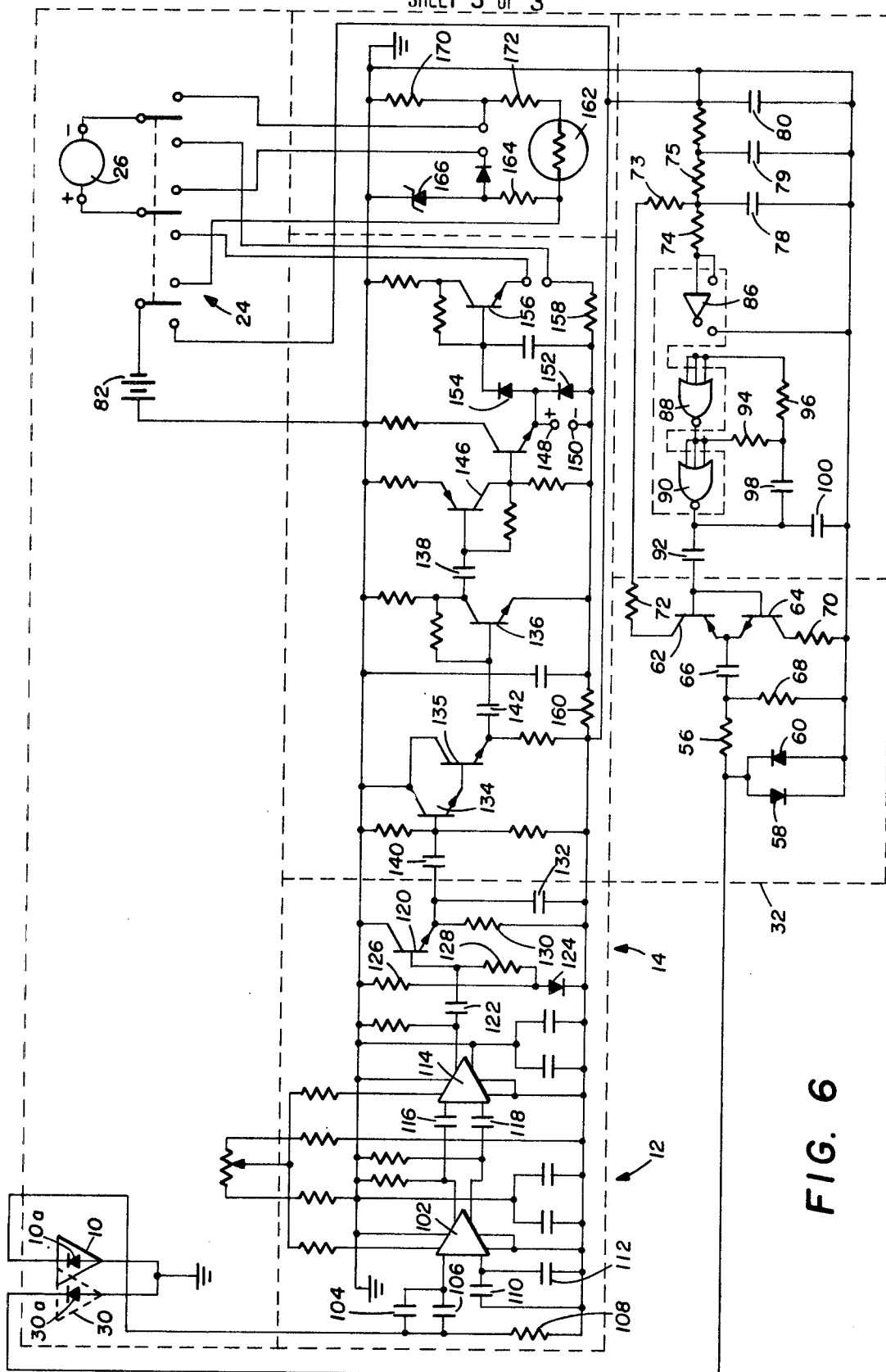


FIG. 6

ELECTROMAGNETIC WAVE RECEIVER

This invention relates to an electromagnetic wave receiver and more particularly to an electromagnetic wave receiver responsive to both pulsed electromagnetic waves and continuous electromagnetic waves throughout a broad frequency spectrum.

Existing apparatus for determining the direction from which signals are received requires extensive and complicated components comprising antennas, transmission lines, modulators and detectors. One type of present day apparatus, for example, measures the angle of signal arrival by employing a phase comparison technique with the phase difference between the signals induced in a pair of proximately spaced antennas providing the desired directional information. Moreover, phase comparison requires the use of either dual radio frequency receiver channels with matched phase and gain characteristics, a relatively cumbersome and difficult mechanism to construct and maintain, or else calibrated wide bandwidth radio frequency phase shifters which are difficult to devise. Furthermore, phase comparison techniques have not proven to be readily adaptable to automatic instrumentation.

Conventional receivers of known design for ultrasonic pulse radio frequency signals rely on digital triggering and counting circuits to provide an audible output. In order to avoid excessive false alarms, each digital system suffers a threshold loss of from 8 to 10 DB.

In accordance with the present invention, a receiving system picks up electromagnetic waves issued from a transmission antenna by an antenna system utilizing the polarization characteristics of such waves to thereby furnish information on the presence and direction of waves from the transmission source. The systems employ a pair of circularly polarized antennas with detector diodes as an integral part thereof which then replaces the conventional five element chain usually employed in detecting continuous wave signals. The integration of the antenna and a diode also produces a component which is simpler and more economical than an identical antenna matched to a transmission line by a wide-band balun over a comparable radio frequency energy bandwidth.

The presence of incoming linearly polarized electromagnetic waves are detected by separating said waves into the right and left-hand circularly polarized components. The two components are picked up by a tandem arrangement of antenna-detectors with the one component passing through the first antenna-detector to be modulated by the second antenna-detector and reflected back to the first antenna. The first antenna-detector then converts the modulated pulse electromagnetic wave into modulated pulse signals which are amplified in a circuit that utilizes pulse stretching techniques.

In accordance with the present invention, an electromagnetic wave receiver includes a modulator antenna polarized to receive a circularly polarized component of an incoming electromagnetic wave. A diode coupled to the modulator antenna provides a modulation component to the received wave which is then reflected back to a receiver antenna polarized to receive a circular polarization component counter in direction to the component received by the modulator antenna. A detector diode coupled to the receiver antenna converts the received modulated signals into low level

pulses. These low level pulses are amplified in a circuit for generating a direction relating output voltage.

A more complete understanding of the invention and its advantages will be apparent from the specification and claims and from the accompanying drawings illustrative of the invention.

Referring to the drawings:

FIG. 1 is a block diagram of a pulse and continuous wave radio frequency receiver for detecting the presence of electromagnetic waves over a broad bandwidth;

FIG. 2 is a partial plan view of an antenna-detector having a dual spiral configuration for use with the system of FIG. 1;

FIG. 3 is a cross-section of an antenna-detector pair mounted in tandem in a cylindrical cavity;

FIG. 4 illustrates a basic receiving system and the antenna patterns for the receiver antenna-detector and modulator antenna-detector of the present invention;

FIGS. 5a, 5b and 5c are waveforms of signals appearing in the system of FIG. 1;

FIG. 6 is a schematic of the radio frequency receiver shown in block diagram in FIG. 1; and

FIG. 7 is a block diagram of a multiple arrangement of tandem pairs of receiver/modulator antennas for a direction finding system in accordance with the present invention.

Referring to FIG. 1, a receiver antenna-detector 10 responds to incoming pulse radio frequency signals and converts them into low level video pulses by means of a detector diode, to be described. These low level video pulses are applied to the input of a preamplifier 12 and then to a pulse stretching circuit 14 that increases the duty cycle of the generated pulses. From the output of the pulse stretching circuit 14 the low level pulses are further amplified in an amplifier 16 and then connected to a headset driver 18 and a meter driver circuit 20. A headset 22, connected to the output of the headset driver 18, allows an operator to hear the pulse radio frequency incoming to the receiver antenna 10. This allows the operator to distinguish if two or more transmitters having different pulse radio frequencies are received simultaneously.

Connected to the meter driver circuit 20 is a battery switch 24 and to a meter indicator 26. A battery tester 28 provides the circuitry for checking the system battery source through the meter 26. The meter 26 provides a visual indication of the integrated pulse radio frequency pulses and allows for direction finding of a specific pulse radio frequency. For direction finding, the azimuth heading of the receiver antenna-detector 10 is swept until a given pulse radio frequency amplitude is maximized. The direction of a specific transmitter then lies directly in front of the antenna 10.

For a continuous wave incoming signal, the receiver antenna-detector 10 merely produces a DC level signal at its terminals which does not pass through the amplifier chain including the amplifiers 12 and 16 and the pulse stretching circuit 14. In accordance with one of the features of the present invention, continuous wave signals are detected by the addition of a modulator antenna-detector 30 coupled to a modulator driver 32 connected to an oscillator 34. The modulator antenna-detector 30 varies the amplitude, i.e., amplitude modulation, of all incoming signals to the receiver antenna 10 at a rate as determined by the modulating frequency from the oscillator 34. These modulated frequency sig-

nals are converted by a receiver antenna 10 into modulated pulse low level signals which are then amplified by the preamplifier 12 to be coupled to the pulse stretching circuit 14 and again amplified in the amplifier 16.

To provide the modulation of a continuous wave signal and the conversion of the pulse radio frequency signals into low level pulses, the receiver antenna 10 and the modulator antenna 30 have a diode mounted integral therewith. Referring to FIG. 2, there is shown an expanded view of a portion of either the antennas 10 or 30. The complete antenna (a part shown in FIG. 2) is a planar, double archimedean spiral with conductor arms 36 and 38 diverging in an ever expanding spiral from a center. The ends of each of the spiral conductor arms 36 and 38 terminate at a lead wire (not shown) coupled to an appropriate part of the system of FIG. 1. A Schottky barrier diode 40 is mounted across the spiral conductor arms 36 and 38 at the center of the antenna. The antennas 10 and 30, of the type illustrated in FIG. 2, may be made by the use of printed circuit techniques wherein the spiral conductor arms 36 and 38 are outlined on an insulating substrate 42.

In addition to planar spirals, the antennas 10 and 30 may be conical spirals, helices, or crossed dipoles, to name a few, all belonging to a class which gives bidirectional spatial coverage with counter-rotating circular polarization in two directions.

For true direction finding with unambiguous results, the antennas 10 and 30 are mounted in a cylindrical cavity 44 as shown in FIG. 3. This renders the antennas unidirectional and responsive to incoming electromagnetic waves only in a direction indicated by the arrow 46. The receiver antenna-detector 10 in the form of the spiral of FIG. 2 is mounted in the cavity 44 with the substrate 42 facing outward to provide mechanical rigidity and protection from the external environment. In tandem with the receiver antenna 10 is the modulator antenna-detector 30 with the identical spiral facing outward toward the spiral of the antenna 10 in order to meet the polarization sense requirement. A radio frequency absorbing material 48 fills the back section of the cavity 44 to reduce reflections and smooth out the frequency response of the antennas.

Electrically, one arm of the spiral of each of the antennas 10 and 30 is connected to ground through the cavity 44 and a lead line to the other spiral arm of each of the antennas is coupled to the appropriate component of the system of FIG. 1. It should be noted, that if the spirals of the antennas 10 and 30 are of opposite winding sense, then both will face in the same direction. Thus, the mounting of the antennas 10 and 30 in the cavity 44 is controlled by the particular configuration of the antennas.

Operationally, the system is illustrated in FIG. 4 where there is shown the receiver antenna-detector 10 sensitive to a right-hand circular polarization component in tandem with a modulator antenna-detector 30 responsive to a left-hand circular polarization component of an incoming wave. The antenna 10 is connected to a video receiver 52 which includes the amplifier 12, the pulse stretching circuit 14, the amplifier 16 and the headset and meter components. The antenna 30 is connected to a modulator 54 which includes the driver 32 and the oscillator 34. It should be noted, that the right-hand and left-hand orientation of the antennas 10 and

30 is by way of illustration in that the sensitivity of such antennas may be reversed.

Assume that a linearly polarized continuous electromagnetic wave approaches from the left as along the arrow 50. This linearly polarized wave is resolved to the right-hand and left-hand circular polarization component in the usual manner. The right-hand component is largely absorbed by the receiver antenna-detector 10 where it provides continuous wave excitation to the detector diode 10a at the center of the spirals thereof. The left-hand component passes through the receiver antenna-detector and is absorbed by the modulator antenna-detector 30 wherein it is applied to the modulator diode 30a and modulated. A portion of the modulated signal generated by the antenna 30 and the diode 30a couples back to the receiver antenna-detector 10.

The mechanism by which the detector diode 10a responds to the combined continuous wave and modulated signals from the modulator antenna-detector 30 is important for its effect on polarization response of the system. Under certain conditions, the modulation frequency output from the detector diode varies with the roll angle of the linear polarization applied to the antennas, i.e., output from a vertical polarized wave may differ from an output obtained from a horizontal polarized wave. Under certain conditions, the modulation frequency output passes through zero for certain roll angles and exhibits a 180° phase shift on opposite sides of the zeroes or nulls. It is a result of this phenomena, which is applicable to roll following servo systems, that enables the system of the present invention to be also applicable to roll following detection.

To analyze the pertinent roll response characteristics of the system, the continuous wave voltage applied to the detector diode 10a is normalized to unity. The coupled modulated voltage will have some magnitude K, where K is ordinarily less than unity. If the phase of the wave at the detector diode 10a is taken as zero, the modulator voltage will have some phase angle ϕ for a given configuration at a given radio frequency; it is noted that ϕ varies at twice the rate of the linear polarization roll angle. Hence a roll from vertical to 45° linear polarization causes ϕ to change by 90°.

Assume that the modulator diode 30a impresses a simple co-sinusoidal amplitude modulation of depth m and rotational frequency p . If the rotational radio frequency is represented by ω , the net radio frequency voltage E applied to the detector diode 10a is given by the equation:

$$E = e^{j\omega t} + K(1 + m \cos pt) e^{j\phi} e^{j\omega t} \quad (1)$$

At the levels generally encountered in the waves of interest, detector response is in accordance with the square law, so that the detector output voltage V varies according to the expression:

$$V \propto E^2 \propto [1 + 2K \cos \phi (1 + m \cos pt) + K^2 (1 + m \cos pt)^2] \quad (2)$$

Only the time varying portion of this couples into the preamplifier 12 so that the output of the amplifier 16 is approximately equal to:

$$\text{video output} [2Km (\cos \phi + K) \cos p t (+K^2 m^2/2) \cos 2 p t]. \quad (3)$$

It is the time varying portion that provides the audio output to the system operator through the headset 22. Roll-following ability of the system described arises from the coefficient $(\cos \phi + K)$ which modulates the fundamental modulation frequency $(\cos p t)$. The second harmonic $(\cos 2 p t)$ is not affected by roll and is ordinarily too weak to be of any importance.

In addition to responding to continuous waves, the system of the present invention also detects ultrasonic frequency pulse signals. These are made audible by the modulator antenna-detector 30 and the coupling between the antennas 10 and 30. Referring to FIGS. 5a, 5b and 5c, FIG. 5a is the video output voltage E of the receiver antenna-detector 10 when receiving ultrasonic radio frequency pulses with no modulation applied and no pulse stretching. This voltage may be expressed by the Fourier expansion:

$$E = A_0 + \sum_{m=1}^{m=\infty} (A_m \cos m\omega t + B_m \sin m\omega t) \quad (4)$$

Where

A_0 = average value over one pulse period,
 $\omega = 2\pi$ (ultrasonic pulse radio frequency) and
 A_m, B_m = amplitude coefficients.

The constant A_0 is directly proportional to the duty cycle of the pulses of FIG. 5a and there are no audible frequency components present in the spectrum. thus, the video receiver circuitry 52 does not provide an output at the headset 22. By means of the modulator antenna-detector 30, the audio modulation illustrated in FIG. 5b is impressed upon the pulse radio frequency signal illustrated in FIG. 5a. The receiver antenna-detector 10, with the diode 10a, converts the modulated pulsed radio frequency into modulated pulse video signals which are applied to the video receiver circuitry 52. This modifies the unstretched video output voltage as given by the equation above to:

$$E = \left[A_0 + \sum_{m=1}^{m=\infty} (A_m \cos m\omega t + B_m \sin m\omega t) \right] [1 + K \cos pt]$$

or

$$E = A_0 + A_0 K \cos pt + [1 + K \cos pt] \left[\sum_{m=1}^{m=\infty} (A_m \cos m\omega t + B_m \sin m\omega t) \right] \quad (5)$$

It will now be seen that the audible modulation frequency of the modulator circuitry 54 appears in the spectrum applied to the video receiver circuitry 52. The amplitude is proportional to $A_0 K$, where K is less than unity.

An important feature of the present invention is the addition of pulse stretching techniques to the output of the preamplifier 12. Considering a response to the ultrasonic frequency pulses, although the pulse stretching also applies to the continuous wave and pulse radio frequency detection, pulse stretching modifies the coefficients of the original Fourier expansion such that:

$$E = \left[C_0 + \sum_{m=1}^{m=\infty} (C_m \cos m\omega t + D_m \sin m\omega t) \right] [1 + K \cos pt] \quad (6)$$

Since the stretched C_0 is greater than the unstretched A_0 (increased duty cycle) it follows that stretching enhances the weak audible signal in the modulated waveform coupled from the antenna 30 to the antenna 10, as illustrated in FIG. 5b. The averaging effect of pulse stretching, as shown by the waveform of FIG. 5c, carries a modulation frequency component through the system to render the signals audible in the manner of a continuous wave input.

Referring to FIG. 6, there is shown a schematic of the system of FIG. 1 with the antenna 30 including the diode 30a having an anode electrode connected to ground and a cathode electrode tied to the output of the modulator driver 32 at an interconnection of a resistor 56 and limiting diodes 58 and 60. The modulator driver 32 also includes transistors 62 and 64 having a common emitter connection to a capacitor 66. The output network of the driver 32 further includes a resistor 68. An emitter electrode of the transistor 64 connects to ground through resistor 70 and the collector electrode of the transistor 62 connects to an input circuit of the oscillator 34 through a resistor 72.

The oscillator 34 includes an input network of resistors 73-76 and capacitors 78-80. An interconnection of the capacitor 80 and the resistor 76 connects to the negative terminal of a DC supply (shown as a battery source 82) through a three-pole, double-throw switch 24. Also included in the oscillator 34 is an inverting amplifier 86 and NAND gates 88 and 90 interconnected to provide a modulating frequency through a coupling capacitor 92 to the interconnected base electrodes of the transistors 62 and 64. The feedback network in the oscillator 34 includes resistors 94 and 96 and capacitors 98 and 100.

As explained, an output frequency from the oscillator 34 modulates through the modulator driver 32 one circular polarization component of a linear polarized wave received at the antennas 10 and 30. The component received at the antenna 30, as modulated by operation of the diode 30a, is coupled to the antenna 10 to provide low level video pulses by means of the diode 10a to the input of a preamplifier 12. An anode electrode of the diode 10a connects to ground and the cathode electrode is tied to the input of an integrated circuit amplifier 102 through coupling capacitors 104 and 106. The detector diode 10a is biased by means of a resistor 108 connected to a negative terminal of the supply 82. A second input to the amplifier 102 is provided by capacitors 110 and 112 connected to the negative terminal of the supply 82. Further amplification of the low level video pulse signals from the antenna 10 is provided by an amplifier 114 coupled to the amplifier 102 through capacitors 116 and 118. The circuit network for each of the amplifiers 102 and 114 includes additional resistors and capacitors to provide the various operating voltages and biases for such amplifiers. These additional networks are not specifically numbered by reference numerals, but are shown to enable those skilled in the art to practice the invention.

Amplified video output pulses from the amplifier 114 are coupled to a transistor 120 through a capacitor 122. The transistor 120 and associated circuitry make

up the pulse stretching circuit 14 of FIG. 1. A diode 124 and resistors 126 and 128 bias the transistor 120 at a threshold such that it acts as a clamper and pulse stretcher. The stretching time constant is established by a resistor 130 and a capacitor 132 connected to the emitter electrode of the transistor 120.

Typical values of components for the pulse stretching circuit include:

Resistor 126	15 K ohms
Resistor 128	
100 K ohms	
Resistor 130	620 K ohms
Capacitor 132	0.0003 μ -farads
Transistor 120	2N2369
Diode 124	1N4152

Stretch modulated pulses from the emitter electrode of the transistor 120 are applied to the amplifier 16 which includes transistors 134-138. Transistor 134 is coupled to the transistor 120 through a capacitor 140 and connected in an emitter-follower configuration with the transistor 135. A coupling capacitor 142 interconnects the transistor 135 to the transistor 136 and a coupling capacitor 144 interconnects the transistor 136 to the transistor 138. Various biasing resistors and capacitors are interconnected to the transistors 134 and 138 to provide the necessary operating voltages and biases. These are not specifically enumerated or identified by reference numeral and are provided to assist those skilled in the art to practice the invention.

An output of the amplifier 16 at the transistor 138 is applied to the headset driver 18 consisting of a transistor 146. The headset 22 is coupled to the transistor 146 at the terminals 148 and 150.

Connected to the emitter electrode of the transistor 146 is the meter driver circuit 20 which includes diodes 152 and 154 with the cathode electrode of the diode 154 connected to the base electrode of a transistor 156. The transistors 146 and 148 also interconnect to various biasing and driving resistors and capacitors, not specifically enumerated.

The meter 26 is driven by the output of the transistor 156 by an interconnection to the emitter electrode through the switch 24 to the negative terminal of the supply 82 through resistors 158 and 160.

The meter check circuit is connected to the supply 82 through the "off" terminal of the switch 24 and includes a thermistor 162 and a resistor 164 interconnected to the negative terminal of the battery supply 82. Also connected to the resistor 164 is a Zener diode 166 and a diode 168, the latter of which has a cathode electrode connected to the meter 26 through the switch 24. Connected to the negative side of the meter 26 is a network of resistors 170 and 172, the latter of which connects to the thermistor 162.

Operationally, the circuit of FIG. 6 is as described with regard to the block diagram of FIG. 1. Amplified video pulses from the amplifier 114 are stretched by the transistor 120 to increase the duty cycle and further amplified by the transistors 134-138. The amplified output of the transistor 138 connects to the headset 22 through the terminals 148 and 150 and to the meter 26 through the meter driver circuit including the transistor 156. A battery test circuit is provided to check the operating condition of the battery 82. A continuous modulation frequency is provided to the diode 30a of the antenna 30 by the modulator driver including the transistors 62 and 64 providing a modulating frequency at the output of the NAND gate 90.

Referring to FIG. 7, to extend the direction finding capabilities of the system of FIG. 1, four pairs of tandem positioned antennas are arranged connected to a modulator 174 and the sequence switch 176 of a receiver 178. Each of the pairs of antennas connected to the receiver 178 and the modulator 174 includes a receiver antenna-detector 182 responsive to a circular polarization component of a linearly polarized wave incident thereon. Associated with each of the receiver antenna-detectors 182 is a modulator antenna-detector 184 supplied a modulating frequency from the modulator 174. The modulator antenna-detectors 184 are polarized to receive the circular component opposite of that from the associated receiver antenna-detector 182. Antennas 182 and 184 may be double archimedean spirals with detector diodes connected across the center terminating points of each spiral. The spirals are mounted facing to provide the opposite circular polarization component sensitivity, as required.

Operationally, the sequence switch 176 individually connects one tandem pair of antennas 182 and 184 to the receiver 178 to detect the presence of any incoming electromagnetic wave. Except for the sequence switching, operation of the circuit of FIG. 7 is as described with regard to FIG. 1. As any one pair of antennas 182 and 184 is connected to the receiver 178, the operation is identical. When any one pair of antennas has incident thereon an electromagnetic wave, the system operator, by means of the headset 22 and the meter 26, determines the general direction of the incoming radiation. He then manually selects this antenna pair to further locate the source of an emitting radiation.

While several embodiments of the invention, together with modifications thereof, have been described in detail herein and shown in the accompanying drawings, it will be evident that various further modifications are possible without departing from the scope of the invention.

What is claimed is:

1. An electromagnetic wave receiver, comprising:
 - a modulator antenna polarized to receive a circular polarization component of an electromagnetic wave,
 - a receiver antenna polarized to receive a circular polarization component of an electromagnetic wave and mounted in tandem with said modulator antenna and electromagnetically coupled thereto for receiving modulated signals therefrom,
 - a detector diode coupled to said receiver antenna for converting received modulated signals into low level pulses,
 - a modulator diode coupled to said modulator antenna for modulating a received electromagnetic energy wave at the modulating antenna, and
 - amplification means responsive to the modulated low level pulses for generating a direction relating output voltage.
2. An electromagnetic wave receiver as set forth in claim 1 wherein said receiver antenna and said modulator antenna have a double archimedean spiral configuration.
3. An electromagnetic wave receiver as set forth in claim 2 wherein said detector diode and said modulator diode are Schottky barrier diodes coupled respectively to the arms of the spiral configuration.
4. An electromagnetic wave receiver as set forth in claim 1 including a cylindrical cavity for mounting said receiver antenna and said modulator antenna to restrict the received electromagnetic waves to a unidirection.

5. An electromagnetic wave receiver as set forth in claim 4 including an energy wave absorbing material in said cavity to reduce reflections and smooth out the frequency response of said antennas.

6. An electromagnetic wave receiver as set forth in claim 1 wherein said receiver antenna and said modulator antenna each include spiral conductors formed on an insulating substrate.

7. An electromagnetic wave receiver as set forth in claim 6 wherein the receiver antenna and said modulator antenna are oriented such that the circular polarization components of like sense face each other.

8. An electromagnetic wave receiver, comprising:

a plurality of modulating antennas polarized to receive a circular polarization component of an electromagnetic wave in one direction and each antenna including a modulating diode coupled thereto for converting received signals into a modulated signal,

a plurality of receiving antennas polarized to receive a circular polarization component of an electromagnetic wave opposite in direction from said modulating antennas and mounted in tandem individually with said modulating antennas and electromagnetically coupled thereto and including a detector diode for each antenna coupled thereto for converting the modulated signals into low level pulses, and

amplification means responsive to the modulated low level pulses from each of the receiver antennas for generating a direction relating output voltage.

9. An electromagnetic wave receiver as set forth in claim 8 wherein each of said receiver antennas and each of said modulator antennas have a double spiral configuration.

10. An electromagnetic energy receiver as set forth in claim 9 wherein said receiver antennas and said modulator antennas are mounted in pairs with counter-rotating faces facing such that circular polarization of

a like sense face each other.

11. An electromagnetic wave receiver as set forth in claim 10 wherein said detector diodes and said modulator diodes are Schottky barrier diodes.

12. An electromagnetic wave receiver as set forth in claim 8 including a plurality cylindrical cavity for mounting said receiver antennas and said modulator antennas in pairs to restrict the received electromagnetic waves to a unidirection.

13. An electromagnetic wave receiver as set forth in claim 12 including an energy wave absorbing material in said cavities to reduce reflections and to smooth out the frequency response of the receiver and modulator antennas.

14. In an electromagnetic wave receiving system with a modulator antenna for modulating a received signal and a receiver antenna coupled to the modulator antenna for receiving the modulated signal and providing modulated low level pulses, comprising in combination: amplification means responsive to the modulated low level pulses for increasing the pulse level at an output thereof,

circuit means coupled to the output of said amplification means for increasing the time duration of each output pulse to thereby vary the duty cycle of the receiver system, and

amplification means responsive to the output of said circuit means for generating a direction relating output voltage.

15. In an electromagnetic wave receiving system as set forth in claim 14 including a modulator driver connected to the modulator antenna for providing a modulation component to the electromagnetic wave.

16. In an electromagnetic wave receiving system as set forth in claim 1 including means responsive to a linear polarization angle in a manner adaptable to roll-following.

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