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WIDE BAND DIRECTIVE ANTENNA

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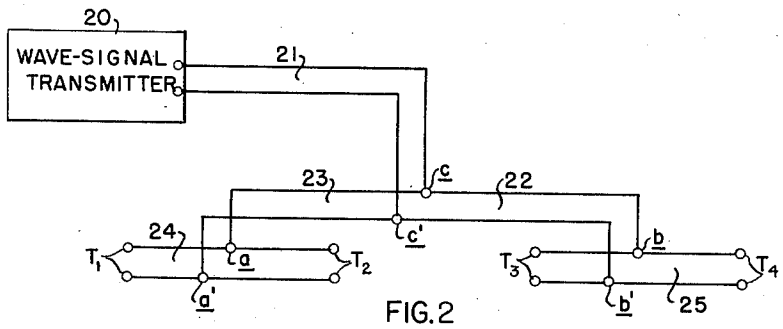


FIG. 2

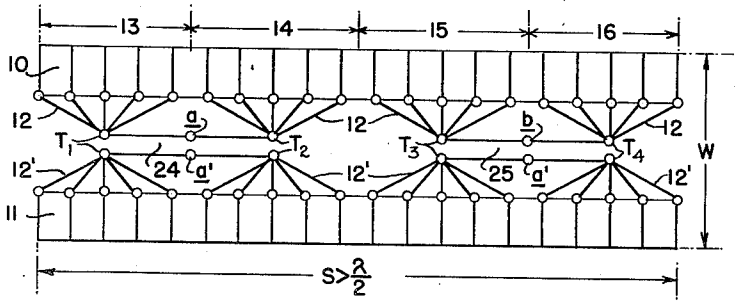


FIG. 1

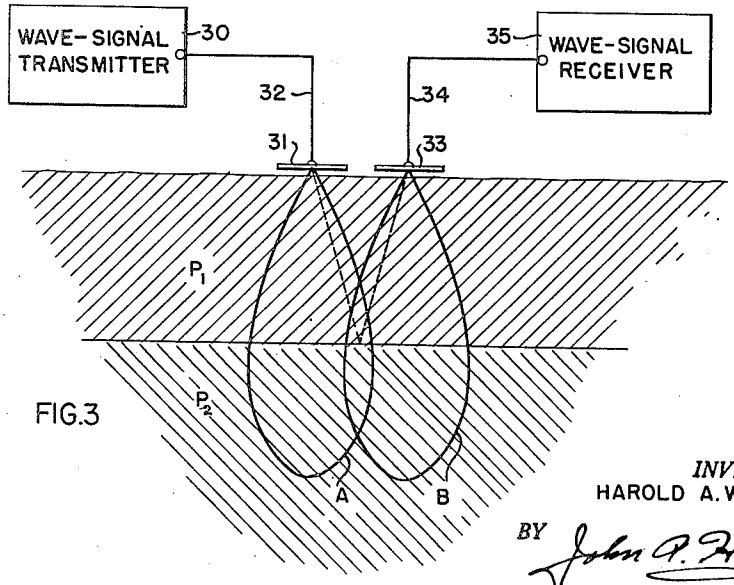


FIG. 3

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WIDE-BAND DIRECTIVE ANTENNA

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10 Claims. (Cl. 250—33.51)

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This invention relates to wide-band, directive antennas. While the antenna of the present invention has utility in a variety of applications, it is especially useful in geophysical exploration systems of the type which determine the characteristics of earth strata by reference to their reflective properties to high-frequency wave signals. As a matter of convenience only, the invention will be particularly described in that connection.

In prior exploration systems, an ordinary dipole antenna is installed on the ground with the antenna elements parallel to the ground surface and is excited by high-frequency signals usually in the form of pulses. Due to the dielectric properties of the ground as contrasted with those of air, the antenna radiates more energy into the ground than into the space above it, although such an antenna in free space is non-directive in a plane normal to the antenna elements. Reflections of the signals thus introduced into the earth are recorded and observed to ascertain the nature of the explored area. While arrangements of this sort have been employed, it is found that the dipole antenna is essentially a narrow band radiator and does not exhibit the degree of directivity nor the operating band width most often desired for such applications, especially for modulation in short pulses to obtain echoes.

There is another antenna structure known to the art which bears a superficial similarity to that of the present invention. It comprises a horizontally arranged conductive radiator positioned above a counterpoise resting on the ground. Conductors connect a signal source to the radiator and to its counterpoise to permit excitation of the structure at several positions along its length. Loading elements, such as inductors, are included in the feed connections so that the structure is excited in phase at each of the several positions. However, that arrangement contemplates operation at relatively long waves and for that reason cannot reasonably approach a half wave length in physical dimensions. The conductive structure thus described is intended to achieve a low antenna resistance and the antenna is a narrow band one, adapted for single frequency operation, and is non-directive.

It is an object of the present invention, therefore, to provide a wide-band, directive antenna which avoids the aforementioned limitations of prior arrangements.

It is another object of the invention to provide a new and improved directive antenna structure for operation over a wide band of short wave lengths.

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It is a further object of the invention to provide a wide-band, directive antenna which is of simplified structure easily and cheaply fabricated.

It is a specific object of the invention to provide a new and improved directive antenna suitable for operation over a wide band of short wave lengths and especially useful for efficiently transmitting wave signals into the earth, as in a geophysical exploration system.

In accordance with the present invention, an antenna for operation over a wide band of short wave lengths comprises a radiating conductive structure in the form of an elongated flat strip having an effectively continuous length which is substantially greater than one-half of the mean operating wave length and having an effective width equal to at least a substantial fraction of one-quarter of the mean wave length. The antenna has an energy-distribution system including a plurality of transmission lines of substantially the same electrical lengths for making connections from a multiplicity of points distributed along a longitudinal edge of the radiating structure to signal-translating apparatus so that wave-signal energy delivered by that system from the translating apparatus energizes the radiating structure in the same phase at each of the multiplicity of points to effect translation of energy by the structure in a transverse electric mode.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is a plan view of a radiating conductive structure embodied in an antenna in accordance with the invention; Fig. 2 is a schematic representation of an energy-distribution system associated with the radiating structure; and Fig. 3 represents schematically a geophysical exploration system utilizing the present invention.

Referring now more particularly to the drawing, it is helpful to an understanding of the invention initially to describe the radiating structure and its energy-distribution system before discussing their application to the exploration system of Fig. 3. The radiating conductive structure of Fig. 1 includes a pair of similar conductive metallic strips 10 and 11 which may be flat areas of metal plates, screen or wire mesh. These strips are coplanar and are in space-opposed relation which is intended to define a mirror-image relationship obtained by coplanar positioning of the strips about

an axis of symmetry in the manner represented in the drawing. Each strip has an effectively continuous length S which is substantially greater than one-half of the mean operating wave length contemplated for the antenna system. Preferably, the length is approximately equal to n times one-half of the mean wave length, where n is any integer greater than unity. Each strip has an effective width equal to at least a substantial fraction of one-quarter of the mean wave length, the width usually being within the range of one-twentieth to three-quarters of the wave length. Preferably, the strips 10 and 11 are so dimensioned and spaced that the width W of the over-all structure is within the range from one-half to one wave length. This dimension is not critical although most efficient operation results by utilizing the preferred dimensions indicated. The strips may be of thin, sheet-like conductive material having a thickness which is small compared with their individual widths.

The band width of the antenna structure as well as its directivity result from the manner in which strips 10 and 11 are excited with signal energy. In particular, for broadside directivity the strips are to be excited substantially in phase at a multiplicity of points distributed along their lengths. This is accomplished through the use of a multiplicity of feed conductors of approximately the same lengths. As shown, groups or sets of conductors 12, 12 are associated with the first metallic strip 10 and similar groups or sets of conductors 12', 12' are associated with the other strip 11. One end of each conductor included in the groups 12, 12 is connected at a particular one of a series or multiplicity of feed points distributed along one edge of strip 10, as shown in Fig. 1, while one end of each of the conductors included in the groups 12', 12' is connected with a corresponding arrangement of feed points distributed along strip 11. The opposite or free ends of the conductors of each group are connected together to provide feed point terminals along the radiating structure. The preferred method of grouping, represented in the drawing, is one wherein the conductors connected with succeeding half wave-length sections of conductive strips 10 and 11 are grouped to provide feed point terminals with a separation of approximately one-half of the mean wave length.

To understand more fully the optimum grouping arrangement, it is convenient to visualize the radiating structure as comprising a series of contiguous half wave-length sections designated 13–16, inclusive, in Fig. 1 where the antenna length is equal to twice the mean wave length. Five feed conductors of the first group 12 are equally distributed along the first half wave-length section 13 of conductor 10 and the conductor arrangement for radiator 11 is essentially the same. The feed point ends of these two groups of conductors are connected together to constitute a first terminal pair T_1, centrally located within the section 13. A generally similar conductor arrangement provides additional terminal pairs T_2, T_3, and T_4 for the sections 14, 15, and 16, respectively.

An energy-distribution system is associated with the radiating structure for making connections through the conductors 12 and 12' to the multiplicity of distributed feed points. This distribution system is represented schematically in Fig. 2, being connected at one end to a wave-signal transmitter 20. The signal-translating

apparatus which is connected through the distribution system to the radiating structure will, of course, vary with the particular installation. Since such apparatus forms no portion of the present invention, unit 20 is shown in block diagram and may have any conventional design and construction. Its output terminals are connected with one end of a transmission line 21 which branches at its opposite end c, c' into parallel feed lines 22 and 23 having equal lengths. These in turn connect as points a, a' and b, b' to the center points of additional transmission lines 24, 25 also having equal lengths. For the embodiment under consideration, line 24 extends between terminal pairs T_1 and T_2 while line 25 extends between the remaining terminal pairs T_3 and T_4. The lines 22–25, inclusive, due to the physical configuration of the radiating structure, preferably provide the same physical and electrical length of line from the end of line 21 to each of the terminal pairs T_1–T_4, inclusive. As a result, the distribution system includes a plurality of transmission lines of the same physical and electrical lengths and, where open-wire lines are employed, they are nonradiating and have no material effect on the directive pattern of the radiating structure.

Considering the combined radiating structure of Fig. 1 and the electrical system of Fig. 2, the signal paths afforded between the transmitter 20 and the multiplicity of feed points along the radiating conductors 10 and 11 have the same physical and electrical lengths so that signal energy delivered by the transmitter energizes each conductive metal strip of the structure in the same phase at each of its several feeding points. In view of the fact that the same potential conditions are established by the feeding system at closely spaced points along the strips 10, 11, the current flow in the radiator strips is substantially transverse thereof, there being little tendency for longitudinal current flow. Therefore, the applied signal energy is radiated in what may be described as a "transverse electric mode." The radiating structure is then analogous to a broadside array of dipoles, where the dipole elements are considered to be provided by corresponding transverse sections of the strips 10 and 11. The antenna exhibits a directive pattern similar to that of a broadside array of dipoles known to the art and is suitable for operation over an exceedingly wide band of short wave lengths.

The groups of feed conductors 12 and 12' may also contribute components of radiation which are readily controlled by orienting the conductor groups relative to the metal strips 10 and 11. Locating the conductor groups in the same plane as the metal strips has the effect of increasing the width of strips 10 and 11 and, therefore, the antenna structure has been described with reference to its "effective width." The radiating strips 10 and 11 have further been described as being of an "effectively" continuous length because the in-phase method of feeding produces the effect of a continuous length even though there may be a condenser or break between any two succeeding ones of the multiplicity of feed points.

The schematic arrangement of Fig. 3 indicates a geophysical exploration system wherein a transmitter 30 is connected with a first transmitting antenna structure 31 through a distribution system 32. The antenna 31 rests upon the earth and is positioned close to a receiving antenna 33

connected through a distribution system 34 to a receiver 35. In each instance, the antenna and its associated distribution system are constructed as described above in connection with Figs. 1 and 2. The directive characteristics of the antennas 31 and 33 are shown by the curves A and B. Wave-signal energy supplied from transmitter 30 is radiated into the earth from the transmitting antenna 31 and, assuming the explored area to have an upper stratum P_1 and a lower stratum P_2 which reflects the transmitted signal, energy is intercepted by the receiving antenna 33 and recorded in the receiver 35. The reflection may be utilized in well-known manner to indicate the nature of the explored area. This system, utilizing antenna structures in accordance with the present invention, is highly efficient because the antenna presents maximum area on the ground surface and has minimum frequency selectivity. It is found that very nearly 100 per cent of the applied energy is transmitted into the earth due to the directive properties of the antenna structure and the difference in dielectric constants of the ether and the earth. While the antennas 31 and 33 have been described as resting on the ground, the system may be operated with these antennas placed slightly above the earth although the energy-distribution system in either case should be above the radiating conductors 10 and 11 of any antenna.

While the invention has been described as utilizing a pair of conductive strips 10 and 11 in the radiating structure, it will be appreciated that this is by way of illustration only. The pair of strips permits a result similar to that obtained by a broadside array of dipole antennas as already indicated, but one strip associated with a ground plane normal thereto likewise has high utility as a broad-band antenna.

Where the dimensions of the antenna have been recited in terms of wave length, it is to be understood that the reference is to the wave length with the antenna in operating position. This is an important design factor where the antenna is placed upon the earth's surface for the reason that the wave length in the earth is different from that in free space so that the close proximity of the ground may cause the effective antenna width to be substantially greater than would be the case were the antenna to be suspended in free space.

The transmitting and receiving antennas 31 and 33 may be placed in longitudinal alignment, close to one another, without danger of appreciable direct transmission therebetween. That is, the radiations from the several excited areas of conductors 10 and 11 add in phase in a broadside direction but are of such phase as to cancel one another in their end directions. The antennas are, therefore, highly directive in the broadside sense and exhibit little end radiation, making it possible to operate satisfactorily with the antennas in close longitudinal alignment as mentioned.

In the detailed discussion of Figs. 1 and 2 it has been convenient to refer particularly to wave-signal transmission. However, it is well understood that the functions of reception and transmission with any such antenna are unavoidably associated by the reciprocity theorem. Therefore, such terms as "a radiating conductive structure" and the like are used in the text and in the appended claims in a generic sense to define an antenna structure in accordance with the

invention whether that antenna be utilized for signal transmission or reception.

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. An antenna for operation over a wide band of short wave lengths comprising: a radiating conductive structure in the form of an elongated flat strip having an effectively continuous length substantially greater than one-half of the mean wave length of said band and having an effective width equal to at least a substantial fraction of one-quarter of said mean wave length; and an energy-distribution system including a plurality of transmission lines of substantially the same electrical lengths for making connections from a multiplicity of points distributed along a longitudinal edge of said structure to signal-translating apparatus so that wave-signal energy delivered by said system from said apparatus energizes said structure in the same phase at each of said points to effect translation of said energy by said structure in a transverse electric mode.

2. An antenna for operation over a wide band of short wave lengths comprising: a radiating conductive structure in the form of an elongated flat strip having an effectively continuous length approximately equal to n times one-half of the mean wave length of said band, where n is any integer greater than unity, and having an effective width at least equal to a substantial fraction of one-quarter of said mean wave length; and an energy-distribution system including a plurality of transmission lines of substantially the same electrical lengths for making connections from a multiplicity of points distributed along a longitudinal edge of said structure to signal-translating apparatus so that wave-signal energy delivered by said system from said apparatus energizes said structure in the same phase at each of said points to effect translation of said energy by said structure in a transverse electric mode.

3. An antenna for operation over a wide band of short wave lengths comprising: a radiating conductive structure in the form of an elongated flat strip having an effectively continuous length substantially greater than one-half of the mean wave length of said band and having an effective width within the range of one-twentieth to three-quarters of said mean wave length; and an energy-distribution system including a plurality of transmission lines of substantially the same electrical lengths for making connections from a multiplicity of points distributed along a longitudinal edge of said structure to signal-translating apparatus so that wave-signal energy delivered by said system from said apparatus energizes said structure in the same phase at each of said points to effect translation of said energy by said structure in a transverse electric mode.

4. An antenna for operation over a wide band of short wave lengths comprising: a radiating structure including a thin substantially flat metallic strip having an effectively continuous length substantially greater than one-half of the mean wave length of said band and having an effective

width equal to at least a substantial fraction of one-quarter of said mean wave length; and an energy-distribution system including a plurality of transmission lines of substantially the same electrical lengths for making connections from a multiplicity of points distributed along a longitudinal edge of said strip to signal-translating apparatus so that wave-signal energy delivered by said system from said apparatus energizes said structure in the same phase at each of said points to effect translation of said energy by said structure in a transverse electric mode.

5. An antenna for operation over a wide band of short wave lengths comprising: a radiating structure including a pair of similar, coplanar, thin metallic strips in space-opposed relation individually having an effectively continuous length substantially greater than one-half of the mean wave length of said band and having an effective width equal to at least a substantial fraction of one-quarter of said mean wave length; and an energy-distribution system including a plurality of transmission lines of substantially the same electrical lengths for making connections from a multiplicity of corresponding points distributed along the adjacent longitudinal edges of said strips to signal-translating apparatus so that wave-signal energy delivered by said system from said apparatus energizes said structure in the same phase at each of said points to effect translation of said energy by said structure in a transverse electric mode.

6. An antenna for operation over a wide band of short wave lengths comprising: a radiating conductive structure in the form of an elongated flat strip having an effectively continuous length substantially greater than one-half of the mean wave length of said band and having an effective width equal to at least a substantial fraction of one-quarter of said mean wave length; and an energy-distribution system including a plurality of transmission lines of substantially the same physical and electrical lengths for making connections from a multiplicity of points distributed along a longitudinal edge of said structure to signal-translating apparatus so that wave-signal energy delivered by said system from said apparatus energizes said structure in the same phase at each of said points to effect translation of said energy by said structure in a transverse electric mode.

7. An antenna for operation over a wide band of short wave lengths comprising: a radiating conductive structure in the form of an elongated flat strip having an effectively continuous length substantially greater than one-half of the mean wave length of said band and having an effective width equal to at least a substantial fraction of one-quarter of said mean wave length; and an energy-distribution system including a plurality of nonradiating transmission lines of substantially the same electrical lengths for making connections from a multiplicity of points distributed along a longitudinal edge of said structure to signal-translating apparatus so that wave-signal energy delivered by said system from said apparatus energizes said structure in the same phase at each of said points to effect translation of said energy by said structure in a transverse electric mode.

8. An antenna for operation over a wide band of short wave lengths comprising: a radiating conductive structure in the form of an elongated flat strip having an effectively continuous length substantially greater than one-half of the mean wave length of said band and having an effective width equal to at least a substantial fraction of one-quarter of said mean wave length; a multiplicity of conductors of approximately the same length each connected at one end to one of several points distributed along a longitudinal edge of said structure; and an energy-distribution system including a plurality of transmission lines of substantially equal electrical lengths for making connections from the opposite end of each of said conductors to signal-translating apparatus so that wave-signal energy delivered by said system from said apparatus energizes said structure in the same phase at each of said points to effect translation of said energy by said structure in a transverse electric mode.

9. An antenna for operation over a wide band of short wave lengths comprising: a radiating conductive structure in the form of an elongated flat strip having an effectively continuous length substantially greater than one-half of the mean wave length of said band and having an effective width equal to at least a substantial fraction of one-quarter of said mean wave length; a multiplicity of conductors of approximately the same length each connected at one end to one of several points distributed along a longitudinal edge of said structure, the free ends of succeeding groups of said conductors being joined together to provide feed point terminals along said structure; and an energy-distribution system including a plurality of transmission lines of substantially equal electrical lengths for making connections from said terminals to signal-translating apparatus so that wave-signal energy delivered by said system from said apparatus energizes said structure in the same phase at each of said points to effect translation of said energy by said structure in a transverse electric mode.

10. An antenna for operation over a wide band of short wave lengths comprising: a radiating conductive structure in the form of an elongated flat strip having an effectively continuous length substantially greater than one-half of the mean wave length of said band and having an effective width equal to at least a substantial fraction of one-quarter of said mean wave length; a multiplicity of conductors of approximately the same length each connected at one end to one of several points distributed along a longitudinal edge of said structure, the free ends of succeeding groups of said conductors being joined together to provide feed point terminals along said structure with a separation between succeeding terminals of approximately one-half of said wave length; and an energy-distribution system including a plurality of transmission lines of substantially equal electrical lengths for making connections from said terminals to signal-translating apparatus so that wave-signal energy delivered by said system from said apparatus energizes said structure in the same phase at each of said points to effect translation of said energy by said structure in a transverse electric mode.

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