

Feb. 23, 1943.

J. H. HAMMOND, JR

2,312,093

RADIANT ENERGY SIGNALING SYSTEM

Original Filed Nov. 23, 1938

4 Sheets-Sheet 1

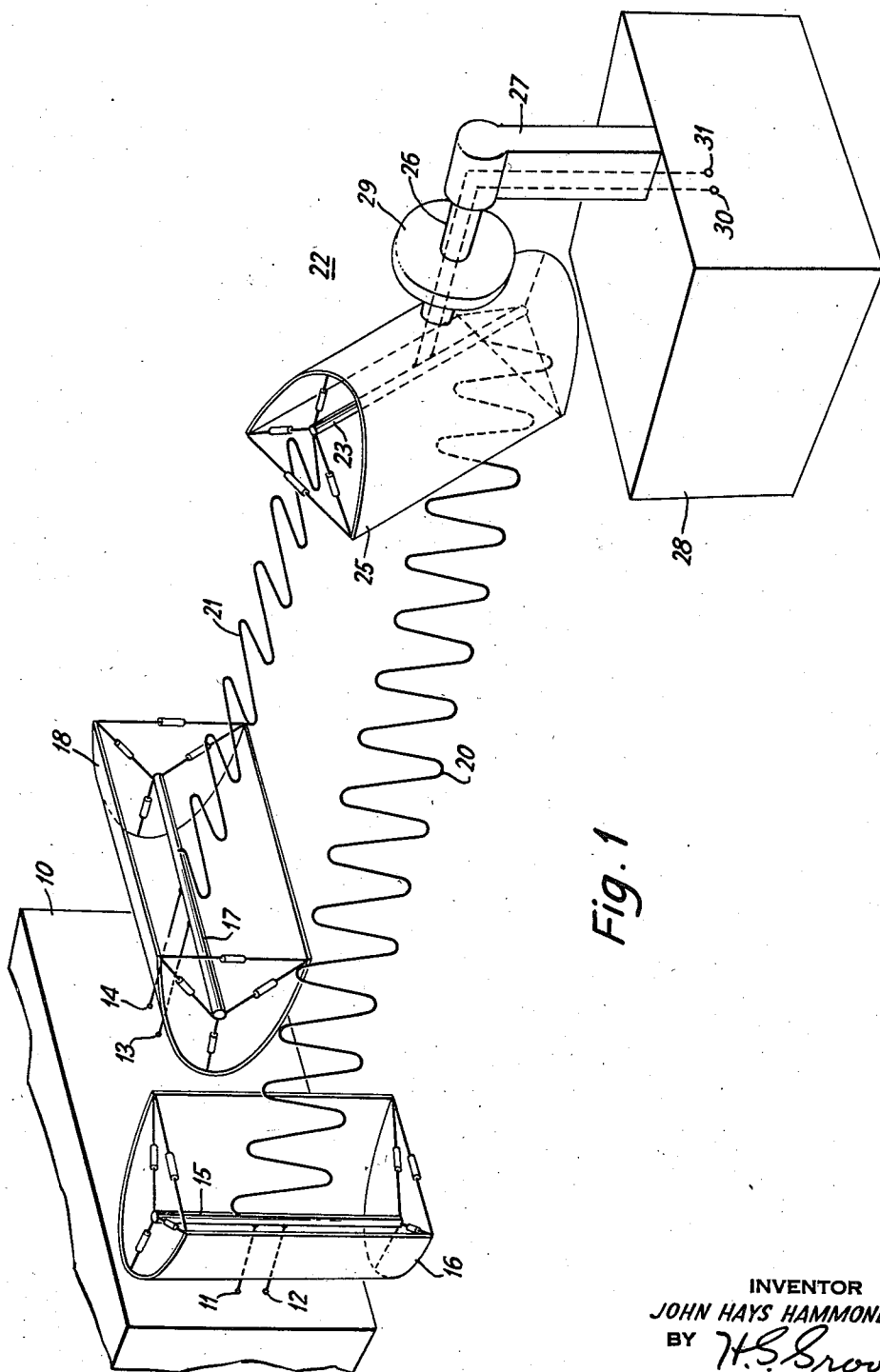


Fig. 1

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Fig. 2

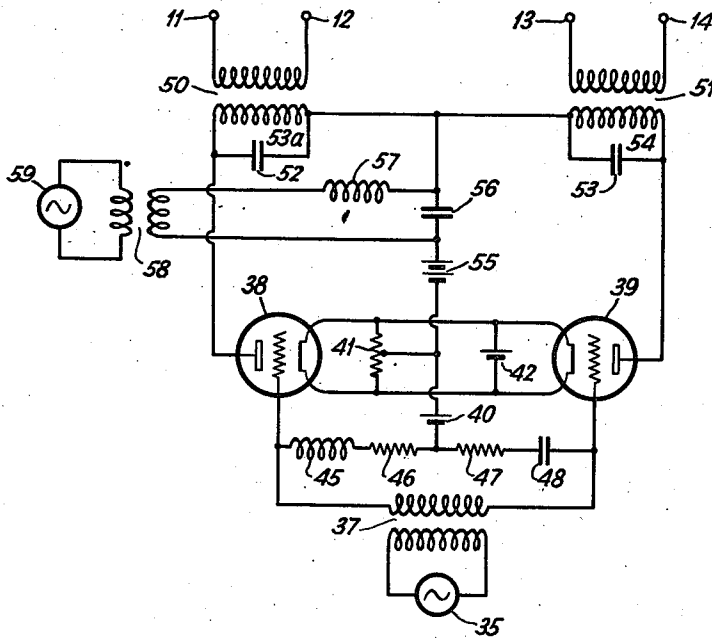
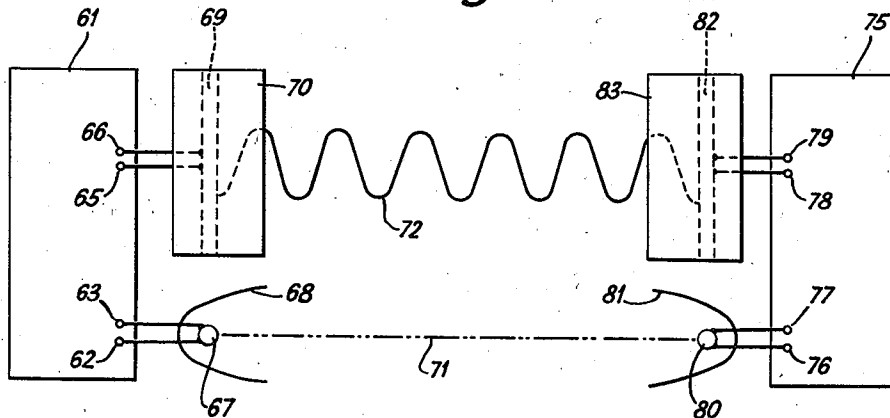


Fig. 3



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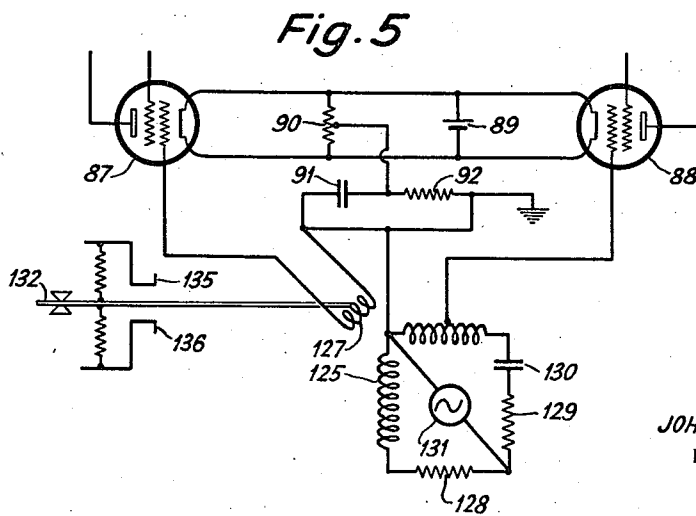
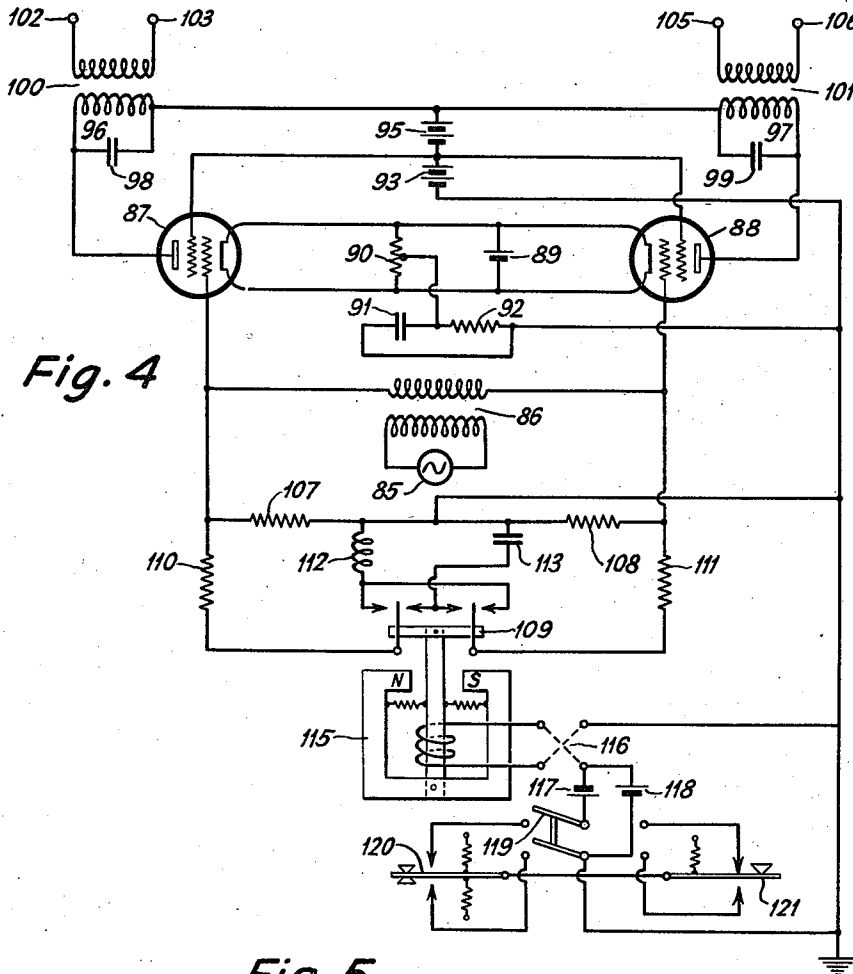
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2,312,093

RADIANT ENERGY SIGNALING SYSTEM

Original Filed Nov. 23, 1938

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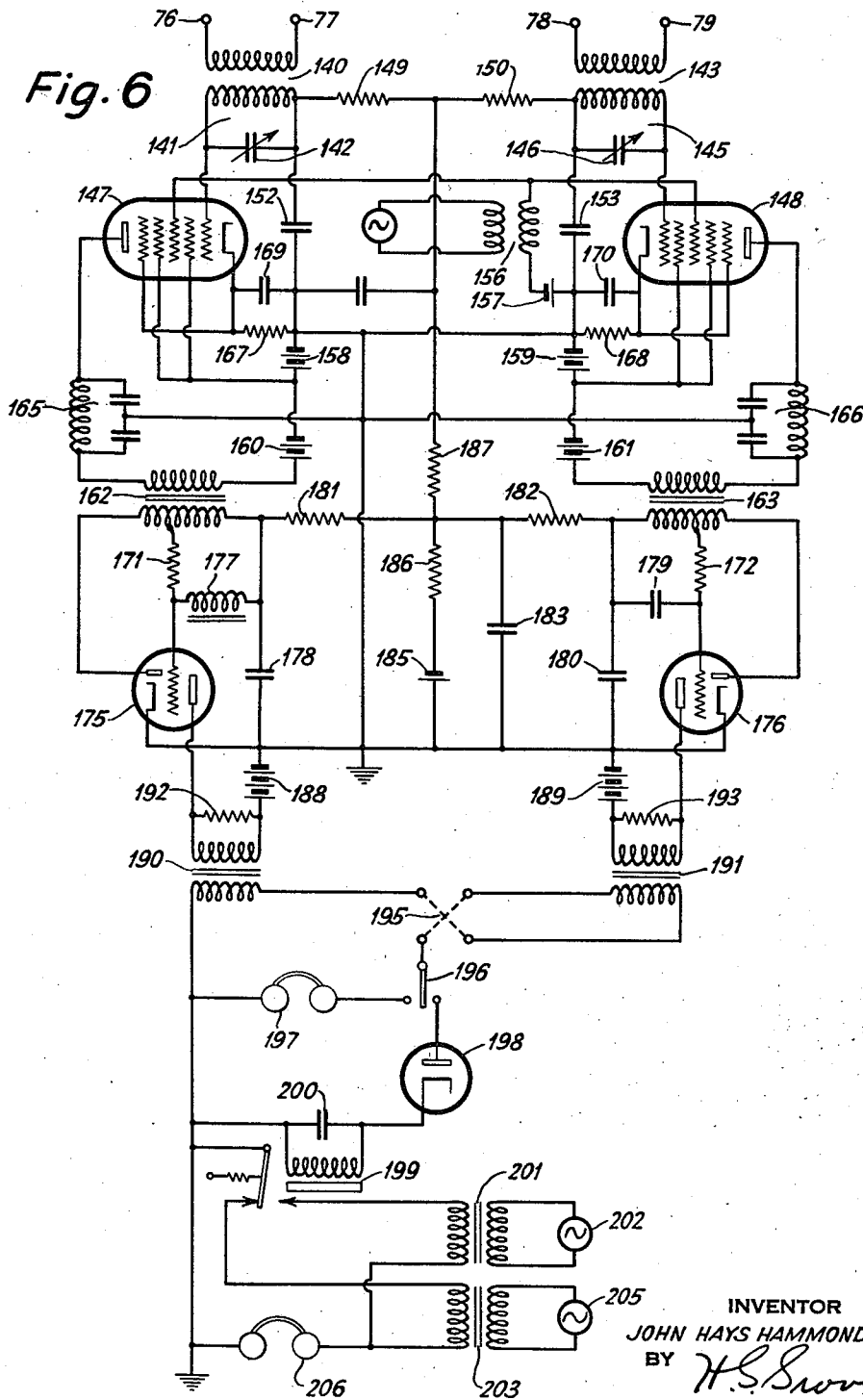
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RADIANT ENERGY SIGNALING SYSTEM

Original Filed Nov. 23, 1938

4 Sheets-Sheet 4



UNITED STATES PATENT OFFICE

2,312,093

RADIANT ENERGY SIGNALING SYSTEM

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Original application November 23, 1938, Serial No. 241,894, now Patent No. 2,272,839, dated February 10, 1942. Divided and this application March 27, 1941, Serial No. 385,456

4 Claims. (Cl. 250—6)

This application is a division of United States patent application Serial No. 241,894, filed November 23, 1938, Patent No. 2,272,839, dated February 10, 1942, entitled "Radiant energy signaling system."

This invention relates to privacy and selective methods of communication by radiant energy.

The invention provides a novel and improved system in which phase modulations are utilized for signaling.

The invention further provides an improved transmission system for producing two carrier waves of the same frequency, but with different planes of polarization, the phases of the radiations having any desired relations.

The invention also provides polarized receiving means which may be rotated so as to eliminate any undesired interference without interfering with the reception of the desired signal.

The present method accomplishes selectivity of transmission against intentional or other interference by similar signals of the same carrier frequency and may be practiced with any type of communication such as continuous wave telegraphy or telephony, facsimile transmission, etc.

The invention also consists in certain new and original features of construction and combinations of parts hereinafter set forth and claimed.

Although the novel features which are believed to be characteristic of this invention will be particularly pointed out in the claims appended hereto, the invention itself, as to its objects and advantages, the mode of its operation and the manner of its organization may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof in which

Fig. 1 illustrates schematically one embodiment of the invention as applied to a transmitting and receiving system for polarized waves;

Fig. 2 illustrates diagrammatically one form of transmitter for use in connection with Fig. 1;

Fig. 3 shows a modified form of a transmitting and receiving system;

Fig. 4 shows diagrammatically the circuits of a continuous wave transmitter which may be used in connection with Fig. 3;

Fig. 5 shows a modified form of signaling for use in the continuous wave transmitter; and

Fig. 6 shows diagrammatically the circuits of a continuous wave receiver which may be used in connection with Fig. 3.

Like reference characters denote like parts in the several figures of the drawings.

In the following description and in the claims parts will be identified by specific names for convenience, but they are intended to be as generic in their application to similar parts as the art will permit.

Referring to the accompanying drawings and more particularly to Fig. 1 a transmitter 10 is provided with output terminals 11, 12 and 13, 14. The terminals 11 and 12 are connected to a vertical radiator consisting of a rod 15 which is mounted in but insulated from a reflector 16. The terminals 13 and 14 are connected to a horizontal radiator consisting of a rod 17 which is mounted in but insulated from a reflector 18. The reflectors 16 and 18 may be of any suitable type, but are preferably of parabolic section and have the rods 15 and 17 located at the foci of these parabolas.

The energies produced by the transmitter 10 at the terminals 11, 12 and 13, 14 are of the same frequency and of the same nature as to modulations, keying, etc. but in general will be of different radio phase. The energy produced at the terminals 11 and 12 will be utilized to drive the vertical radiator 15 which produces a substantially vertically polarized wave shown diagrammatically by the sinusoidal line 20. The energy produced at the terminals 13 and 14 will be utilized to drive the horizontal radiator 17 which produces a substantially horizontally polarized wave shown diagrammatically by the sinusoidal line 21. It is to be understood that the reflectors 16 and 18 are not essential to the operation of the system but are used to reinforce the strength and polarization of the radiations. While the planes of polarization of the two radiations 20 and 21 are shown to be vertical and horizontal respectively, they may be produced at any desired angles by suitably mounting the radiators and reflectors.

The radiations 20 and 21 are both directed to a single collecting antenna system 22 which is shown as consisting of a rod 23 mounted in but insulated from a collector 25 which is preferably of parabolic form with the rod 23 mounted at its focus. The antenna system 22 is supported on a hollow shaft 26 which is rotatably mounted in a bracket 27 secured to a receiver 28. A wheel 29 is fastened to the shaft 26 so that the antenna system 22 may be turned through a range of 180°. The rod 23 is connected through the hollow shaft 26 and bracket 27 to the two input terminals 30 and 31 of the

receiver 28 which is suitably designed for the reception of the type of signal produced by the transmitter. By rotating the antenna system 22 the receiver 28 may be made to respond to the vertically polarized radiation 20 or to the horizontally polarized radiation 21 or in part to both.

Preferably the transmitter 10 should be so arranged that at the receiver the vertically polarized radiation 20 differs from the horizontally polarized radiation 21 by 90 electrical degrees, which may be described as a circularly polarized radiation. Under these conditions the amount of signal from the transmitter 10 which actuates the receiver 28 is independent of the angular setting of the collecting antenna system 22. The system, however, may be operated if there is not exactly 90 degrees difference of electrical phase or of the plane of polarization of the two radiations at the receiver, as some energy will be received from the transmitter at any angular position of the collecting antenna system 22.

In the operation of the system the transmitter and receiver circuits are adjusted in the usual way and continuous wave, telephonic, facsimile or any privacy or selective system can be used with the circuits of the receiver 28 suitably coordinated with the circuits of the transmitter 10. The amount of signal received from the transmitter 10 will be substantially independent of the angular setting of the collecting antenna system 22.

Since interference in general is usually of plane polarized nature it is evident that by rotating the collecting antenna system 22 until its axis is perpendicular to the plane of polarization of the interference it is possible to eliminate this interference almost entirely without affecting the intensity of the desired signal from the transmitter 10. It is thus seen that this arrangement provides a means of transmission and reception quite free from disturbances of plane polarized radiation of the same frequency and general nature as those being conveyed, thus an added method of selectivity is provided over and above any selectivity which may be provided by the nature of the transmitting and receiving circuits.

Referring to Fig. 2 a transmitter circuit is shown which may be used for producing the energy to excite the two radiators 15 and 17 shown in Fig. 1. In the circuit shown in Fig. 2 a source of carrier energy is diagrammatically illustrated at 35, which may be keyed if desired for telegraphic purposes. The source of carrier energy 35 is connected through a transformer 37 to the grids of two power amplifier tubes 38 and 39 which are biased by a battery 40 with respect to the center tap of a resistor 41 which is bridged across the filaments of the tubes 38 and 39. These filaments are heated by a battery 42.

The grids of the tubes 38 and 39 are excited in phase quadrature with the same intensity of signal by the use of input elements such as an inductance 45 and a resistor 46 for the tube 38 and a resistor 47 and a condenser 48 for the tube 39. These input elements are so arranged that the input impedance of the tube 38, shunted by the inductance 45 in series with the resistor 46, represents a 45 degree inductive load, whereas the input impedance of the tube 39, shunted by the resistor 47 in series with the condenser 48, represents a 45 degree capacitive load. These two load impedances are preferably equal numerically. Because of the different loadings the center of the secondary of the transformer 37 is at radio frequency with respect to ground. In practice the

numerical impedances of the input elements 45, 46, 47 and 48 will be small in comparison with the input impedances of the tubes 38 and 39 and therefore these input elements will be chosen of substantially the same numerical impedance at the frequency of operation. The overall load on the secondary of the transformer 37 is a resistance load, but the A. C. voltage from the grid of tube 38 to ground will differ by 90 electrical degrees from the voltage from the grid of the tube 39 to ground.

The output circuits of the tubes 38 and 39 include the primaries of two transformers 50 and 51 which are shunted by condensers 52 and 53 forming two tank circuits 53a and 54. The secondary winding of the transformer 50 is connected to the terminals 11 and 12 of the transmitter 10 and the secondary winding of the transformer 51 is connected to the terminals 13 and 14 of said transmitter. The output circuits of the tubes 38 and 39 are energized by a battery 55 which is connected in series with a condenser 56. Across the condenser 56 and in circuit with a choke 57 is the secondary of a transformer 58, the primary of which is shown as connected to a source 59 of modulating energy. When the modulating energy is operative, the carrier energy will in general not be keyed but will be continuously operative. The condenser 56 and choke 57 are used to minimize the flow of energy from the tubes 38 and 39 to the modulation source 59.

The two tank circuits 53a and 54 are tuned to the radio frequency of the transmitter 10. As a result of the phase quadrature relation of the grid excitation the plate circuits will also be actuated in phase quadrature, and both output circuits will also be actuated by radio frequencies in phase quadrature, but not at a modulating frequency as represented by the output of the modulator 59.

It is to be understood that the circuit depicted in Fig. 2 is only illustrative and that any other suitable method could be used for producing the same results and that the receiver 28 will be of suitable construction for responding to the system of communication which the circuits shown in Fig. 2 may be organized to create.

In addition to the superselective features achieved by the system depicted in Figs. 1 and 2 it is possible to use the two polarized waves for super privacy purposes by using a transmitter in which the relative phase of the radiations may be changed for purposes of signaling and a receiving system by which the phases of the radiations from the transmitter may be compared.

The general arrangement of such a system is shown schematically in Fig. 3. A transmitter 61, of the same general type as shown in Fig. 1, is used for producing the two beams of polarized radiation but is provided with a means for shifting the phase relations. The transmitter 61, shown in plan view, is provided with the output terminals 62, 63, and 65, 66. The terminals 62 and 63 are connected to a vertical rod radiator 67 which is located at the focus of a parabolic reflector 68. The terminals 65 and 66 are connected to a horizontal rod radiator 69 located at the focus of a parabolic reflector 70. The vertical radiator 67 produces a vertically polarized wave indicated by the dotted line 71 and the horizontal radiator 69 produces a horizontally polarized wave indicated by the sinusoidal line 72.

A receiver 75 is provided with input terminals 76, 77 and 78, 79. The terminals 76 and 77 are connected to a vertical rod antenna 80, located at

the focus of a parabolic collector 81, and used to receive the vertically polarized wave 71. The terminals 78 and 79 are connected to a horizontal rod antenna 82, located at the focus of a parabolic collector 83, and used to receive the horizontally polarized wave 72. Signaling is preferably of the continuous wave type, but wave amplitude modulation may be introduced as an aid to privacy if desired. Signaling is accomplished by changing the relative phases of the two radiations 71 and 72 with the receiver 75 arranged so as to be differently responsive under the two conditions.

A transmitter for producing the desired relative phase shifting is shown in Fig. 4 and is similar to the transmitter shown in Fig. 2 with the exception that keying means are provided for modifying the phase relations. A single phase source of carrier frequency energy is provided at 85 and is connected through a transformer 86 to the input circuits of two tubes 87 and 88, which are provided with a filament battery 89 and biasing resistor 90 the mid-point of which is connected through condenser 91 and resistor 92 to ground. A suitable polarizing battery 93 and plate battery 95 are also provided. The output circuits of the tubes 87 and 88 are connected to two tank circuits 96 and 97 comprising condensers 98 and 99 and the primaries of two transformers 100 and 101 the secondaries of which are connected to output terminals 102, 103 and 105, 106 respectively which correspond to the output terminals 11, 12 and 13, 14 of Fig. 1.

Connected between the grids of the tubes 87 and 88 and ground are two resistors 107 and 108 and connected between these grids and the blades of a reversing switch 109 are two resistors 110 and 111, the resistors 107 and 108 being greater than the resistors 110 and 111. Connected between the contacts of the switch 109 and ground are an inductance 112 and a condenser 113. The impedances of the resistors 110 and 111 and of the inductance 112 and condenser 113 are about equal. The reversing switch 109 is operated by a polarized relay 115 the armature coil of which is connected to a reversing switch 116. One pole of this switch is connected through two oppositely polarized batteries 117 and 118 to the blades of a double pole double throw switch 119. The left hand contacts of the switch 119 are connected to the contacts of a double acting key 120 the armature of which is normally held in a central position. The right hand contacts of the switch 119 are connected to the contacts of a single acting key 121 which is normally held in the up position.

In the operation of the transmitter shown in Fig. 4 when the switch 119 is thrown to the left the key 120 is put into operation. With the key in the central position as shown no current will flow through the armature winding of the relay 115 so that the switch 109 will be held in the central position as shown. The paths from the grids of tubes 87 and 88 to ground will then be through resistors 107 and 108 in which case the two grids will be excited in phase opposition, these impedances serving to maintain the grid bias and excitation under these conditions. The grid energy is thus repeated into the plate circuits and then through the tank circuits 96 and 97 and the transformers 101 and 102 to the two sets of output terminals 102, 103 and 105, 106. From these the energy passes to the radiators 67 and 69 shown in Fig. 3 where it is radiated as vertically and horizontally polarized waves, the phases of which are equal or in opposition according to

the terminology arbitrarily set up for designating equality of phase.

When the key 120 is depressed a circuit from the battery 118 is closed through the armature winding of the relay 115 causing this armature of the relay 115 to be moved to the left which in turn moves the switch 109 to the left. This causes the resistor 107 to be shunted by the resistor 110 and inductance 112 and the resistor 108 to be shunted by the resistor 111 and condenser 113. This makes an inductive impedance from the grid of the tube 87 to ground and a capacitive impedance from the grid of the tube 88 to ground. This causes the phase of the radiation generated by the tube 87 to be advanced 45 electrical degrees and the phase of the radiation generated by the tube 88 to be retarded 45 electrical degrees, so that the radiation emitted by the radiator 67 leads the radiation emitted by the radiator 69 by 90 electrical degrees.

When the key 120 is elevated the battery 117 will be thrown in circuit with the armature winding of the relay 115, thus reversing the current through this winding and causing the armature to move to the right thus throwing the switch 109 to the right. This will reverse the action just described and produce a capacitive impedance from the grid of the tube 87 to ground and an inductive impedance from the grid of the tube 88 to ground. This will cause the radiation emitted by the radiator 67 to lag 90 electrical degrees behind the radiation of the radiator 69.

When it is desired to use the key 121 the double pole switch 119 is thrown to the right. Under these conditions a circuit is normally closed from the battery 117 through the armature winding of the relay 115, which causes the switch 109 to be thrown to the right. This, as already described, causes the radiation of vertically and horizontally polarized waves from the radiators 67 and 69 respectively, the former lagging behind the latter by 90 electrical degrees. When the key 121 is depressed a circuit will be closed from the battery 118 through the armature winding of the relay 115 causing the switch 109 to be thrown to the left, which, as already described causes the vertically polarized wave to lead by 90 electrical degrees the horizontally polarized wave. The action of the keys 120 and 121 may be reversed by throwing the reversing switch 116 into the opposite position.

When operating the key 120 telegraphic code may be sent by using one position of the key for dashes and the other position for dots regardless of the extent of contact. With the key 121 operative dots and dashes are sent depending upon the lengths of time that the key is depressed. The transmitter shown in Fig. 4 thus provides for both types of keying and the reversing switch 116 provides a choice of correlations of key contacts and relative output phases.

With a transmitter as shown in Fig. 4 and suitably set up for 90 degrees phase lead or lag of one radiation with respect to the other and with the radiations plane polarized at 90 degrees in space the resulting radiations are circularly polarized with one direction of rotation with the key on one contact and with the opposite direction of rotation with the key on the other contact. A standard continuous wave receiver cannot distinguish any difference between these two forms of polarization, while a suitably constructed receiver can so distinguish. In case the radiations are not exactly circu-

larly polarized, but are elliptically polarized, it might be possible to distinguish between the two directions of rotation by the strength of the signals under the two conditions. For this reason it may be advantageous to provide in the carrier source 85 a keying arrangement for varying the carrier strength abruptly at dot and dash rates so that the true signals sent by the key 120 or key 121 cannot be distinguished on the basis of differences of signal strength, but must be distinguished on the basis of phase relations.

Instead of using the abrupt keying arrangements shown in Fig. 4 a continuous phase shifting arrangement may be used as shown in Fig. 5. In this figure the tubes 87 and 88 are identical with the tubes 87 and 88 of Fig. 4 and their output circuits would be connected through the transformers 100 and 101 to the output terminals 102, 103 and 105, 106 as shown in that figure.

In Fig. 5 a three coil arrangement is provided which comprises two fixed coils 125 and 126 coupled to a rotatable coil 127. The grid of the tube 87 is connected to the rotatable coil 127 and the grid of the tube 88 is connected to a tap on the fixed coil 125. Phase splitting circuits including two resistors 128 and 129 and a condenser 130 are connected to the fixed coils 125 and 126 and a single phase source of carrier frequency energy 131 is provided which is similar to that shown at 85 in Fig. 4. The coils 125 and 126 are so arranged with their axes at right angles that they produce a so-called rotating field analogous to that of a two phase induction motor in which the currents in the coils differ by 90 electrical degrees. The rotatable coil 127 is mounted in this rotating field and is operatively connected to a key 132 in such a way that when this key is depressed it will cause the coil 127 to be rotated in one direction and when it is elevated it will cause the coil 127 to be rotated in the other direction. Stops 135 and 136 are provided so that the coil 127 is rotated through the desired angles when the key 132 is depressed or elevated. The arrangement of the circuits is such that the voltages impressed on the grids of the two tubes 87 and 88 are substantially equal in magnitude regardless of the angular setting of the coil 127.

In the operation of the modified form of the invention shown in Fig. 5 the coil 127 may be so set that the tubes 87 and 88 are excited equally in phase when the key 132 is in a central position. When the key 132 is depressed the coil 127 will be rotated through the desired angle in the rotating magnetic field produced by the fixed coils 125 and 126 and will cause the wave generated by the tube 87 to lead the wave generated by the tube 88 by an amount dependent upon the rotation of the coil 127. When the key 132 is elevated the reverse action will take place and the wave generated by the tube 87 will lag behind the wave generated by the tube 88 an amount dependent upon the rotation of the coil 127. In this way the keying may be accomplished by rotating the coil 127 in one direction for a dash and the other direction for a dot. Remote control of the keying system may be provided if desired.

The difference of electrical angular displacement between the two waves need not be 90 electrical degrees but may be much smaller, the minimum depending in part on the sensitivity of the receiving device as a detector of phase shifts. In order to prevent the rotation of the

coil 127 from being noted at an ordinary receiver because of any slight amplitude modulation or slight phase or frequency modulation which may be produced in the wave radiated by one of the tubes 87 or 88, it may be desirable to vary the frequency, amplitude or frequency and amplitude of the carrier source 131 sufficiently at keying rates so that as a practical matter the motion of the key 132 can be determined only by phase comparison of the two radiations.

The receiver 75, shown in Fig. 3, which is used for receiving and interpreting the two polarized waves 71 and 72 generated by the transmitter shown in Fig. 4 or that shown in Fig. 5, in conjunction with Fig. 4, may be provided with a receiving circuit as shown in Fig. 6. In this circuit the input terminals 76 and 77 are connected through a transformer 140 to a tuned circuit 141 which comprises the secondary of the transformer 140 and a variable condenser 142. The input terminals 78 and 79 are connected through a transformer 143 to a tuned circuit 145 which comprises the secondary of the transformer 143 and a variable condenser 146. The tuned circuits 141 and 145 are connected to the first grids of two pentagrid mixer tubes 147 and 148. The ground ends of these circuits are connected through four resistors 149, 150, 187, 186 and a battery 185 to ground and are suitably by-passed to ground by four condensers 151, 152, 153 and 183.

A source of heterodyning current 155 is provided which is connected through a transformer 156 to the third grids of the tubes 147 and 148. A battery 157 for suitably biasing these grids is connected in the circuit of the secondary of the transformer 156. The second and fourth grids of the tubes 147 and 148 are polarized by two batteries 158 and 159, while the plates of these tubes are further polarized by two additional batteries 160 and 161 which are connected through the primaries of two transformers 162 and 163 and through two radio frequency filters 165 and 166 to these plates. The fifth grids of the tubes 148 and 147 are connected to the cathodes, which may be self-polarized by two condensers 169 and 170.

The secondaries of the transformers 162 and 163 are suitably tapped and connected through two resistors 171 and 172 to the grids of two audio frequency amplifier tubes 175 and 176. Bridged across a part of the secondary of the transformer 162 is the resistor 171 and an inductor 177 and bridged across part of the secondary of the transformer 163 is the resistor 172 and a condenser 179. The ground ends of the secondaries of the transformers 162 and 163 are connected to ground through two resistors 181 and 182 and the resistor 186 and battery 185 and are suitably by-passed by two condensers 178 and 183. The plate circuits of the tubes 175 and 176 include two plate batteries 188 and 189 and the primaries of two transformers 190 and 191 which are shunted by two resistors 192 and 193.

The secondaries of the two transformers 190 and 191 are connected through a reversing switch 195 to the blade of a single-pole, double-throw switch 196. One contact of the switch 196 is connected to a pair of head phones 197 and the other contact to the plate of a diode rectifier 198. The cathode of this rectifier is connected to the winding of a relay 199 which is shunted by a condenser 200. The front contact of the relay 199 is connected through a transformer 201

to a tone source 202 and the back contact is connected through a transformer 203 to a different tone source 205. The secondaries of the two transformers 201 and 203 are connected through a pair of head phones 206 to ground.

In the operation of the receiving system shown in Fig. 6 use is made of the fact that if two waves of the same frequency but of different phase are both heterodyned by the same source the resulting beat notes will have the same phase difference as the original waves and involves the use of two receiving devices which are separately actuated by the two polarized waves and cause two audio frequency currents to be like phased or oppositely phased depending upon which wave leads the other by 90 electrical degrees.

When the two polarized waves 71 and 72 are received by the two rod antennas 80 and 82, shown in Fig. 3, the signals will be impressed upon the input terminals 76, 77 and 78, 79. From these terminals the signals will pass through the transformers 140 and 143 (Fig. 6) to the tuned circuits 141 and 145 and will be impressed upon the first grids of the tubes 147 and 148. The input signals are heterodyned to audio or other low frequency by the oscillator 155 which impresses corresponding voltages on the third grids of the pentagrid tubes 147 and 148. The detected output currents from the tubes 147 and 148 will pass through the radio frequency filters 165 and 166 and will actuate the transformers 162 and 163 with audio or other low frequency currents.

These circuits are of a well known arrangement for frequency changing purposes and the relation between the output current and input voltage is given by the equation

$$i_p = a + be_1 + ce_3 + de_1^2 + fe_3^2 + ge_1e_3 \dots \text{etc.}$$

in which i_p is the plate current; e_1 and e_3 are the voltages impressed on the first and third grids respectively and all the other letters represent constants. The output audio currents arise from the term ge_1e_3 .

Let

$$e_1 = m \sin \omega t \text{ for the tube 147}$$

$$e_1 = m \sin (\omega t + \phi) \text{ for the tube 148.}$$

Let

$$e_3 = n \sin (\omega - p)t \text{ for both tubes}$$

where m and n are constants ω and p refer to radio and audio frequencies and ϕ is the phase difference between e_1 for tube 147 and e_1 for tube 148. Then the audio currents are evaluated to be

$$i_p = g \frac{mn}{2} \cos pt \text{ for tube 147}$$

$$i_p = g \frac{mn}{2} \cos (pt + \phi) \text{ for tube 148}$$

It is evident therefore that if the voltages impressed on the grids of the tubes 147 and 148 correspond to those on the grids of the tubes 87 and 88 (Figs. 4 and 5) then the difference of phase of the audio currents at the transformers 162 and 163 will be the same as the differences of the radio phases. In place of comparing the radio phases of the voltages it is only necessary to compare the phases of the detected currents.

The audio circuits are so designed as to produce a phase shift of 45 electrical degrees in opposite senses in the two channels so that a net differential shift of 90 electrical degrees occurs in the audio circuits. As a result the audio currents become in phase with each other or out of phase with each other depending on which of the radio channels leads the other by 90 electrical de-

grees. This is accomplished by the phase shifting circuits which comprise the resistor 171 and inductor 177 for the tube 175 and the resistor 172 and condenser 179 for the tube 176. These circuits advance by 45 electrical degrees the voltage impressed on the grid of the tube 175 and retard by 45 electrical degrees the voltage impressed on the grid of the tube 176. These voltages are amplified in the plate circuit of the tubes 175 and 176 and are impressed through the transformers 190 and 191 upon the combining circuit including the head phones 197 or the rectifier 198.

Automatic volume control may be used for making the voltage outputs of the transformers 190 and 191 substantially equal in magnitude. This may be accomplished by the signal currents which are rectified by the anodes of the tubes 175 and 176 from the grid transformer and which develop automatic bias voltage across the bias resistor 186 which is applied to the control grids of all the tubes. The battery 185 causes the automatic volume control to be inoperative unless a satisfactory signal exists.

The rectified voltage developed across the resistor 186 is impressed through the resistors 187, 149 and 150, suitably by-passed and filtered by the condensers 183, 151, 152 and 153, to control the grid bias of the tubes 147 and 148, so that the audio voltages at the transformers 162 and 163 are a slowly increasing function of the signal voltages. The voltage across the resistor 186, supplemented by the voltage across the resistor 181, controls the bias on the tube 175 and the voltage across the resistor 185 supplemented by the voltage across the resistor 182 controls the bias on the tube 176. In this way increasing signals at the transformers 162 and 163 decrease the gain ratios of the tubes 175 and 176. This volume control is so designed that the audio outputs at the transformers 190 and 191 are substantially the same and are of a definite amount regardless of the total signal strength impressed on the two channels or of considerable differences of signal strength.

It is therefore evident that two substantially equal audio voltages result at the secondaries of the transformers 190 and 191, the phases of which are dependent on the keying positions at the transmitter shown in Figs. 4 and 5. With the keys in the neutral position the voltages at the output sides of the transformers 190 and 191 will differ in phase by 90 electrical degrees, but with the keys in the operative positions the phase difference of these audio voltages will become zero or 180 degrees, depending on the position of the keys and the setting of the switch 116 of Fig. 4. By operating the reversing switch 195 the outputs of the two transformers 190 and 191 may be made additive, for example when the key 120 is down, and subtractive when it is up. The two reversing switches 116 and 195 may be coordinated and synchronously thrown from time to time to change the correspondence of phases and signals as desired.

The selector switch 196 may be thrown to the left for indicating the combined signals in the head phones 197 in response to the operation of the key 121 at the transmitter. With the key 121 in the down position the voltages combine to produce a loud signal and with the key in the up position the voltages oppose to produce a small or zero signal. For indicating in response to the operation of the key 120 at the transmitter the switch 196 may be thrown to the right. The signal will then be impressed on the diode rectifier 198 which will produce a direct current in the

winding of the relay 199 the strength of which is controlled by the position of the key 120 at the transmitter. Thus when the key 120 is in the down position a strong current will pass through the winding of the relay 199 thus moving its armature to the right which will close a circuit from the tone source 202 through the head phones 206 producing a given tone in these phones. When the key 120 is in the up position a weak current will pass through the winding of the relay 199 which will not be sufficient to operate this relay so that the tone source 205 will be thrown in circuit with the head phones 206 to produce a different tone in these phones. The relay 199 will be operated in a similar manner when the key 132 in Fig. 5 is operated. It is thus seen that the position of the key 120 or the key 132 would be indicated by the tonal value of the sound in the head phones 206.

It is to be understood that the relative phases of the currents at the receiver may be compared in other ways than that described. For example the secondaries of the transformers 190 and 191 may be connected to the deflecting plates of a cathode ray oscillograph yielding a circular diagram with the key 120 in a neutral position, a vertical line when the key is down and a horizontal line when it is up.

Another method may use receivers in which an intermediate frequency circuit is placed between the radio and audio frequency circuits.

It is also to be understood that for receiving the waves generated by the system shown in Fig. 1 the audio outputs of the tubes 147 and 148 may be combined to make a so-called rotating magnetic field in which may be mounted an adjustable, rotatable secondary, suitably connected to an audio amplifier. This rotatable secondary would pick up the signals from the transmitter shown in Fig. 1 in any position, but for superselectivity purposes it would be so adjusted as to minimize the effects of any plane polarized radiation constituting interference.

Although only a few of the various forms in which this invention may be embodied have been shown herein, it is to be understood that the invention is not limited to any specific construction but may be embodied in various forms without departing from the spirit of the invention or the scope of the appended claims.

What I claim is:

1. In a signaling system which includes a transmitter and a receiver, said receiver being provided with a signal receptor, the method of minimizing interference in a given plane of polarization which comprises, transmitting the signal energy as two independent plane polarized phase displaced waves having mutually perpendicular planes of polarization to provide a substantially circularly polarized transmitted wave, intercepting the transmitted waves, and orienting the re-

ceptor to a position which is substantially perpendicular to the plane of polarization of the interference wave.

2. In a radio signaling system adapted for signaling over a path which is so short that the polarization of the transmitted waves is substantially unaffected by the transmission medium, said system including means for transmitting signaling energy as a substantially circularly polarized wave and a receiver including an antenna structure adapted to be unresponsive to waves having a certain polarization relative to the receiver antenna structure, said antenna structure being arranged to be adjustably orientated with respect to the plane of polarization of received waves, the method of eliminating interference with desired signals caused by undesired plane polarized waves which consists in adjusting the receiving antenna structure to the orientation at which it is non-responsive to said interfering waves but fully responsive to that component of the circularly polarized wave which is at right angles to the plane of polarization of the undesired wave.

3. In a short wave radio signaling system adapted for signaling over a path which is so short that the polarization of the transmitted waves is substantially unaffected by the transmission medium, said system including means for transmitting signaling energy as a substantially circularly polarized wave and a receiver including an antenna structure adapted to be unresponsive to waves having a certain polarization relative to the receiver antenna structure, said antenna structure being arranged to be adjustably orientated with respect to the plane of polarization of received waves, the method of eliminating interference with desired signals caused by undesired plane polarized waves which consists in adjusting the receiving antenna structure to the orientation at which it is non-responsive to said interfering waves but fully responsive to that component of the circularly polarized wave which is at right angles to the plane of polarization of the undesired wave.

4. In a short wave radio signaling system adapted for signaling over a path which is so short that the polarization of the transmitted waves is substantially unaffected by the transmission medium, means for transmitting signaling energy as a substantially circularly polarized wave, a receiver including an antenna structure adapted to be unresponsive to waves having a certain polarization relative to the receiver antenna structure, and means for orientating said antenna structure with respect to the plane of polarization of received waves, to a position at which it is non-responsive to undesired plane polarized interfering waves but fully responsive to that component of the circularly polarized wave which is at right angles to the plane of polarization of the undesired wave.

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