Aug. 18, 1936. I. WOLFF ET AL 2,051,537

MODULATION SYSTEM

Filed Dec. 23, 1933 2 Sheets-Sheet 1

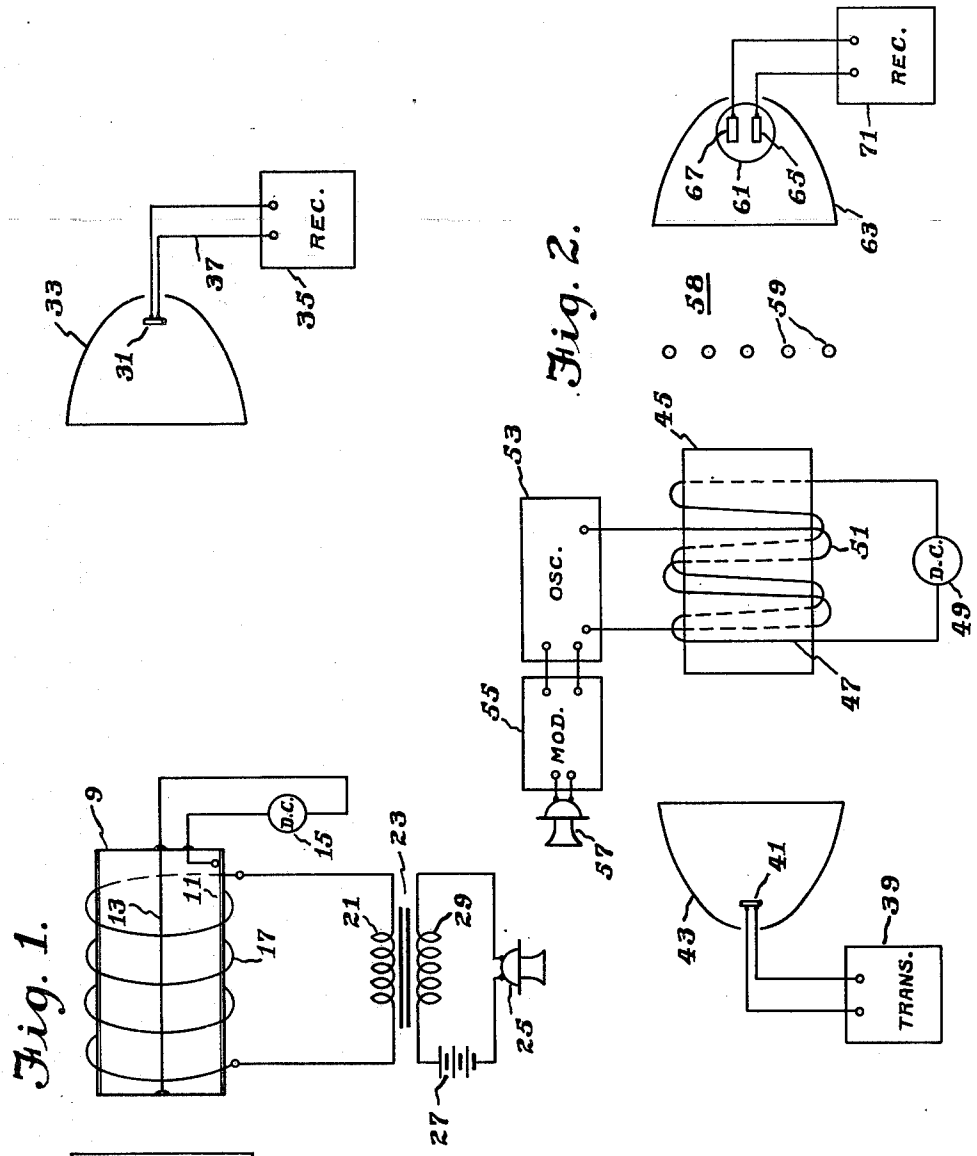


Fig. 1.

Fig. 2.

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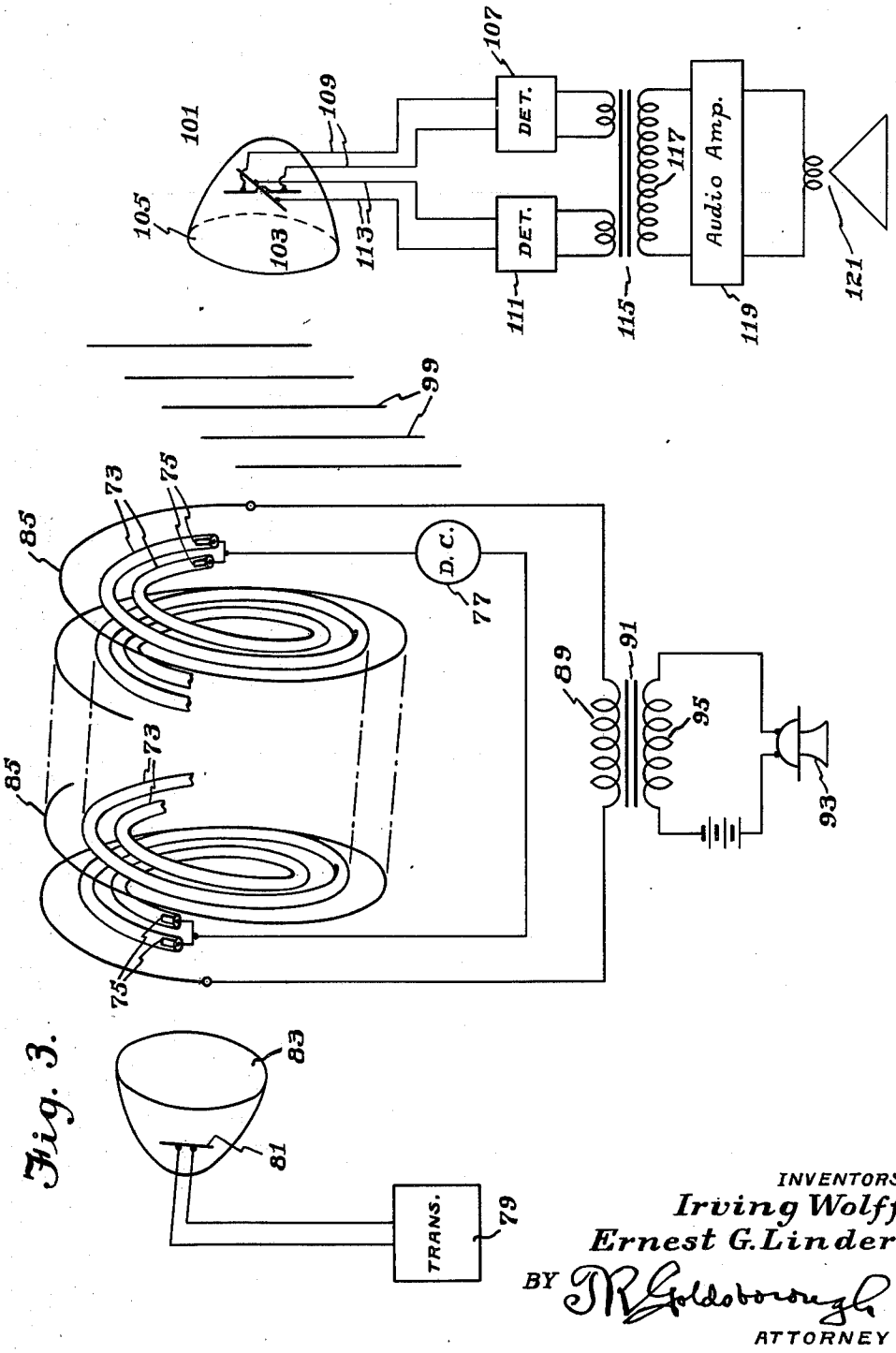


Fig. 3.

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MODULATION SYSTEM

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13 Claims. (Cl. 250—6)

Our invention relates to radio systems and particularly to systems employing radio waves having a short wave length.

It is well known that a radio system which employs electro-magnetic waves having an ultra-short wave length of 10 centimeters, for example, has many advantages over systems operating on the longer wave lengths. It has been found, however, that there are difficulties in modulating the ultra-short electro-magnetic waves. In particular, it has been found that when employing the usual amplitude modulation circuits, a certain amount of frequency-modulation of the short waves is obtained when pure amplitude modulation is desired.

It is, accordingly, an object of our invention to provide an improved method and means for modulating electromagnetic waves having a short wave length.

It is a further object of our invention to provide an improved short wave radio communication system.

In practicing our invention, we take advantage of the fact that the plane of polarization of a plane polarized radio wave may be rotated by passing the radio wave through an ionized gas in the direction of the lines of force of a magnetic field, in which the ionized gas is located. The degree of rotation of the plane of polarization may be varied either by varying the strength of the magnetic field or by varying the ionization of the gas. By varying either the magnetic field or the ionization of the gas in accordance with a signal, and by employing either a suitable analyzing device, or a receiver which has maximum pickup for a certain plane of polarization, an amplitude modulated radio wave may be received. Where the magnetic field alone is varied, there is no frequency modulation. Where the ionization of the gas is varied, there generally is some frequency modulation, but it is of comparatively small magnitude.

Other objects, features, and advantages of our invention will appear from the following description taken in connection with the accompanying drawings in which—

Fig. 1 is a schematic diagram of one embodiment of our invention and

Figs. 2 and 3 are schematic diagrams of other embodiments of our invention.

Referring to Fig. 1, the transmitting apparatus comprises any suitable source 1 of high frequency oscillations, such as a magnetron oscillator, which is connected to a dipole antenna 3 through a transmission line 5. A reflector 7 is provided for directing the energy radiated from the dipole antenna 3 into the form of a beam. Reflector 7 is preferably of the parabolic type, the dipole antenna 3 being located at or near the focal point of the reflector.

The above described apparatus transmits a radio beam which is plane polarized, the plane of electric polarization being in a plane determined by the axis of the reflector and the antenna.

In accordance with our invention we modulate the radio beam by rotating the plane of polarization in accordance with a signal. The apparatus for rotating the plane of polarization includes an envelope 9 located near the transmitting antenna 3 and in the path of the radio beam, the envelope being filled with a gas such as neon under a reduced pressure. In the embodiment illustrated, the envelope 9 is in the form of a cylinder, but it should be understood that it may be given any convenient shape.

The gas in the envelope is ionized in any suitable manner as by means of electrodes 11 and 13 inside the envelope which are connected to a direct current source 15. The electrode 11 may be in the form of a metallic coating on the inner surface of the envelope and the electrode 13 in the form of a central electrode running lengthwise of the envelope, as illustrated.

The rotation of the plane of polarization is produced by means of a coil or solenoid 17 surrounding the envelope 9 so that the lines of force of its magnetic field are parallel to the longitudinal axis of the envelope. The solenoid 17 is connected across the secondary 21 of an audio frequency transformer 23 whereby an alternating magnetic field will be produced which has a value depending upon the output of transformer 23.

The plane of polarization of the radio beam is rotated in accordance with a signal as the beam passes through the ionized gas and magnetic field, this being accomplished by means of a microphone 25 which is connected through a battery 27 to the primary winding 29 of the audio frequency transformer 23. When sound waves strike the microphone 25, the field strength of the magnetic field produced by the coil 17 is varied, thus varying the rotation of the plane of polarization of the radio beam. Obviously, suitable amplifiers (not shown) may be interposed between the microphone and the solenoid, if desired.

Assuming that the plane of polarization of a radio beam will not be rotated during transmis-

sion from the ionized gas device to the radio receiver, the simple receiving apparatus shown in Fig. 1 is all that is required to complete the radio system. This receiving apparatus is of the usual type employed in radio beam communication and consists of a dipole antenna 31 positioned in a reflector 33. The antenna is connected to any suitable receiver 35 through a transmission line 37. Since the dipole antenna 31 has a maximum pickup when the polarization of the radio beam is in the same place as the antenna, the strength of the received signal will vary in accordance with the rotation of said plane of polarization. Thus, a radio signal will be transmitted from the antenna to the receiver which is amplitude modulated in accordance with the signal impressed upon the microphone 25.

For the condition of no modulation on the transmitter, the angle of the receiving antenna with respect to the plane of polarization of the radio wave is preferably so adjusted that the value of the received electric current is about half way between its minimum and maximum values. More specifically, a preferred adjustment is one where the receiving antenna is at an angle of 60 degrees with respect to the plane of electric polarization during the condition of no modulation. In other words, as indicated in Fig. 1, antenna 31 is preferably at an angle of 60 degrees with respect to antenna 3. With this adjustment, rotation of the plane of polarization 30 degrees in one direction will cause zero pick-up by antenna 31, while a rotation of 30 degrees in the opposite direction will cause a pick-up equal to sine 60° times maximum pick-up.

It should be understood that the adjustment of the angle of the receiving antenna with respect to the plane of polarization is not critical. However, as the current picked up by the receiving antenna follows a sine curve, the above described adjustment is preferred because it permits operation along a part of the curve which approximates a straight line whereby distortion is a minimum.

It should be understood that in place of the dipole antenna 3 and reflector 7 any other suitable source of polarized radio energy may be employed. Likewise any receiving device sensitive to the angle of the plane of polarization may be substituted for the dipole antenna 31 at the receiver. For example, a loop antenna may be substituted for the dipole antenna 31.

The magnitude of the rotation of the plane of polarization of the radio beam depends on the length of its path in the ionized gas, the degree of ionization, the strength of the magnetic field, and the pressure of the gas, as the most important factors. This will be understood more clearly by referring to the formula for determining the rotation of the plane of polarization which is given below:

$$\phi=\frac{\pi l}{\lambda}(n_1-n_2)$$

where l is the length of path through the gas and λ is the wave length, while n_1 and n_2 are given by

$$n_1^2=1-\frac{4\pi Ne^2}{m\omega}\frac{\omega+\frac{eH}{mc}}{\left(\omega+\frac{eH}{mc}\right)^2+S^2}$$

and

$$n_2^2=1-\frac{4\pi Ne^2}{m\omega}\frac{\omega-\frac{eH}{mc}}{\left(\omega-\frac{eH}{mc}\right)^2+S^2}$$

where N is the number of free electrons per unit volume, e is the charge per electron, m the mass of an electron, $\omega=2\pi$ times the frequency, H is the magnetic field strength, c the velocity of light, and S the average collision frequency of an electron which results in an absorption of energy.

From the above equation it will be evident that the amount the plane of polarization is rotated may be varied by varying the strength of the magnetic field as described in connection with Fig. 1, by varying the degree of ionization of the gas whereby the quantity N in the equation is varied, or by varying the length of the path through the gas. The system shown in Fig. 2 is designed for modulating a radio beam in accordance with the second-named manner.

Referring to Fig. 2, the transmitter is the same as the transmitter shown in Fig. 1 and comprises a source of high frequency oscillations 39, a dipole antenna 41 and a reflector 43. A cylindrical envelope 45 containing a gas such as neon at a low pressure is positioned in the path of the radio beam directed from the reflector 43. A constant magnetic field is applied to the gas by means of a solenoid 47 and a direct current source 49 connected thereto.

Although the gas may be ionized by means of a discharge between electrodes as shown in Fig. 1 and this discharge varied in accordance with a modulating current, a different method of ionizing the gas is illustrated. The method illustrated consists in applying a high frequency field to the gas by means of a coil 51 surrounding the envelope 45, the coil being supplied with energy from any suitable high frequency oscillator, indicated at 53. The high frequency output of the oscillator 53 may be modulated in accordance with a signal by means of any suitable modulating device 55 having a microphone 57 connected to its input.

When modulating by voice frequencies, the frequency of oscillations delivered by the generator 53 must, of course, be sufficiently high to permit of modulation by audio-frequencies. Such frequency, however, must differ from the frequency of the transmitter 39 by an inaudible frequency or else reception will be interfered with. In the case of telegraphy, these precautions need not be strictly taken.

Since the degree of ionization of the gas in envelope 45 depends upon the intensity of the high frequency field, the degree of ionization changes in accordance with the modulation of this field and the plane of polarization of the radio beam is correspondingly rotated. Under ordinary circumstances, the radio beam thus transmitted, which is modulated as to its plane of polarization, may be received by the same receiving device as described in connection with Fig. 1.

In the event that atmospheric conditions cause a rotation of the plane of polarization, it will be necessary to provide some type of analyzing device 58 at the transmitter such as a screen of parallel conductors 59 positioned adjacent to the ionized gas container 45 on the side away from the transmitter. Conductors 59 should be spaced apart less than one wave length for best results. Also, they are preferably positioned at an angle to the dipole antenna 41 having a value depending upon the amount the plane of polarization is rotated in passing through the ionized gas.

In the drawing, antenna 41 is shown at an angle of minus 10 degrees with respect to conductors 59, this angle being chosen for the condition of a plus 40 degree rotation of the plane of polarization

by the ionized gas during the period of zero modulation. Therefore, the plane of electric polarization of the wave, after it passes through the ionized gas, makes an angle of 30 degrees with respect to the screen conductors 59. It will be noted that with this adjustment, the modulating signal can rotate the plane of electric polarization to a position parallel with the screen conductors (the position of minimum signal), while the gas is still ionized a certain amount.

The screen 58 has the characteristic that it will permit a radio beam to pass therethrough substantially unimpeded, providing the plane of electric polarization of the beam is at right angles to the conductors. If the plane of polarization is at an angle to the conductors the beam is impeded to a degree depending upon the angle. The law connecting the amplitude of the wave transmitted through this screen and the strength of the wave which originates on the other side is $a=a_o \sin \theta$ where a_o is the amplitude of the wave before it reaches the screen and θ is the angle between the conductors in the screen and the plane of electric polarization of the radio wave.

It will be apparent that a radio beam which leaves the screen or analyzer 58 while the microphone 57 is being spoken into, is amplitude modulated.

As in the case of the apparatus shown in Fig. 1, the angle of the plane of electric polarization with respect to the analyzing device is not critical. Also, the particular angle specified is for the purpose of keeping distortion to a minimum by operating along a portion of a sine curve which closely approaches a straight line.

Since, in the system shown in Fig. 2, the received signal must be independent of any rotation of the plane of polarization produced by atmospheric disturbances or the like, it is necessary that the receiving device have an equal pickup in all planes. One such device consists of a gas tube 61 positioned at or near the focal point of a reflector 63. The tube contains a gas such as neon at a low pressure and has two electrodes 65 and 67 which are connected to a receiver 71. The neon tube 61 picks up and demodulates the received signal as described in connection with Fig. 2 of application Serial No. 687,544 filed Aug. 31, 1933 in the name of Ernest G. Linder and assigned to Radio Corporation of America.

In Fig. 3, there is illustrated another modification of our invention in which the cylindrical container for the ionized gas is replaced by a plurality of long gas-filled tubes 73, each wound in the form of a spiral. Two spiral tubes are illustrated, a section being removed from the middle to simplify the drawing, one tube being positioned inside the other. Preferably additional tubes are provided, formed in the shape of spirals, and positioned inside the tubes shown to form a substantially solid cylinder of ionized gas, but, in order to simplify the drawing, these are not shown. The gas in these tubes is maintained ionized by means of a discharge between electrodes 75 at the ends of the tubes. The electrodes are connected to a source 77 of direct current as illustrated.

The spiral tube structure is placed in the path of a plane polarized radio beam which may be produced by any suitable apparatus such as a high frequency generator 79, a dipole antenna 81, and a reflector 83. As in the case of the system shown in Fig. 1, in order to modulate the radio beam, its plane of polarization is rotated by means of a magnetic field which is produced by a solenoid 85 surrounding the coiled tube structure 73. The solenoid 85 is connected across the secondary winding 89 of an audio frequency transformer 91. Modulating signal current may be supplied to the secondary winding by means of a microphone 93 which is connected to the primary winding 95 of transformer 91 through a battery 97. An amplifier (not shown) may, of course, be added.

The above described modulating device may be utilized with the type of receiver shown in Fig. 1 or with an analyzing device as described in connection with Fig. 2. In Fig. 3, an analyzing device is shown consisting of a plurality of parallel conductors 99 spaced less than one wave length apart.

As in the system shown in Fig. 2, for the condition of zero modulation it is preferred that the plane of electric polarization make an angle of 30 degrees with respect to the screen conductors 99. In the system of Fig. 3, since the plane of polarization is not rotated as it passes through the ionized gas under the condition of zero modulation, this adjustment is obtained by setting antenna 81 at an angle of 30 degrees with respect to conductors 99.

As previously described, when an analyzing device is employed at the transmitter, the receiver should have the same pickup for signals regardless of their plane of polarization. In place of the gas tube receiver shown in Fig. 2, a receiver consisting of two dipole antennas 101 and 103 positioned at right angles to each other, may be utilized. These antennas are preferably located at or near the focal point of a reflector, 105, antenna 101 being connected to a detector 107 through a transmission line 109 and antenna 103 being connected to a detector 111 through a transmission line 113. The output circuits of the two detectors are connected to two primary windings of an audio frequency transformer 115 whereby the demodulated signal from each dipole antenna is impressed upon a common secondary winding 117. This signal may be amplified by any suitable audio frequency amplifier 119 and applied to a loud speaker 121.

From the foregoing description it will be apparent that various modifications may be made in our invention without departing from the spirit and scope thereof and we desire, therefore, that only such limitations shall be placed thereon as are necessitated by prior art and set forth in the appended claims.

We claim as our invention:

1. The method of transmitting a radio signal which comprises producing a polarized electrical wave at a radio frequency, and rotating the plane of polarization of said wave in accordance with a signal.

2. The method of transmitting a radio signal which comprises generating and radiating a beam of energy at a radio frequency which is plane polarized, and rotating the plane of polarization of said beam in accordance with a signal.

3. The method of transmitting a radio signal which comprises generating and radiating a beam of radio energy which is polarized, passing said beam through a region of ionized gas, producing a magnetic field in said region which has its lines of force parallel to said beam, and varying the strength of said field in accordance with a signal.

4. The method of transmitting a radio signal which comprises generating and radiating a beam of radio energy which is polarized, passing said beam through a region of ionized gas, producing a magnetic field in said region which has its lines

of force parallel to said beam, and varying the ionization of said gas in accordance with a signal.

5. In combination, means for producing a polarized electrical wave at a radio frequency, and means for rotating the plane of polarization of said wave in accordance with a signal.

6. In combination, means for producing a region of ionized gas, means for generating and radiating a polarized radio wave, said ionized gas being in the path of said radio wave, means for producing a magnetic field in said region and means for varying the strength of said field in accordance with a signal.

7. In combination, means for producing a region of ionized gas within a gas filled envelope, means for generating and radiating a polarized radio wave, said ionized gas being in the path of said radio wave, means for producing a magnetic field in said region, and means for varying the ionization of said gas.

8. In a radio system, a transmitter comprising means for generating and radiating a polarized electrical wave at a radio frequency, means for rotating the plane of polarization of said wave in accordance with a signal, and a receiver which receives said wave most efficiently when it is polarized in a particular plane.

9. In a radio system, a transmitter comprising means for generating and radiating a polarized electrical wave at a radio frequency, means for rotating the plane of polarization of said wave in accordance with a signal, a receiver which receives said wave with substantially the same efficiency regardless of its plane of polarization, and an analyzing device positioned between said second means and said receiver, said device presenting an impedance to said radio wave which varies with the degree of rotation of said plane.

10. In a radio system, a transmitter comprising means for generating and radiating a polarized electrical wave at a radio frequency, means for rotating the plane of polarization of said wave in accordance with a signal, a receiver which receives said wave with substantially the same efficiency regardless of its plane of polarization, and a screen of parallel conductors positioned between said second means and said receiver whereby said wave is amplitude modulated upon passing said screen.

11. A radio system comprising a reflector, a dipole antenna positioned at substantially the focal point of said reflector, means for supplying high frequency radio energy to said antenna whereby a plane polarized wave is radiated therefrom, and means positioned in the path of said wave for rotating said plane of polarization in accordance with a signal.

12. A radio system comprising a dipole antenna, means for supplying high frequency radio energy to said antenna whereby a plane polarized radio wave is radiated therefrom, means positioned near said reflector and in the path of said wave for rotating said plane of polarization in accordance with a signal, a receiving dipole antenna located in the path of said wave, and receiving apparatus connected to said receiving antenna.

13. A radio system comprising a transmitting reflector, a dipole antenna positioned at substantially the focal point of said reflector, means for supplying high frequency radio energy to said antenna whereby a plane polarized radio wave is radiated therefrom, means positioned near said reflector and in the path of said wave for rotating said plane of polarization in accordance with a signal, a receiving reflector positioned in the path of said wave, a receiving dipole antenna positioned at substantially the focal point of said receiving reflector, and receiving apparatus connected to said receiving antenna.

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