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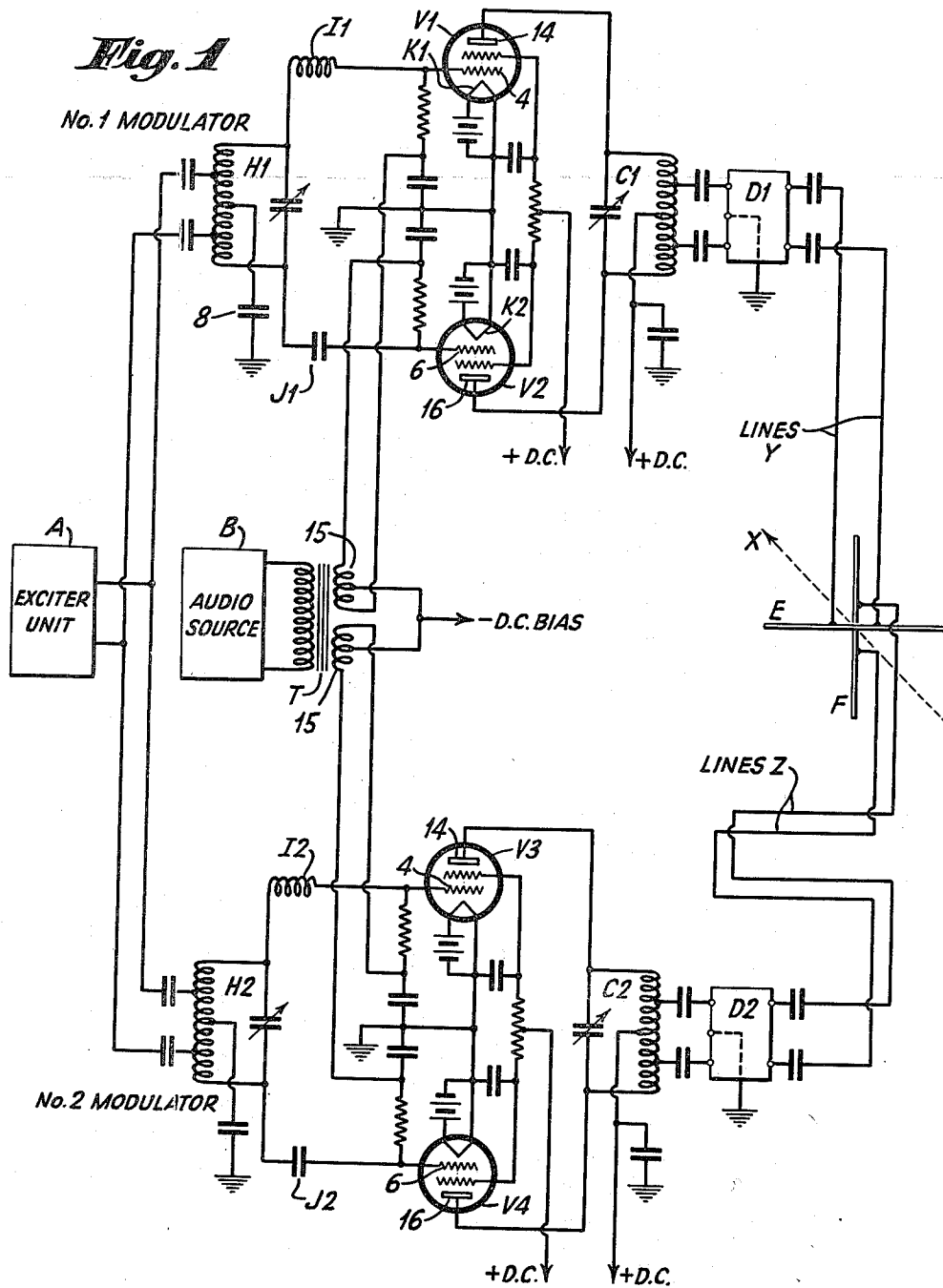
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2,273,161

POLARIZED WAVE MODULATION BY PHASE VARIATION

Filed June 17, 1939

2 Sheets-Sheet 1



BY

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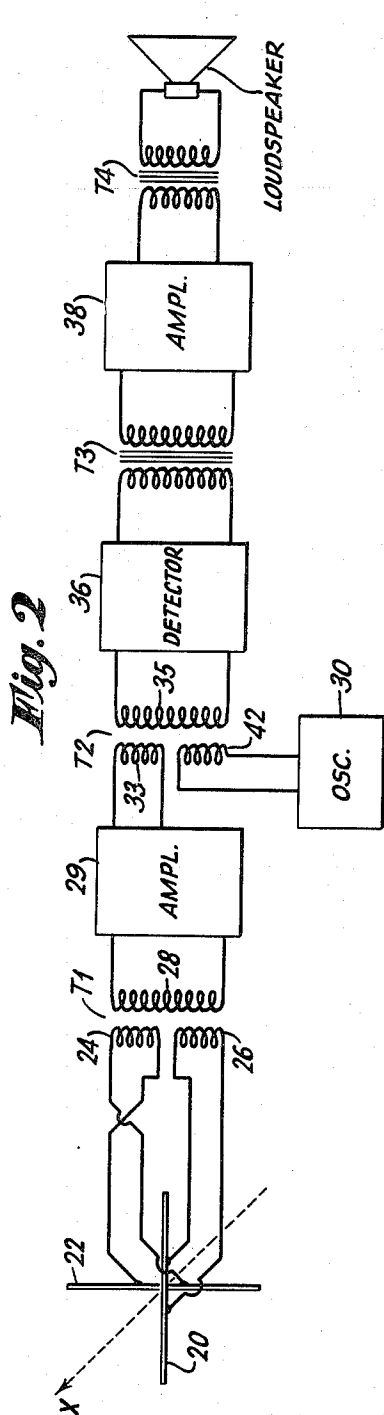
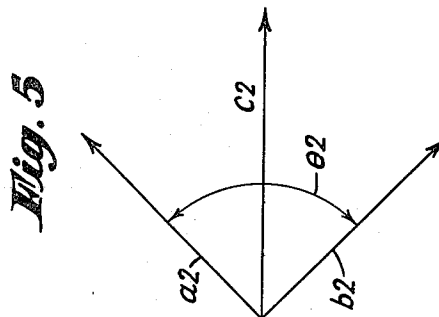
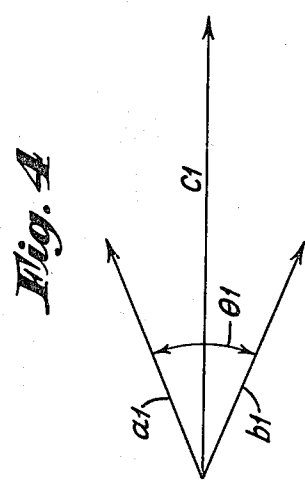
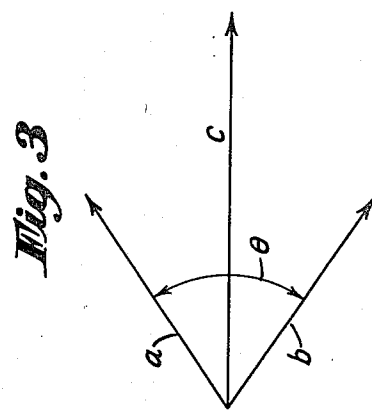
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POLARIZED WAVE MODULATION BY PHASE VARIATION

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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

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POLARIZED WAVE MODULATION BY PHASE
VARIATIONGeorge L. Usselman, Port Jefferson, N. Y., as-
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poration of Delaware

Application June 17, 1939, Serial No. 279,657

7 Claims. (Cl. 250—6)

This invention concerns a new and improved method of and system for radio communication and, more particularly, a system of radio communication by means of polarization modulation with phase shifting of polarization in accordance with signals.

In my United States application #279,656, filed June 17, 1939, I disclose a system of polarization modulation wherein two antenna elements are set relative to each other in a manner such that their respective radiations are polarized in planes at some desired angle to each other. The carrier energies supplied to these two antenna elements are of like phase in time but their amplitudes are differentially modulated to produce radiations, in different planes, of varying amplitude.

The present application discloses a system of polarization modulation wherein two antenna elements are set to radiate energy polarized in planes at some suitable angle with respect to each other. The carrier energies supplied to these two antenna elements are of constant amplitude and the phases of these energies are differentially modulated in relation to each other to produce radiation, in different planes, of radiant energy the phases of which vary at signal frequency.

In describing my invention in detail reference will be made to the attached drawings wherein Fig. 1 and Fig. 2 illustrate a transmitter and a receiver arranged for signalling in accordance with my invention, while Figs. 3, 4 and 5 are vector diagrams used in disclosing the operation of my invention.

A schematic circuit of the transmitter for this system is shown in Fig. 1. Here, briefly, two conventional phase modulators are supplied with carrier energy from the same exciter A. However, the two phase modulators are differentially modulated from the audio source B by means of transformer T. The tank circuit C1 of No. 1 modulator is connected to antenna element E through the radio-frequency amplifier, repeater or multiplier stage D1. Likewise, the tank circuit C2 of No. 2 modulator is connected to antenna element F through the radio-frequency amplifier, repeater or multiplier stage D2.

More in detail wave energy to be modulated is supplied to tuned circuit H1 from A. The tuned circuit H1 is connected to the grid 4 of tube V1 by means of a phase retarding inductance I1. The tuned circuit H1 is also connected by a phase advancing condenser J1 to the grid 6 of tube V2. These radio-frequency circuits

are completed by coupling condenser 8 connected to the cathodes K1 and K2 of tubes V1 and V2. An electrode of each of the tubes such as, for example, electrodes 4 and 6 are connected to the secondary winding 14 of a transformer T the primary winding of which is coupled to a modulating potential source B. The anodes 14 and 16 of tubes V1 and V2 are coupled to tuned circuit C1 to supply phase modulated wave energy to D1 and from D1 through lines 20 to the aerial E. A second phase modulator, as described, comprising tubes V3 and V4 is also connected to an antenna F in a plane at an angle with respect to the angle of the plane including E. The lines Y and Z are of different length, the line Z being longer than the line Y in the modification illustrated.

Phase modulators such as comprised by sources A and B and tubes V1 and V2 and their circuits have been described in several of my United States patents such as, for example, Patent #2,049,143, dated July 28, 1936, filed April 1, 1932. Carrier energy is supplied to the grids 4 and 6 in phase displaced relation due to the action of the phase displacing reactances I1 and J1. In the absence of modulating potentials, each tube supplies wave energy of substantially the same amplitude to circuit C1. This sets up in C1 resultant wave energy of a phase which is the mean of the phases of the wave energy supplied by V1 and V2. Now, if the tubes are modulated, due to the differential connections one tube supplies more energy than the other and the phase of the resultant changes swinging toward the phase of the energy supplied by that tube supplying the most energy to the circuit C1. In other words, the phase modulator comprising the tubes V1, V2 is supplying to the aerial E high frequency oscillations of substantially constant amplitude the phase of which varies at signal frequency.

The phase modulator comprising tubes V3, V4 operates, as described above in connection with the phase modulator comprising tubes V1 and V2, to produce wave energy of substantially constant frequency the phase of which varies at signal frequency and impressing the same on circuit C2. The phase modulated energy from circuit C2 either directly or by way of amplifiers and/or frequency multipliers in D2 is supplied to the aerial F. Note that the aerial F is connected to D2 by a line of a length greater than the line Y connecting D1 to the aerial E to impart to the high frequency oscillations reaching the respective aeri-als a fixed phase displacement.

A schematic circuit of a receiver for this system of modulation is shown in Fig. 2. In Fig. 2 two antenna elements 20 and 22 are set to radiate waves whose polarizations are disposed at an angle. Each antenna element is connected to a section of the primary winding 24 and 26 of transformer T2 as shown. The secondary winding 28 of this transformer is connected to an amplifier 29. The remaining parts of this circuit comprise a conventional receiver such as radio-frequency amplifier 29, detector 36, oscillator 30, audio amplifier 38 and loudspeaker or utilization circuit LS all with the various coupling transformers, T2, T3, T4, etc.

More in detail the receiver of Fig. 2 comprises two aerials 20 and 22 located in planes at angles with respect to each other so that they respond differently to differently polarized waves. Preferably, the antennas 20 and 22 are located in a manner similar to the radio antennas E and F. However, in locating the antennas 20 and 22 they are positioned for maximum reception from the respective antennas E and F of the transmitter and in some cases the angle of displacement between the antennas at the receiver is different than the angle of displacement of the antennas at the transmitter. This is because the polarization of the waves during transmission may be altered. The antennas supply energy to a pair of primary windings 24 and 26 of a transformer T1 having a secondary 28 connected to the input of the necessary amplifiers operating at radio frequency and included in the unit 29. The amplified radio-frequency waves picked up by both antennas are supplied to the winding 33 of a transformer T2 the secondary winding 35 of which is connected to a detector 36. The heterodyning action is obtained here by supplying oscillations from an oscillator 30 to a winding 42 coupled to the winding 35 in transformer T2. The unit 36 may also include the necessary intermediate-frequency amplifiers, detectors, etc., and the audio output therefrom is supplied from a transformer T3 to an audio-frequency amplifier 38 coupled by appropriate means T4 to an indicator LS.

The principle of operation is as follows:

It might be stated to begin with that one of the purposes of using radiation of two polarizations is to obtain two paths through space for the same frequency.

When no signal modulations are being transmitted from source B in Fig. 1, the carrier energies from exciter A will be transmitted unmodulated in regard to phase (or amplitude for that matter) through modulators No. 1 and No. 2 and through amplifiers D1 and D2 to antenna elements E and F respectively. However, it may be noted that the lines Z to antenna F are longer than lines Y to antenna E. This gives a permanent phase shift or displacement to the energy radiated from antenna F as compared to the energy radiated from antenna E. The radiation from antenna F being retarded by an amount equivalent to the increase in electrical length of lines Z over lines Y. (This, by the way, gives in effect a rotating polarization or what is called circular polarization.)

When no modulation is being applied, the radiated energy from antenna E may be represented by vector *a* in vector diagram Fig. 3, and the radiated energy from antenna F may be represented by vector *b*. The angle θ represents the difference in time phase between the energies radiated from antennas E and F. The energies

radiated by E and F are picked up by the antennas 20 and 22 at the receiver each of which, as pointed out before, is oriented to be responsive to radiation from a particular transmitter antenna. Say, for example, antenna 20 receives radiation best from transmitter antenna E and antenna 22 receives radiation best from antenna F of the transmitter, the energies picked up by 20 and 22 add in the primaries 24 and 26 and their effect on the amplifier 29 is accumulative. The output of the receiver is represented by vector sum of the two vectors *a* and *b* of Fig. 3. These vector quantities add up in the receiver and may be represented by the resultant *C* as shown in Fig. 3.

Now, if we apply signal modulation to the transmitter of Fig. 1 and take some instant of a cycle in the signal potential when the control grid of tube V1 is more positive than the grid of V2 in modulator No. 1 and the grid of tube V4 is more positive than the grid of tube V3 in No. 2 modulator, then according to the operation of phase modulators as described above the energy delivered to and radiated from antenna E will be retarded in phase and the energy delivered to and radiated from antenna F will be advanced in phase. The amplitudes of the energy radiated from each antenna will remain constant. These energies radiated from E and F may be represented as vectors *a*1 and *b*1 respectively in Fig. 4 with phase relation θ 1. The receiver antennas now pick up radiant energy the phase of which is displaced relative to the no modulation condition and the resultant energy produced in the secondary of T1 is of different amplitude. In the case shown in Fig. 4, the phases of the radiated energies from antennas E and F are assumed to have swung toward each other so that the resultant *c*1 becomes greater. They will add up in the receiver (Fig. 2) as vector *c*1 in Fig. 4.

Again, if we take some instant of the signal oscillation when, referring to Fig. 1, the control grid of tube V2 is more positive than the grid of tube V1 in No. 1 modulator and the grid of tube V3 is more positive than the grid of tube V4 in No. 2 modulator, then according to the theory of phase modulator operation, the carrier energy delivered to and radiated from antenna E will be advanced in phase and the carrier energy delivered to and radiated from antenna F will be retarded in phase and, as before, the amplitude of the energy in each antenna will remain constant. These energies radiated from E and F may be represented in this case by vectors *a*2 and *b*2 respectively with phase relation as indicated by θ 2 in Fig. 5. As stated before, the two energies represented by *a*2 and *b*2 will add up in the receiver (Fig. 2) as represented by vector *c*2, Fig. 5.

Now it can be seen that as the transmitter is modulated by the signal oscillations, carrier energies are radiated by the antennas E and F, which radiate energies polarized at an angle, and the energy radiated from antenna F also is given a fixed phase rotation or displacement relative to the energy radiated from antenna E. The carrier energy from each of these antennas remains at constant amplitude but the phase of the carrier energy oscillations will be varied differentially, or, in other words, in opposition according to the signal modulation oscillations so that the vectors of these energies go through various changes in which Figs. 3 and 5 may represent the extreme positions and Fig. 4 represents the point of average relation where the modu-

lating potentials cross the zero line or where no modulation is being applied.

In the receiver the two carrier energies are received and added vectorially as per Figs. 3, 4 and 5, so that these two radiated carrier energies, each having constant amplitude but having oppositely varied phase relations, results in amplitude modulation of the receiver carrier energy. This can be seen by noting the action of the resultant vector *c* in Figs. 3, 4 and 5.

Of course, the vectors in Figs. 3, 4 and 5 are assumed to rotate counter-clockwise, but in considering the phase relations between the two vector quantities, the vectors could be considered as not rotating.

What is claimed is:

1. The method of receiving wave energies of like frequency, the phase relations of which are differentially displaced in accordance with signals which includes the steps of, separately intercepting of said wave energies in substantially like amounts, combining said intercepted wave energies vectorially to produce a resultant the amplitude of which is a function of the relative phase displacement thereof, and detecting the said resultant to render the signal.

2. The method of receiving wave energies of like frequency the phase relations of which are differentially displaced in accordance with signals which includes the steps of, separately intercepting said wave energies in substantially like amounts, combining said wave energies vectorially to produce a resultant the amplitude of which is a function of the relative phase displacement thereof, and detecting the said resultant to render the signal.

3. An apparatus for demodulating wave energies of substantially like amplitudes and of unlike phases which phases are relatively displaced an amount which varies in accordance with signalling potentials, a first aerial predominantly responsive to one of said wave energies, a second aerial predominantly responsive to the other of said wave energies, means for additively combining the outputs of said aerials, and detecting means connected with said combining means.

4. An apparatus for demodulating wave energies of different polarizations, of like frequencies and of different phases, which phases are relatively displaced an amount which is a function of signalling potentials, a first aerial predominantly responsive to wave energy of one polarization, a second aerial predominantly responsive to wave energy of a second polarization, means for additively combining the outputs of said aerials, and detecting means connected with said combining means.

5. In a signalling system, means for radiating

two wave energies of unlike polarization, like frequency and substantially like amplitude and of unlike phase, means for modulating the phases of said energies differentially between limits in accordance with signals, a first receiving aerial predominantly responsive to wave energy of a polarization substantially the same as the polarization of one of said wave energies, a second receiving aerial predominantly responsive to wave energy of a polarization substantially the same as the polarization of the other of said wave energies, combining means coupled to said aerials, and detecting means coupled to said combining means.

6. In a signalling system, an aerial adapted to radiate energy of a first polarization, a second aerial adapted to radiate wave energy of a second and different polarization, means for impressing wave energy of substantially like amplitude and frequency in displaced phase relation on said aerials, means for differentially modulating the phases of the energies impressed on said aerials in accordance with signals whereby wave energies of fixed polarization and of relative phases which vary in accordance with signals are radiated from said aerials, and means for receiving and demodulating the radiant energies, comprising a first receiving aerial predominantly responsive to wave energy of said first polarization, a second receiving aerial predominantly responsive to wave energy of said second and different polarization, a combining amplifier coupled to said aerials and detecting means coupled to said combining amplifier.

7. In a signalling system, an aerial adapted to radiate wave energy of a first polarization, a second aerial adapted to radiate wave energy of a second and different polarization, means for impressing wave energy of substantially like amplitude and frequency in displaced phase relation on said aerials, electron discharge tube means for differentially modulating the phases of the energies impressed on said aerials in accordance with signals whereby wave energies of fixed polarization and of relative phases which vary in accordance with signals are radiated from said aerials, and receiving means including a first receiving aerial predominantly responsive to wave energy of said first polarization, a second receiving aerial predominantly responsive to wave energy of said second and different polarization, an amplifier having an input and an output circuit, means coupling said input circuit to said aerials to combine the energy supplied by said aerials additively, and a detector coupled to the output circuit of said amplifier.

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