

UNITED STATES PATENT OFFICE

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DIRECTIVE ANTENNA SYSTEM

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This invention relates to antenna systems, and more especially to antenna systems designed to transmit in a specified direction.

It is well known in radio systems that the propagated energy ordinarily travels both horizontally, in the so-called "ground wave", and at an angle to the horizontal, in the so-called "sky wave"; and that the ground wave is usually more effective at relatively near cooperating stations whereas at the more distant stations the sky wave is generally more effective. In systems designed for distant transmission it is, therefore, desirable to concentrate the entire radiation insofar as practicable in the sky wave. In addition, it is often desirable to eliminate the ground wave for the purpose of reducing fading at such receiving stations as are positioned to receive both waves, since one of the common causes for signal fading is the fact that the ground and sky waves may be received simultaneously and in varying relative phase.

One object of this invention is to concentrate the propagation of radio waves in a direction inclined to the horizontal.

Another object of this invention is to prevent radiation in a particular direction from a transmitting system.

Another object of this invention is to reduce the amount of energy absorbed by the ground from propagated waves.

Still another object of the invention is to reduce fading in radio systems.

These and other objects are accomplished by utilizing an antenna comprising an inclined open-ended exciter and a similarly inclined open-ended reflector spaced to the rear of the exciter substantially one-quarter of the wave length or an odd multiple thereof. When the exciter is energized, standing waves are produced both on the exciter and on the reflector in a manner well known at present. Means are provided for making the phases of currents in the different parts of the exciter the same so that correspondingly radiated disturbances are emitted in substantially the same phase. Similarly, the waves radiated from all portions of the reflector are made identical in phase and these waves cooperate with the exciter waves to produce

unilateral directivity. The amount of inclination from the vertical of both the exciter and the reflector is such that the projection of each on a horizontal plane is substantially a wave length or a multiple thereof with the result that very little energy is radiated in a horizontal direction.

The invention will be more fully understood from the following description taken in connection with the drawing, in which:

Fig. 1 represents a simple antenna tilted in accordance with the invention;

Fig. 2 is a table analyzing the vectorial relationship in the radiation produced by the system of Fig. 1;

Fig. 3 shows an exciter-reflector radiating system constructed in accordance with the invention; and

Fig. 4 illustrates a complete unilateral broadside antenna system arranged to radiate its maximum signal in a direction inclined to the ground.

In Fig. 1 reference numeral 1 is a single conductor antenna tilted in a vertical plane away from a distant cooperating station at such an angle that its projection along the ground 2 is equivalent to one wave length. The antenna is associated by means of a transformer 3 and transmission line 4 with a translation system, such as a transmitter or receiver; not shown on the drawing. The reference letters *a*, *b*, *c* and *d* represent segments of antenna 1 which may lie anywhere along the antenna but for purposes of this explanation have been assumed to be at the midpoint of the half-wave sections of the antenna and equally spaced so that the projections of the segments *b*, *c* and *d* on the horizontal or ground are spaced

$$\frac{\lambda}{4}, \frac{\lambda}{2}, \text{ and } \frac{3\lambda}{4},$$

respectively, from the horizontal projection of point "a" where λ represents a wave length. Reference letters *b'*, *c'* and *d'* represent the projection of segments *b*, *c* and *d* on the vertical line *a d'*, respectively. The double-headed arrow M represents the bilateral direction of propagation of the maximum signal radiated from antenna 1 and

double-headed arrow N represents the bilateral direction of null radiation. The operation of the system of Fig. 1 will be understood from a consideration of the table shown in Fig. 2.

Assuming that the antenna 1 is employed for radiating energy supplied by a transmitter over line 4 and that the infinitesimal signal components to be radiated are in phase, the vector of the small waves radiated from segments *a*, *b*, *c* and *d* may be represented as shown in the second column from the left in the table of Fig. 2. For field points equally spaced from all the segments the vectors are in the same direction and hence combine to give a maximum signal in that direction. That is the vectors combine in directions shown by arrow "M" or in directions parallel thereto. Considering the radiation reaching the vertical plane including the projections *a*, *b'*, *c'* and *d'*, the vectors will have the direction shown in the last column from the left in Fig. 2. At *b'* radiation from segment *b* will lag behind that from segment *a* by 90°. At *c'* radiation from *c* will lag behind that from segment *a* by 180°. In a similar manner the phase of the wave radiated from segment "*d*" and arriving at *d'* will lag behind that emanating from segment *a* by 270° respectively. As shown at the bottom of the table in Fig. 2, the vector sum in the two opposite directions represented by arrow "N", will be zero, indicating that no radiation takes place in these directions.

In the system shown in this figure as well as in the systems illustrated in the other figures one important advantage of producing maximum radiation in the sky wave and null radiation in the ground wave is that transmission to a relatively close station, as for example, to a ship situated 300 to 400 miles away from the transmitting point, may be improved. In other words, by eliminating the ground wave and utilizing the sky wave only, fading at the receiving station may be reduced since one factor causing fading is the interference between a received ground and sky wave.

The antenna system shown in Figure 3 comprises an exciter having a plurality of colinear half-wave sections 5 separated by the inductances or loaded sections 6 and a reflector having a plurality of half-wave colinear sections 7 separated by the inductances 8. The inductance sections function as half-wave phase suppressors. It should be understood in this connection that other types of phase suppressors may be employed without exceeding the scope of the invention. The exciter and reflector are tilted in a vertical plane so that the projection of each in a horizontal direction, that is along the ground, is equal to one wave length. The reflector is positioned parallel to and substantially an odd one-quarter multiple of one wave length

in back of the exciter measured on a line perpendicular to the exciter and reflector. The exciter is associated with a source of energy (not shown on the drawing) by means of transformer 10 and transmission line 11. Dotted lines 12 and 13 merely show the in-phase and suppressed portions of the standing wave produced on the exciter and reflector, respectively.

In the system of Fig. 3 energy is radiated unilaterally in the direction indicated by a single-headed arrow S in a manner well known at present. Assuming that the excited is energized over line 11 in-phase radiation takes place from the exciter sections 5 since the inductances 6 effectively suppress radiation from alternate half-wave length portions of the standing waves. The currents in the exciter set up currents in the reflector, the phase and magnitude of these induced currents being controlled by the geometrical configuration of the system and the tuning of the reflector. Inductances 8 suppress radiation from alternate half-wave length portions of the reflector standing waves. With the spacing between front and rear curtains equal to one quarter wavelength, substantially, and with the reflector substantially in resonance, the requirements with respect to phase and amplitude of the induced currents are satisfied and unidirectivity is achieved.

In Fig. 4 reference numeral 14 represents the exciter row and numeral 15 the reflector row of a broadside unilateral transmitting system such as disclosed in a copending application of E. J. Sterba, Serial No. 382,103, filed July 30, 1929. These rows are supported and held in position by guy wires 16, the long top horizontal guy wires being supported between towers 17. Each row is shown as comprising three panels insulated from each other, the ground 18 and the guy wires 16 by means of insulators 19. As described in the copending application mentioned above, each panel comprises a plurality of radiating elements 20 arranged in two rows or sections. These rows are described in the above mentioned application as being vertical but they are tilted in accordance with this invention as explained below. The top and bottom radiating elements are approximately a quarter wave length long and the intermediate elements approximately one-half wave length long. Elements 20 are connected by means of horizontal half-wave length elements 21 to alternate radiating elements 20 of the other line so that radiation from the horizontal elements is suppressed substantially and in-phase radiation occurs only from each panel. Because of the broadside arrangement and also because of the reflector, unilateral propagation is achieved. Both exciter and reflector panels are tilted so that the horizontal projection of each on the

ground is equal to a wave length. Each exciter panel is connected by means of a branch line 22 and a main line 23 to a source 24 of radio frequency power. The dotted line xx' represents the vertical plane and dotted line yy' the horizontal plane and arrow T the direction of propagation which, as shown on the drawing, is in a vertical plane at an angle to the horizontal.

The operation of the system shown in Fig. 4 is obvious from a consideration of the description already given of the system of the preceding figures. When power is supplied from source 24 radiation occurs from the tilted elements 20 only, and this radiation is in-phase. Substantially no radiation takes place in the horizontal plane yy' because of the tilt of the antenna system. Within certain limits better results in this respect may be obtained by increasing the number of panels in rows 14 and 15. The reflector functions to produce unilateral directivity in the manner explained in connection with Fig. 3.

In the antenna system shown on the drawing as well as in other systems tilted in accordance with the invention the antenna of course may be tilted so as to produce substantially zero radiation in other directions aside from the horizontal and suitable means may be employed if so desired for the purpose of adjustably tilting the antenna to any desired angle. One important advantage of providing means for easily and quickly changing the angle of tilt is that the angle of wave deflection from the Heaviside layer may be controlled so that transmission to a particular distant cooperating station at the optimum angle of tilt, which may change several times a day, may be insured. Another important advantage is that the direction of the wave may be controlled for the purpose of selecting and transmitting to a particular distant station and preventing at the same time, to some degree, reception by certain other distant stations.

Although the invention has been explained in connection with transmitting systems, it is to be understood that the invention is equally applicable to receiving systems; and moreover it is to be understood that the invention is not to be limited to the specific type of antenna shown in the drawing, as it may be satisfactorily employed in connection with various types of antennæ.

What is claimed is:

1. The method of suppressing radiation in a specified direction from an antenna utilizing an antenna connected to a source of energy, which comprises supplying in-phase currents to all sections of said antenna and tilting the antenna toward or away from said specified direction at such an angle that the vector sum of the wave components radiated

in the specified direction equals substantially zero.

2. The method of improving radio transmission utilizing a transmitting antenna connected to a source of energy which comprises supplying in-phase currents to all sections of said antenna and tilting said antenna at such an angle to the vertical that its horizontal projection is equal to one wave length or a multiple thereof.

3. An antenna comprising a conductor inclined with respect to an undesired direction of propagation at such an angle that its projection in said direction is substantially equal to a multiple of one wave length.

4. An antenna comprising a conductor inclined to the vertical to such a degree that its projection on the horizontal is substantially equivalent to a multiple of one wave length, and means for producing in-phase currents in practically all portions of said conductor.

5. An open-ended antenna tilted at such an angle to the vertical that its horizontal projection is equal to a multiple of one wave length, a source of radio frequency energy associated with said antenna, and means for eliminating radiation from one group of similarly phased portions of the standing waves produced on said antenna.

6. A transmitting antenna system comprising an exciter inclined to the vertical to such a degree that its horizontal projection is substantially equal to one wave length, a reflector similarly inclined and spaced at odd multiple of a quarter wave length to the rear of the exciter, radio frequency energizing means connected to said exciter, means included in said exciter and said reflector for producing in-phase radiation.

7. A transmitting antenna system comprising an exciter and a reflector, the reflector being positioned parallel to and substantially an odd multiple of a quarter wave length to the rear of the exciter, the exciter and reflector each comprising a plurality of panels in broadside arrangement spaced a half wave length apart, each panel inclined from the vertical at such an angle that its horizontal projection is equal substantially to a multiple of a wave length of the radiated wave, each panel comprising two sets of colinear inclined elements, each element being connected to alternate inclined elements of the other set, said sets being spaced a half wave length apart, and a source of radio frequency energy associated with said exciter.

In witness whereof, I hereunto subscribe my name this 15th day of August, 1930.

JOHN C. SCHELLENG.