Aug. 9, 1966 P. CURRY 3,265,972

UNDERWATER ELECTRIC FIELD COMMUNICATION SYSTEM

Filed April 10, 1962

Fig. 1

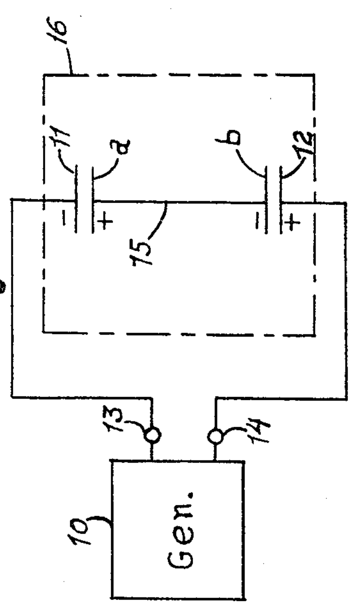


Fig. 2

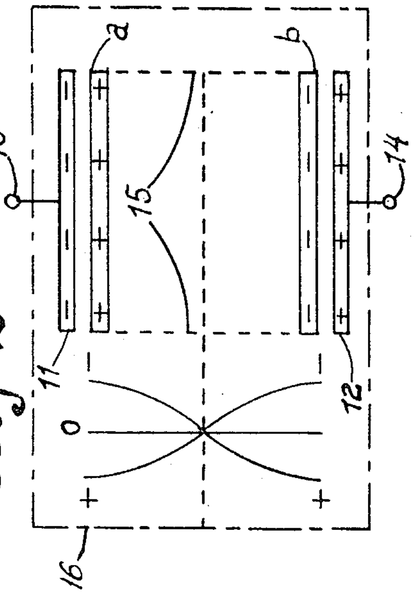
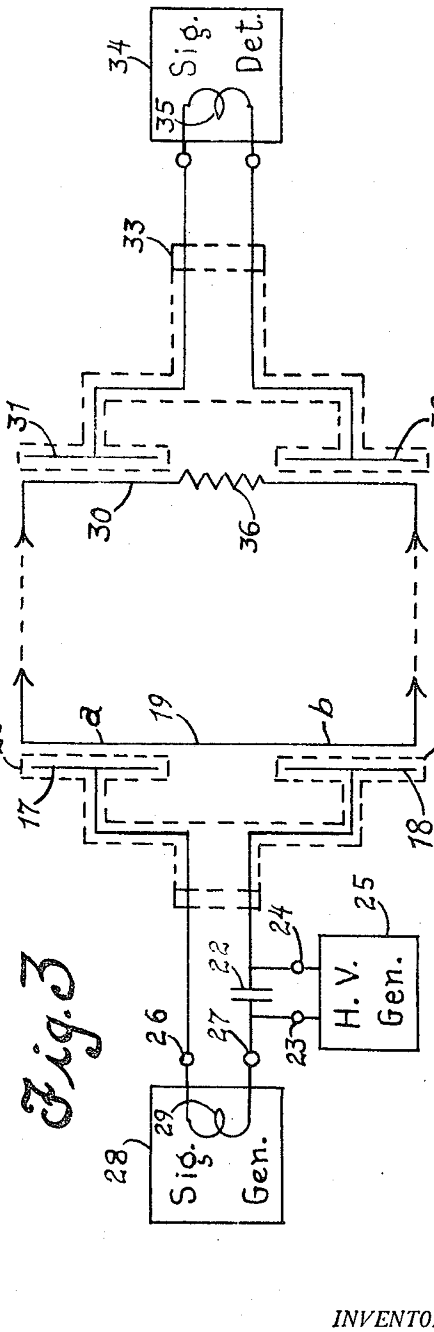


Fig. 3



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UNDERWATER ELECTRIC FIELD COMMUNICATION SYSTEM

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The present invention relates to electrical communication systems, and more particularly to a method of communicating intelligence by electrostatic induction.

A method of transmitting and receiving intelligence by electrostatic induction through an intervening physical medium, such as a body of water, also constitutes an improvement in antenna systems.

The energy radiated from a transmitting system in air possesses, in addition to its direct magnetic and electrostatic fields, components of induced magnetic and electrostatic fields. But the induction fields are important only in the vicinity of the radiator, the principal emission being in the form of the direct magnetic field.

The antenna system for an electromagnetic emission into space circulates energy in accordance with the laws governing electrical current in motion. Since the field strength produced by an antenna is proportional to the alternating currents circulating in it, its optimum structural relationships are directed to a reduction of the total antenna resistance, thus to increase the total current for a given power input to the radiator.

Being a current-actuated device, such an antenna will not operate in any physical conducting medium such as water or earth.

It is found that electrical disturbances caused at one point in a conducting physical medium, by the induction of electrostatic charges, are propagated to every other point within the body of the medium, in accordance with the laws governing the distribution of electrostatic charges. It is therefore proposed to communicate in conducting mediums, such as a body of water for example, by transmitting and receiving signals by electrostatic induction. Such a method makes possible an electrical communication system capable of achieving a greater range of under water communication than is possible with systems of prior art.

While a radiator for electromagnetic emission produces its field strength by the effect of changing currents; the radiator for electrostatic emission of the type here to be described produces its field strength by the effect of changing potentials.

In a representative system, the electrical potentials of the signal to be transmitted are applied to two equal metal plates, each of which is hermetically sealed within an insulating material having an appropriate dielectric constant. Both plates physically separated from each other, are immersed in a conducting fluid such as a body of sea water, in which case the connections between the plates and the source of signal potentials applied to them, are also hermetically insulated from the water.

Under the circumstances just described, the electrical charges upon the plates will be of opposite polarity. Each plate will induce in the water surrounding it, an electrostatic charge opposite to the sign of its own charge. In accordance with well-known laws governing electric stress, the intensity of such induced charges in the vicinity of each plate is compensated for by the distribution of unlike charges in more remote regions of the medium in which the plates are immersed. The disturbances produced in the vicinity of the plates, having the form of current in motion, are propagated to every point in the medium.

Assuming the signal to be a periodical reversal of the charges allied to the two plates, the region of greatest electric stress between them, being directional, this characteristic will also be propagated throughout the medium.

If another pair of plates, similarly insulated and also physically separated like the first pair, are immersed in the same body of the conducting medium, at some distance from the first pair the differential in the current densities representing charges in the vicinity of each of the second pair of plates, will induce charges in each plate of the second pair representing, in the sum, a potential difference between the plates. By connecting the second pair of plates through appropriate means hermetically insulated from the conducting medium, to a detecting device, it is seen that a signal transmitted by the first pair of plates is received by the second pair, while both pairs are immersed in a conducting medium.

Whether the conducting medium is a liquid body such as sea water, or a solid body of earth, the concept described herewith applies with equal force. However, it is not intended to thus limit the invention. For it may be understood from the present disclosure that the method of electrostatic transmission and reception of electrical energy may be utilized for the communication of intelligence in air, as well as in a vacuum.

It is therefore an object of the present invention to provide a communication method for under water operation which is capable of increasing the range of communication, and for extended ranging.

Another object is to increase the effectiveness of underground detection operations.

Another object of the invention is to provide a superior method of transmitting and receiving electrical communication in air.

A still further object is to provide plane waves from large area electrostatic radiators for more effective outer space communication.

Since the force of an electric field at any point varies with the square of the voltage applied to it, it is proposed to connect a source of relatively high uniform potential difference between the two radiators of the transmitting system, and to modulate this potential by the alternating current of relatively low potential of the signal to be transmitted.

The object of this form of the invention is to add a polarizing fiield of direct potential difference to the potential variation representing the transmitted signal, thus to increase the intensity of the signal and its consequent range.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, together with additional features, objects and advantages thereof, will best be understood from the following description of the specific embodiments when read in connection with the accompanying drawings in which:

FIG. 1 is a schematic wiring diagram of an electrical circuit including capacitors in series connection;

FIG. 2 is a schematic wiring block diagram showing the distribution of induced charges;

FIG. 3 is a combination wiring-block diagram of a transmitting and receiving system for electrical communication in a conducting medium.

Structure of FIGURE 1

While the parameters of an electrical network designed for the transmission of power by electromagnetic radiation are directed to the production of maximum current intensities from applied potentials; those connected with the transmission of power in the method herewith to be described, are directed to the production of maximum electrostatic charges from potential differences.

This will be discussed in connection with the schematic wiring diagram of FIG. 1, in which the energy of an alternating current generator **10** is applied to two equal capacitors **11** and **12** in series connection with the generator, through terminals **13** and **14**.

For present purposes, it will be assumed that the output of generator **10** applies to terminals **13** and **14**, an alternating potential difference of 200 volts at a frequency of 100 kilocycles per second, which is equally divided between the two capacitors **11** and **12**, each having a capacitance of .0053 microfarad.

The capacitors are so arranged that the plate designated as *a*, of capacitor **11**, is directly connected to the plate designated as *b*, of capacitor **12**, as shown in FIG. 1. The connecting means are assumed to be conventional, as by a wire conductor **15**. The structures of both capacitors are shown enclosed by the dash-dot line block **16**, which is extended into an expanded representation in FIG. 2.

While direct current resistance is present in the circuit, it is assumed to be negligible and thus need not be taken into account. In such a capacitive network, the alternating potential supplied by the generator **10**, and applied to terminals **13** and **14**, will be divided equally across the plates of both capacitors, so that each will have 100 volts, though 200 volts is applied by the generator across the network.

The current through the series circuit will be

$$I=\frac{E}{2X_c}$$

where X_c represents a capacitive reactance of $1/\omega C$. Each capacitance having a reactance of 300 ohms, the impedance for the system is 600 ohms, and the current will be .333 ampere, for the given potential of 200 volts.

Since the current equals $I=\omega Q$, the maximum charge during the time of ¼ cycle is $Q_m=1.41I/\omega$, or .00000075 coulomb, this being the charge during $1/4f$ or .0000025 second.

It would be expected that, under the circumstances here described, where the plate *a* of capacitor **11**, and the plate *b* of capacitor **12**, are in direct connection, there should be no potential difference between the two. Under ordinary circumstances, such is the case.

However it is known that charges of polarization which are induced on the faces of both plates *a* and *b* are of opposite sign. And the induced charges on their respective outer faces connected by wire **15**, undergo a complete cycle of change from plus sign to minus sign during each cycle of the impressed potential.

Structure of FIGURE 2

In FIG. 2 is shown a schematic wiring block diagram showing the distribution of induced charges in an expanded representation of block **16**, in FIG. 1. Here the external plate of the capacitor **11**–*a* is shown to be momentarily at a minus potential, as indicated by the scattered minus symbols; while its other plate *a* is shown by the plus symbols to be at plus potential. The external plate of capacitor **12**–*b* is at plus potential and its other plate B is at minus potential similarly as shown by the scattered symbols of the respective signs. But, where the connecting means between the plates *a* and *b* is a wire conductor **15**, in FIG. 1; in the extended structure of FIG. 2 the connecting means **15** is expanded to a width comparable to the representative lengths of the capacitor plates *a* and *b*, as shown by the dashed lines designated by the numeral **15**.

It may be assumed that the area enclosed by the dashed lines **15** here represents a conducting body, instead of a conducting wire, as in FIG. 1, and that the capacitor plates *a* and *b* are now segments of that conducting body. It will appear, therefore, that capacitor plates **11** and **12**, instead of being in electrostatic relationship with their respective other plates *a* and *b* as before, are now in electrostatic relationship on opposite faces of the conducting body **15**, of which the elements *a* and *b* are merely segments. The potential difference applied from the generator **10** to terminals **13** and **14**, FIG. 1, and also to **13** and **14**, of FIG. 2, appear across the capacitor plates **11** and **12** through their corresponding connections, and at the moment shown in the figure, possess the direct charges on the plates, and the induced charges on the facing segments, having the polarities shown.

While the charges induced in the body **15** tend to collect on the surfaces of the segments *a* and *b* facing the respective plates **11** and **12**, these charges are drawn from the central portions of the body. Consequently, there is a charge gradient extending throughout the body, extending from a maximum charge of one polarity, for example, a plus potential at segment *a*; to a maximum charge of opposite polarity, such as the negative potential at segment *b*. It will later be shown that a phase displacement of 90 degrees exists between the wave of charge potentials induced by an alternating current signal upon the water segments *a* and *b*, and the resulting wave of charge displacements occurring in the water body between the segments. For the present purpose, the effect of reversing potentials alone need be considered.

For an alternating potential the changing signs in the distribution of the charges assume a pattern of standing waves which, for a long path between the segments *a* and *b* may be represented by the curves at the left of the structure within block **16** where the straight vertical line designated as 0 indicated the zero axis, and the two diagonal lines, really curves, which cross at the midpoint, represent the maximum of the charge gradient, going through a complete change of sign from maximum positive to maximum negative and back to maximum positive during each alternation. The midpoint of the zero axis where the two diagonals meet, represents the nodal point of the system, where the charge differential is always zero.

If the length of the path between segments *a* and *b* could be extended to the order of more than one wave length of the propagation of the charge differentials through the conducting body **15**, there would be at least two standing waves having, at any instant, opposite polarity on the charge gradient.

Assuming, however, that the path is on the order of a half wavelength, for present purposes; at the moment when segment *a* is at maximum positive charge and *b* is at maximum negative charge, the potential difference between segments *a* and *b*, is at maximum, and the displacement of charges in the conducting body **15** is at its greatest intensity. It should be pointed out, however, that while this is true even in the case of a very short path between segments *a* and *b*, as in the case of a short wire connection between the capacitors **11** and **12** of FIG. 1, the differential between the successive polarity changes would be negligible. This is so, since the convection of charges during successive alternations of polarity would be practically instantaneous.

Having discussed some theoretical considerations underlying the operation of the present invention, it is now proposed to show one application serving the object of under water communication through the transmission and reception of electrical energy by the method of electrostatic induction. It is understood, of course, that while one application is shown, other useful applications will be envisioned from the disclosure, by those trained in the art. Such other applications as under earth exploration and communication in air may be carried out without departing from the spirit of the invention.

Transmitting structure of FIGURE 3

FIG. 3 is a schematic wiring-block diagram of a transmitting unit for the convection of electrical signal energy in a conducting medium, by the method of electrostatic induction.

It will be assumed that the elements **11** and **12** of FIG. 2 are here two radiators **17** and **18**, immersed in a conducting medium **19**, to form a capacitive network comprising the element **17** and the segment designated as *a*, of conducting medium **19**, as one capacitance, and the element **18** and the segment designated as *b*, as the other capacitance. The capacitances **17**–*a* and **18**–*b* are in series by connection through the conducting medium **19**.

In the practical case, the radiators **17** and **18** will be metal plates of appropriate area, and hermetically sealed in an insulating material shown as dashed lines **20** and **21** around elements **17** and **18** respectively, and sufficiently ruggedized for immersion in a conducting medium such as a body of water.

The bypass-polarizing capacitor **22** is a combination polarizing capacitance serving the dual purpose of applying a relatively high potential difference to the radiators **17** and **18**; and of bypassing the signal potentials to the radiators. The polarizing voltage is applied to capacitor **22** from the terminals **23** and **24**, of the high voltage generator **25**. The signal energy is applied to the radiators from terminals **26** and **27** of the signal generator **28**.

Under the circumstances, it will be supposed that the signal energy, as previously described in connection with FIG. 1, will have a potential of 200 volts at a frequency of 100 kilocycles per second.

For purposes of this discussion it will be understood that the radiators will be so constructed that when immersed in the conducting medium **19**, the area of each element **17** and **18** in capacitive relationship with the corresponding segment *a* and *b* of the medium **19**, will form a capacitance of .0053 microfarad. As before explained in connection with the capacitors **11** and **12** of FIG. 1, their series connection with a signal potential at a frequency of 100 kilocycles, produces a reactance of 600 ohms.

With the potential of the energy from the output of the signal generator **28** at 200 volts, the current through the series network including the radiators **17** and **18**, and the conducting medium **19** with which they are in capacitive relationship, is .3333 ampere. As before explained, the maximum charge during the time of ¼ cycle is $Q_m=1.41I/\omega$ or .00000075 coulomb, and this is the value of the charge induced in the medium **19** by the radiators **17** and **18**. With no polarizing voltage applied to the polarizing capacitor **22**, this is the maximum value which would cause displacement of charges in the conducting medium **19**.

These charge displacements will be distributed throughout its body. If it is large, as would be the practical case with a body of sea water, the displacements will form patterns of standing waves, in the manner described in connection with FIG. 2.

The power transfer into the medium **19** by electrostatic induction depends upon the effective potential, $V=200$ volts, applied to the radiators, and the effective charge $Q=.707$, $Q_m=.00000053$ through the medium. The value in watts-second, derived from the common notation ½ QV is

$$W=\frac{\omega QV}{2}$$

or 33.33 watts. It should be noted that this is not real power such as would be dissipated in heat through a pure resistance, but a component of capacitive reactance which is transmitted through the conductive medium. The component of pure resistance which is encountered in all physical media will dissipate a portion of the total transmitted energy as heat, but specific structures to carry out the principles of the invention may be designed to minimize this component of impedance in a manner well known to the art.

Returning to FIG. 3, it may be assumed that a high potential of, for example, 1,000 volts, is generated by the high voltage generator **25**, and maintained constant by methods so well known as not to require description. This is applied through the terminals **23** and **24** to produce the potential difference across the bypass capacitor **22**, which is applied to the radiators **17** and **18**.

The methods of coupling the energy of the signal generator **28** to the capacitance represented by the radiator system, are also well known, but it should be pointed out that the method which minimizes the inclusion of a prominent resistive component is that of including in the network an inductive reactance equal to the capacitive reactance of the system. Such an inductance is represented by the secondary winding **29**, of generator **28**. While the winding **29** is included to show circuit continuity, it is thought to be unnecessary to describe the means by which energy is coupled into the resonant network. The Q factor $\omega L/R$ is not of great concern, since the pure resistance of the network, which will include that of the resistance path through the conducting medium **19**, may be much higher than for conventional resonant networks concerned with electromagnetic radiation. Such resistance will not be high enough to substantially affect the operation of the invention, as described.

Since, as is well known in electric theory, the force of an electrostatic field increases with the square of the applied potential it is proposed to apply a constant polarizing potential to the radiators **17** and **18**, to increase the force of the charges induced in the medium **19**.

The total force of the charge induced in the medium is equal to $F=QV$. The erg being equivalent to the dyne-centimeter of force, the total power

$$\frac{E_2}{2X_c}10^7=W$$

in ergs per second, is equal to $(\omega V^2C)10^7=F$, in dynes. The force $F=V^2C$, for a signal alternation of 200 effective volts is $.000106\times10^7$, or 1060 dynes. The force for a charge displacement V^2C, with a constant potential of 1,000 volts, is 26,500 dynes.

By superimposing a signal energy of 200 volts upon the constant polarizing potential of 1,000 volts, there is an effective signal rise to 1,200 volts, and a signal fall to 800 volts during each cycle. The force due to the signal amplitude will therefore vary from 38,160 dynes to 16,960 dynes, representing a differential of 21,200 dynes. The signal amplitude variation thus is increased to one-half of this value, or 10,600 dynes which, compared to the force of 1,060 dynes developed by the signal amplitude without polarization, represents a substantial increase in the force of the charge displacement in the conducting medium **19**.

As may be expected, higher polarizing potentials can be utilized as described, to achieve greater intensification of the force field due to the transmitted signal, thus to increase the range within the body of the conducting medium within which the signal may be effectively detected. It is understood, however, that the invention will operate even without the cooperation of the polarizing potential described in connection with FIG. 3.

Receiving structure of FIGURE 3

It may be assumed that a portion of the signal electrostatically transmitted through the medium **19**, FIG. 3, in the manner described, appears at a distant point in the medium. A second pair of plates, similar to the first pair described in connection with elements **17** and **18**, FIG. 3, are immersed in the conducting medium in a similar relationship to that described for the transmitting pair, where **30** is the conducting medium at the point of reception, and **31** and **32** are two dipoles of a receiving antenna which, though differing in their functions from the radiators **17** and **18**, are nevertheless structurally similar to them. Like the radiators before described, the elements **31** and **32** are hermetically insulated from the medium **30**, as is indicated by the dashed lines surrounding both antenna elements. Insulated connecting means designated as **33**, serve to isolate the connections from the dipoles **31** and **32**, to the signal detector **34** inputs. The primary inductance **35** within the unit **34** completes the circuit of the receiving structure, its purpose being to provide a means of conveying the signals detected by the antenna dipoles **31** and **32** to other amplifying and translating means within the unit **34**, so well known that they need no further description.

The receiving structure comprising the elements **31** to **35** inclusive show no equivalent elements to the high voltage generator **25** and the bypass polarizing capacitor **22** of the transmitting structure described. Except for this change and the additional element **36**, it may be seen that the receiving structure is in all respects similar to that of the transmitting structure, although it serves the opposite function of receiving instead of transmitting signals. The unit **36** is a resistance element serving to indicate the pure resistance of the medium **30**, in the path between the antenna dipoles **31** and **32**. Such resistance is always present, of course, in any medium, to some degree.

It may be supposed that a signal is being transmitted at some distant point as described in connection with FIG. 3, and a portion of the signal intensity appears in the medium **30**, surrounding the antenna dipoles **31** and **32**, in the form of standing waves of energy. By adjusting the distance between the dipoles to equal or at least to approach a quarter wavelength of the standing waves, according to well understood concepts in the field of electromagnetic transmission and reception, the dipoles may be aligned with the direction of the charge gradient of the standing waves.

The charge gradient may be expected to attenuate substantially even at moderate distances from the point of transmission. For example, it may be assumed that the signal intensity of 10,600 dynes at the point of transmission is reduced by a factor of one billion in traveling a substantial distance to a point of reception, to appear in the conducting medium **30**, surrounding the antenna dipoles **31** and **32** of the structure described.

The dipoles, when in appropriate alignment with the standing waves of the signal energy, will therefore be charged with a force differential of 1.06×10^{-5} dynes. If the capacitance of the dipoles **31** and **32** in cooperation with the conducting medium **30**, is the same as that of the radiators **17** and **18**, in cooperation with the conducting medium **19**, as may conveniently be the case, the value will be .00265 microfarad for the network, though each dipole will have a value of .0053 microfarad, as explained in connection with FIG. 3.

The voltage developed in the network comprising the conducting medium **30**, the two dipoles **31** and **32**, and the primary inductance **35**, of signal detector **34**, will be

$$e=\sqrt{\frac{F}{C\times10^7}}$$

Where, as before mentioned, the received signal has a force of 1.06×10^{-5} dynes and the capacitance of the system is .00265 microfarad, the voltage induced in the radiators **31** and **32**, and consequently impressed upon the inputs to signal detector **34**, is .02 volt. This is substantially above the minimum requirements of signal intensity for the detection of electrical signal energies.

It has been shown in connection with FIGS. 1, 2 and 3, how the principle of electrostatic induction may be utilized to transmit electrical signals in a conducting medium and how such signals, conveyed by electric field propagation, may be detected by means of electrostatic induction.

It has also been shown how the process of electric field polarization, by which an electric field of constant potential is modulated by the signal it is desired to transmit, effectively amplifies the intensity of the signal substantially above the amplitude of the signal transmitted without such polarization.

The calculations used herewith may be considered as approximations only, representing rounded sums which more effectively lend themselves to the maintenance of clarity in the description. It is thought unnecessary to burden the disclosure with extreme exactitude, however, since the concepts disclosed are based upon well known laws which have been verified to the highest degree of exactness, in the literature covering electric field theory.

The unique features of the invention have been described as a system for the transmission and reception if signals in a conducting medium. In general, the conducting medium may be fluent, as in the case of a body of sea water; or it may be rigid, as in the case of a segment of earth. But, as before mentioned, the invention is not confined to a highly conducting medium, for its principles may be effectively carried out in a poorly conductive medium, such as air, and even in the absence of a physical medium, for it is known that an electric field exists even in a vacuum.

It should be pointed out that while the signals described were themselves unmodulated alternating energies, it is understood that such signals may be modulated to produce envelopes conveying more complicated intelligence. Methods by which such modulations are imposed upon alternating energies of constant amplitude constitute well known art, and their description would needlessly encumber the specification. It is contemplated that any type of modulated signal may be used in the operation of the invention, including pulse modulation; and one of the operation of the invention, including pulse modulation; and one of its effective applications may be under water ranging for extended surveillance.

While specific examples of circuits to carry out the methods have been described, it is understood that other equivalent circuits may also be employed. Various other changes may be made in the elements or steps above described in detail without departing from the intent or scope of the invention as defined in the appended claims.

What I claim is:

1. A method of communicating intelligence by electric field propagation comprising the steps of: (a) positioning a first pair of conducting plates in a propagating medium; (b) generating an alternating current signal; (c) applying said alternating current signal to opposite plates of said pair of plates to induce an electrostatic charge to said medium; (d) superimposing a direct current signal on said alternating current signal to supply a constant polarizing potential to said pair of plates; (e) transmitting a component of said alternating current signal into said medium as a varying electric potential difference; (f) positioning a second pair of plates in said medium at a remote point in the path of the transmitted signal; (g) receiving the transmitted signal by means of said second plates; (h) detecting the alternating current component to produce a representation of the alternating current signal generated at the transmitter.

2. A method according to claim **1** wherein the respective plates of said pairs of conducting plates are electrostatically separated by the said propagating medium.

3. A method according to claim **1**, wherein the amplitude of the constant polarizing poential supplied to the first pair of conducting plates controls the amplitude of the alternating current signal transmitted into said medium.

References Cited by the Examiner

UNITED STATES PATENTS

350,299	10/1886	Dolbear	325—28
685,955	11/1901	Telsa	325—28
714,246	11/1902	Shoemaker	225—28
1,377,129	5/1921	Hahnemann	325—28
1,382,590	6/1921	Ziegler	325—28
1,429,240	9/1922	Hanson et al.	343—719
1,675,879	7/1928	Crandall	340—12 X
1,678,182	7/1928	Estes	340—12

FOREIGN PATENTS

230,510	3/1925	Great Britain.

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