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COMMUNICATION SYSTEM

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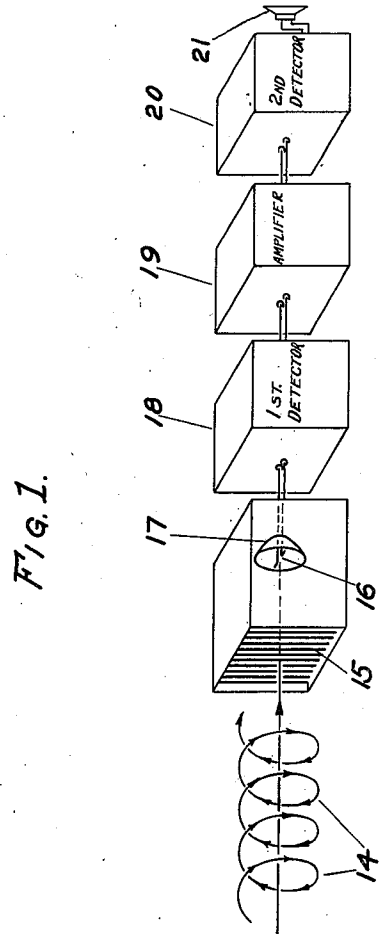



FIG. 1.

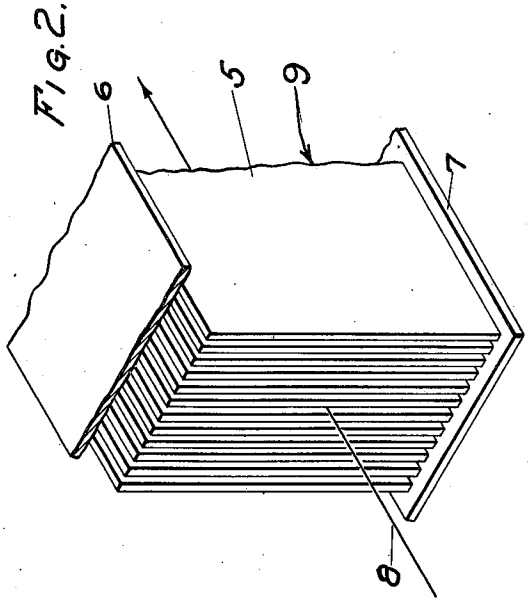



FIG. 2.

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2,473,613

## COMMUNICATION SYSTEM

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3 Claims. (Cl. 250—6)

1

This invention relates to methods and systems for conveying intelligence. More particularly, this invention relates to communication systems.

Heretofore communication has been accomplished by radio beams that are modulated either in amplitude or frequency. The present invention is directed towards communicating by utilizing modulation of the state of polarization of the radio beam.

An object of the present invention is the provision of a communication system utilizing modulation of the state of polarization of the radio beam.

Another object of the present invention is the provision of a communication system in which a non-circularly polarized radio beam has its electrical vectors continuously rotated.

A further object of the present invention is the provision of a system of communication in which a non-circularly polarized radio beam is rotated, and in which modulation may be accomplished by varying the rate of rotation.

A feature of this invention is the diminution of static and other forms of interference. Another feature of this invention is that only a very minute modulating power is required to obtain a controllable output modulated to any desired degree, and modulated so as to produce high fidelity in the resulting communication.

Other and further objects, advantages, and features inherent in this invention will become apparent from the following description of an embodiment thereof, reference being had to the drawing in which,

Fig. 1 is a schematic diagram of a communication system embodying my invention; and

Fig. 2 is a perspective view of one type of plate or structure adapted to change plane polarized waves into circularly polarized waves.

Referring now to Fig. 1, a pair of transmitters A and B are each provided with an oscillator 1, which may be of the ultra-high frequency type, and are adapted to develop oscillations of a given frequency. One of these transmitters, such as, for example, transmitter A, may be controlled by a modulator 2 adapted to modulate the frequency of its associated oscillator. Modulator 2 may be controlled by any signal input device, such as, for example, a microphone. The oscillations generated in transmitters A and B are fed to radiant dipoles 3 and are propagated therefrom as radio beams. For directing the radio beams and concentrating them, a suitable parabolic reflector 4 may be arranged behind each of the dipoles 3 with said dipoles at the foci of the reflectors. The

2

waves projected from the dipoles 3 are plane polarized or substantially so. In order to change each of said plane polarized waves into circularly polarized waves, a structure or plate may be used, such as that disclosed in my copending application for a Method and means for controlling the polarization of radiant energy, Serial No. 446,847, filed June 12, 1942, now Patent No. 2,464,269 granted March 15, 1949. One type of such structure is illustrated in Fig. 2.

Referring now to Figure 2, the structure there illustrated consists of a plurality of plates of glass 5 arranged parallel to each other and spaced a distance apart. These glass plates may be held in position by providing a cover 6 and a bottom 7 to which said plates 5 are secured. The arrow 8 shows the direction in which a radio wave is propagated through said structure. The dielectric constant of this structure along a horizontal axis is less than its dielectric constant along a vertical axis. Therefore, if the radio wave 8 has its plane of polarization arranged at an angle of 45° to the vertical, then the two equal vectorial components into which the electrical field of said radio wave may be resolved will lie respectively along a horizontal axis and a vertical axis. The component along the vertical axis will have presented to it a greater dielectric constant and as a result this component will be retarded relative to the other component. If the structure of Fig. 2 is made of proper depth, the emerging wave will consist of a vertical component which is 90° out of phase with the horizontal component, but is otherwise equal to said component. The emerging wave will therefore be circularly polarized.

The structure of Fig. 2 is preferably of substantially greater height and width than the wave length of the wave to be propagated therethrough and preferably also is of greater depth than one wave length. The distances between the glass plates in said structure are preferably small in relation to the wave length of the wave. The structure described in Fig. 2 is but one of many possible forms of such structure as is explained in my hereinabove mentioned copending application. The structure of Fig. 2 and similar structures will be referred to hereinafter as "orthophase plates."

Referring back to Fig. 1, each of the transmitters A and B has an orthophase plate 9 arranged in front of its dipole 3 in the path of propagation of the waves radiated therefrom. Transmitter A is arranged relative to its plate 9 so that the wave 10 emerging from its plate 9

is circularly polarized in one sense, whereas transmitter B is arranged in relation to its plate 9 so that its emerging wave 11 is circularly polarized in the opposite sense. This may be accomplished by arranging the orthophase plate 9 of transmitter A with its axis of maximum dielectric constant at right angles to the axis of maximum dielectric constant of the orthophase plate 9 of transmitter B. When orthophase plates 9 are arranged in this manner and the dipoles 3 of both transmitters are arranged to propagate waves whose planes of polarization are parallel to each other and make an angle of 45° with the axis of maximum dielectric constant of the orthophase plates 9, then the circularly polarized waves 10 and 11 will be circularly polarized in opposite senses. Another way of accomplishing this is by arranging orthophase plates 9 so that their axes of maximum dielectric constant are parallel. With this arrangement the dipole 3 of transmitter A is arranged at right angles to the dipole 3 of transmitter B. The resultant waves 10 and 11 are thereby circularly polarized in opposite senses.

In order that the transmitters A and B should not undesirably interfere with each other, a suitable shielding means may be employed. For this purpose transmitter A and transmitter B with their associated elements each may be completely enclosed within a container 12 made of a suitable shielding material. The containers 12 may be grounded. The containers 12 are preferably provided with openings at the forward end thereof, adjacent the plate 9, so as to permit the radio waves to pass outwardly therethrough in the desired direction.

Transmitter A and transmitter B are preferably arranged so as to propagate their radio waves close to and parallel with each other. Their circularly polarized waves 10 and 11 will spread and interfere with each other. Since these two waves are circularly polarized in opposite sense, the resultant of these two waves may be considered as being a plane polarized wave 14, or as a wave whose electrical vectors have substantially planar characteristics. If the frequencies of waves 10 and 11 are alike, the resultant waves will be plane polarized in a fixed plane, the particular plane being determined by the phase relationship between waves 10 and 11. If, however, there is a difference in frequency between waves 10 and 11, the resultant will be a plane polarized wave which will rotate at a frequency equal to the difference between the frequency of waves 10 and 11. The direction of rotation of the resultant wave will be determined by which of the two waves 10 or 11 has the greater frequency. It will therefore be seen that a simple way of modulating the resultant wave 14 is to change the frequency of either wave 10 or wave 11 to thereby cause a change in the state of polarization of wave 14.

In systems in which modulation is accomplished by varying the frequency, waves 10 and 11 may have the same or different frequencies in their unmodulated condition. Where waves 10 and 11 have the same frequency in their unmodulated condition, the resultant plane of polarization is fixed; where waves 10 and 11 have different frequencies in their unmodulated condition, the resultant plane of polarization continuously rotates at a frequency equal to the difference in frequency between waves 10 and 11. In the first of these systems modulation by varying the frequency of either wave 10 or 11 will cause the resultant fixed plane of polarization to rotate, whereas in the second of these systems modulation will vary the rate of rotation of the resultant continuously rotating plane of polarization.

It will also be seen that another way of modulating the resultant wave is to have the two waves 10 and 11 at the same frequency, but to shift the phase of one wave relative to the other. In the latter system the resultant angular position of the plane of the wave is changed, but it is not continuously rotated.

If the orthophase plates 9 are not of the hereinbefore described depth, or if the plane polarized waves emitted from the dipoles 3 enter the plates at an angle other than 45° to the axis of maximum dielectric constant of said plates, the waves emerging from said plates may be elliptically, instead of circularly, polarized. If waves 10 and 11 are elliptically polarized, the resultant wave produced by their interference may also be elliptically polarized with the major axis of the ellipse rotating at the difference of frequency between said waves. Said rotating elliptically polarized resultant wave may be treated as if it were a rotating plane-polarized wave in the system here described and will behave similarly.

In the specification and claims I use the term "circularly-polarized wave" to designate a wave in which the electrical vector at a point in space rotates substantially at the basic frequency of said wave and is essentially constant in absolute magnitude during a single rotation. I use the term "elliptically-polarized wave" to designate a wave in which the electrical vector at a point in space rotates at substantially the basic frequency of said wave and varies in absolute magnitude cyclically substantially at said basic frequency. I use the term "polyphase wave" to designate a wave in which the electrical vector at a point in space rotates at substantially the basic frequency of said wave, whether or not the absolute magnitude of said vector remains constant during such rotation. The term "polyphase wave" is therefore a generic term which includes both circularly-polarized and elliptically-polarized waves. I use the term "plane-polarized wave" to designate a wave in which the electrical vector at a point in space lies in a predetermined plane and said plane remains substantially fixed or rotates or oscillates at a frequency of a substantially lower order of magnitude than that of the basic frequency of said wave. As already pointed out, an elliptically-polarized wave having the major axis of the ellipse predominating substantially over the minor axis may be treated as a plane-polarized wave having its plane of polarization determined by said major axis, and the term "plane-polarized wave" will be used to include such an elliptically-polarized wave.

It will be seen that if the difference in frequency in the unmodulated state between wave 10 and wave 11 is one megacycle per second, then the resultant wave will have its plane of polarization rotating at a frequency of one megacycle per second. Thus, if wave 10 had a frequency of one thousand megacycles and the wave 11 had a frequency of one thousand megacycles plus one megacycle per second, then the resultant wave 14 would have its plane of polarization rotating at the rate of one megacycle per second. It will therefore be seen that very minute differences between wave 10 and wave 11 will produce appreciable, and, as will be seen from the following, readily detectable effects,

thereby providing a system of considerable sensitivity and wide range of modulation. If the difference of frequency is even a single cycle per second, or a fraction of a cycle, this difference can also be readily detected.

Various systems responsive to the changing state of polarization of wave 14 may be employed. One such system is illustrated in Fig. 1. A grid 15 consisting of a plurality of parallel conducting wires may be arranged in front of a receiving dipole 16 which has a parabolic reflector 17 arranged adjacent thereto, which reflector cooperates with said dipole 16 by directing the radio wave thereto. The grid 15 which is arranged in the path of wave 14 acts as a selective reflector as will readily be understood by those versed in this art. When the electric field of wave 14 is parallel to the wires of grid 15, the radio wave is reflected. When the electric field of wave 14 is perpendicular to the wires of grid 15, the wave passes through said grid and impinges on the dipole 16. It will therefore be seen that for every complete cycle of rotation of the plane of polarization of wave 14, two impulses will pass through the grid 15. Thus, the wave reaching dipole 16 will consist of two different frequencies, one frequency being the mean of the basic frequencies imparted to said wave by the transmitters 1 and 2, and the other frequency being twice the frequency of rotation of the plane of polarization of the resultant wave 14. The dipole 16 is tuned to said mean basic frequency.

The energy received by the dipole 16 is fed to a first detector 18. The detector 18 eliminates the basic frequency from said wave, leaving a wave having twice the frequency of the rate of rotation of wave 14, said wave being modulated in frequency according to the modulation of the rotation of the plane of polarization of wave 14. Assuming the wave 14 rotates at a frequency of one megacycle per second in its unmodulated condition, if the signal being sent is, for example, the note *c* which has 256 vibrations per second, the rate of rotation of the plane of polarization of wave 14 is greater than one megacycle for $1/512$ of a second and less for $1/512$ of a second. This signal is then transmitted to amplifier 19. The amplifier 19 would in the instant case here described be tuned to a comparatively narrow band near two megacycles. This is twice the frequency of the rate of rotation of the plane of polarization of wave 14 when said wave is unmodulated. When said wave is modulated, however, it will be seen that, due to the tuning of the amplifier to a comparatively narrow band near two megacycles, the received and amplified energy will rise and fall accordingly as it approaches or deviates from the two megacycle range. Thus, the amplitude of reception of the note *c* would vary with the amplitude of the deviation from the unmodulated rate of rotation of the plane of polarization of wave 14. The amplified signal, which is now amplitude modulated, is fed through a second detector 20 and from thence to any suitable utilization device, preferably through another amplifier. Such utilization device may be, for example, a loud speaker 21 as shown, or a cathode ray tube, a galvanometer, an oscillograph, etc.

In a system in which the frequencies of waves 10 and 11 are the same and modulation is accomplished by shifting the phase of one of said waves with respect to the other, the angular position of the plane of polarization of the resultant wave will be varied in accordance with the modulation. It will be seen when such a resultant wave is propagated through the grating 15 that the strength of the signal received by the receiving dipole 16 will depend on whether the plane of polarization of said resultant wave is at right angles to the wires forming grating 15, or is parallel to said wires. The maximum signal strength received will occur when the resultant wave is propagated through the grating 15 with its plane of polarization, or electrical vectors, at right angles to the wires of the grating 15, and the strength of this signal will diminish in proportion to the variation from this angular position. Thus, it will be seen that by shifting the phase of waves 10 or 11 the received signal will correspondingly be modulated in amplitude and this modulation will be thereafter impressed upon any suitable utilization device through the first detector 18, amplifier 19, and second detector 20 as aforedescribed.



While I have hereinbefore described by way of exemplification a comparatively simple receiving system utilized in my invention, numerous other receiving systems responsive to the state of polarization of a wave and utilizing the inherent advantages of my invention will become apparent from the foregoing description.

While in the foregoing embodiment I have described a system in which the rate of rotation of the plane of polarization of a wave is varied to modulate said wave, it will also be seen that modulation may be accomplished by varying the direction of rotation of the plane of polarization of wave 14. The direction of rotation of plane polarized wave 14 depends upon whether the circularly polarized wave 10 or the circularly polarized wave 11 has the higher frequency.

While I have mentioned a plane polarized resultant wave 14, as has been pointed out hereinabove, any non-circularly polarized wave may be utilized. Furthermore, while I have described waves 10 and 11 as being circularly polarized, these waves may be elliptically polarized and still produce a wave adapted to being modulated in the manner hereinabove described. Numerous changes and refinements upon the system herein disucssed will readily suggest themselves to those versed in the art from the suggestions and ideas contained herein. It is accordingly desired that the appended claims be given a broad scope commensurate with the state of this invention within the art.

What is claimed is:

1. The method of communication which comprises producing a plurality of circularly-polarized waves, the polarization of each of said waves being in the opposite sense to the polarization of another of said waves, propagating said circularly-polarized radio waves to a common point in space whereby they interfere in space to produce a resultant plane polarized wave, causing the frequency of said circularly-polarized waves to differ from each other whereby the plane of polarization of the resultant wave is continuously rotating, and signaling by varying the frequency of said circularly polarized waves relative to each other to thereby vary the rate of rotation of the plane of polarization of the resultant wave.

2. The method of signalling which comprises producing a plurality of polyphase waves, the polarization of each of said waves being in the opposite sense to the polarization of another of said waves, propagating said polyphase waves to

a common point in space whereby they interfere in space to produce a resultant plane-polarized wave, and signalling by varying the phase relations of said polyphase waves with respect to each other to produce a rotation in the plane of polarization of said plane-polarized wave in accordance with a desired signal variation.

3. The method of signalling which comprises producing a plurality of polyphase waves, the polarization of each of said waves being in the opposite sense to the polarization of another of said waves, propagating said poylphase waves to a common point in space whereby they interfere in space to produce a resultant plane-polarized wave, and signalling by varying the frequency of said polyphase waves with respect to each other to produce a rotation in the plane of polarization



of said plane-polarized wave in accordance with a desired signal variation.

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