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ANTENNA SYSTEM

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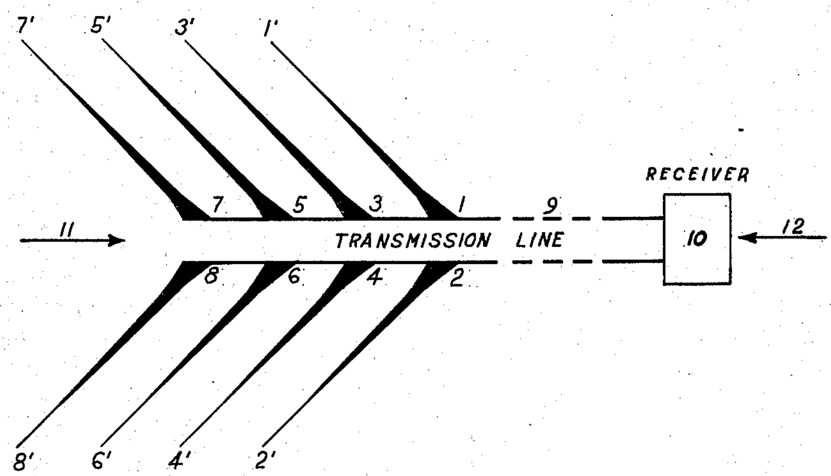

FIG. 1

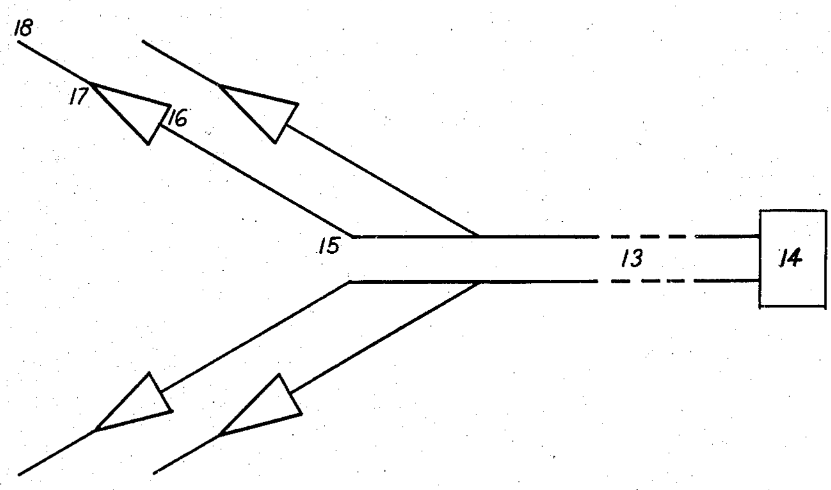

FIG. 2

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ANTENNA SYSTEM

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6 Claims. (Cl. 250—33)

This invention relates to new and useful improvements in antenna systems.

The object of the invention is to provide an inexpensive directive antenna for short waves and one in which the reflection of waves from the ends of the antenna wire is minimized.

The invention is applicable to radio receiving and transmitting systems and its nature will be best understood from the following detailed description of a few embodiments thereof and the appended claims.

The invention will be best understood by reference to the following description taken in conjunction with the accompanying Figs. 1 and 2 illustrating in plan views two embodiments of the invention.

Fig. 1 shows in diagrammatic form an idealistic conception of my invention which is useful in explaining the underlying theory of tapering the attenuation along the collector wires; Fig. 2 illustrates a practical embodiment in which the tapering of the collector wires is effected by the joint use of more than one kind and size of conductor, each having a substantially different attenuation characteristic per unit of length.

Consider first the diagram of Fig. 1 in which 1, 1', 3, 3', 5, 5' and 7, 7' are antenna collector wires connected to successive points along one side of the transmission line 9, and 2, 2', 4, 4', 6, 6' and 8, 8' the collector wires connected to the corresponding successive points along the other side of the transmission line. The collector wires branch off in pairs from a common transmission line, are preferably of equal length, and make equal angles on either side of the axis of symmetry of the collector system. Points of connection 1 and 2 can be made at the outermost pole carrying the transmission line, 3 and 4 at the next to the last pole, and so on. The transmission line 9 is designed for efficient transfer of energy from the collector system to a radio receiver 10 in the manner well known to one skilled in the art.

It will be noted that the lines representing the collector wires are drawn with varying thickness, i. e., thick at the ends connecting to the transmission line, and tapering off to a thin line at the outer ends. The object of this method of representation is to show that the wires are not of uniform conductivity throughout the length of each, but are of graduated conductivity according to the thickness of the line. The significance of this is that the attenuation or loss per unit length of line varies in the opposite manner to the thickness of the line, i. e., a collector of wire will have low attenuation per unit length at the transmission line end and relatively high attenuation at the outer end being graduated between these limits throughout its length. This will be clear upon considering the effect of resistance on the attenuation characteristic of a wire line.

In transmission line theory it is well known that the attenuation constant A of a given line may be expressed in terms of the parameters of the line as follows:

$$A=\sqrt{\frac{1}{2}\sqrt{(R^2+\omega^2L^2)(G^2+\omega^2C^2)}+\frac{RG-\omega^2LC}{2}}$$

where

R=resistance per unit length of line
L=inductance per unit length of line
G=leakage conductance per unit length of line
C=capacitance
$\omega=2\pi f$, f, being the frequency.

At very high frequencies such as I am dealing with it is found in practice that R is very much less in magnitude than ωL and G is likewise very much less in magnitude than ωC. This being the case, it is permissible to simplify greatly the expression for A. Hence:

$$A=\frac{R}{2}\sqrt{\frac{C}{L}}$$

very closely for high frequencies. Thus it will be seen the attenuation constant for the purpose of my invention is proportional to the conductor resistance and, therefore, inversely proportional to the conductance. It will be appreciated that the resistance referred to is the effective resistance in the range of frequencies considered.

Assuming uniform attenuation in the collector wires, consider what happens when radiant energy is impinging on the collector system in the direction of the arrow 11. Energy picked up near the outer ends of the collectors must suffer the attenuation of the whole length of the collectors before reaching the transmission line whereby it is considerably weakened. Energy picked up by the middle portion of the collectors need traverse only a part of their length and arrives at the transmission line in less weakened condition than that which is picked up near the outer ends. Finally, the energy picked up by the portion adjacent to the transmission line is collected with practically no weakening at all. Consequently, all portions of the collectors are not equally effective in collecting the radiant energy and delivering it to the transmission line, the portions adjacent to the transmission line being most effective and the portions near the outer ends being least effective.

Assuming now that the attenuation is not uniform, but tapered in accordance with my invention, it will be readily apparent that the attenuation is greatest in the portions where the energy picked up contributes the least to the sum total. Consequently, the energy received with the tapered attenuation is almost as great as that received with a uniform attenuation, if the uniform attenuation were equal to the portion of the tapered attenuation adjacent to the transmission line. This slight sacrifice in received energy is accompanied by important advantages.

Consider, for example, radiant energy arriving from exactly the opposite direction as indicated by arrow 12. This energy impinging on the collectors can be delivered to the transmission line only by reflection at the outer ends of the collectors on account of its direction. In this case, energy picked up near the outer ends is there reflected and must traverse the entire collector to be delivered to the transmission line. Energy picked up in the middle portion must first travel to the outer end being attenuated in the process and, after being reflected, traverse the entire collector before reaching the transmission line. Similarly, energy picked up adjacent to the transmission line must traverse the collector twice, i. e., make a round trip, before being delivered to the transmission line. Therefore, the radiant energy being received from the direction indicated by arrow 12 can be delivered to the transmission line only via the outer ends of the collectors and the contributions to the sum total for various portions of the collectors is the inverse of the case where radiant energy arrives from direction 11.

Assuming the radiation from direction 11 to be desired, and that from direction 12 undesired, it will be seen that even with collectors having uniform attenuation there will be some discrimination between front and back reception by the amount of the attenuation of a collector and to that extent it will be desirable. However, it has not been considered beneficial to use collectors of uniformly high attenuation, but rather as low as practicable. This militates against the desired front to back discrimination so that it will not be very great. On the other hand, by tapering the attenuation along the collectors as described, the front to back discrimination is greatly enhanced. The very high attenuation near the outer ends when tapering is employed acts like a bottle-neck to all the back or undesired radiant energy, but the bottle-neck effect does not come into play when receiving energy from the front or desired direction. My invention, therefore, provides a means for reducing the interfering effect on the receiver of radiation arriving from the back direction and at the same time maintaining practically undiminished the effect on the receiver of radiation arriving from the front.

This discriminating effect is still further enhanced by the use of a plurality of pairs of collectors because energy arriving from the front is picked up by the separate pairs of collectors and is delivered to the transmission line in such a manner that the contribution of each pair of collectors adds substantially in phase with the contribution of every other pair, whereas, the energy arriving from the back is not only squeezed through the bottle-neck of each pair of collectors leaving a relatively small amount to be delivered to the transmission line but the contributions of the individual pairs add in random phase. It will be appreciated that "in phase" addition means the arithmetical sum of the terms involved, whereas, "random phase" addition means the sum of component parts of the terms depending on their relative phases which sum is always less in magnitude compared with "in phase" addition and may in some cases amount to complete cancellation.

So far, the behavior of the collector system has been treated only in respect to front and back radiation. This is the most important case because an open-ended antenna system of this general type but not employing my arrangement of tapered collectors is arranged to be most receptive in both directions along the axis of the collector system, i. e., front and back reception. In all other directions, except for a small angle on either side of the axis of the collector system, reception is greatly reduced. Therefore, when reception from the back is practically eliminated, as it is with the tapered collectors, the antenna is receptive in substantially one direction, namely, along the axis of the system to radiation arriving from the front as indicated by arrow 11.

In determining the angle at which the collector wires should fan out from the transmission line, it should be noted that the portions adjacent to the outer ends are more or less inactive as far as collecting energy is concerned. The angle is usually determined by the electrical length of the collector, being smaller as the electrical length is greater. This assumes the collector to be uniformly active throughout its entire length. It is necessary, therefore, to consider only the active length for this purpose. The net result is that a somewhat wider angle should be employed than would be the case if the collector were uniformly active throughout its length. The angle is not very critical and may be estimated closely enough for practical purposes.

Fig. 2 shows one embodiment in which the attenuation of each collector wire is tapered in discreet steps rather than gradually, as in Fig. 1. Referring to Fig. 2, 13 is the transmission line for conveying the received energy from the collector system to the receiver 14. The collector system itself is composed of a plurality of pairs of similar composite collector wires connected at successive points to the transmission line and spreading out at equal angles, the geometry of the system being substantially as described above for Fig. 1. It will suffice to differentiate from Fig. 1 by describing in detail one of the composite collector wires of Fig. 2.

Each composite collector wire is composed of several sections each section having uniform attenuation throughout the length of a section, said attenuation being substantially different for the different sections and relatively short impedance matching devices for interconnecting successive sections. Furthermore, the section of lowest attenuation is adjacent to the transmission line, the remaining sections being of progressively higher attenuation. In Fig. 2, for example, each collector is composed of two sections, 15, 16 and 17, 18 joined by the impedance matching device 16, 17. Section 15, 16 is adjacent to the transmission line and is of low attenuation, while section 11, 17 is adjacent to the outer end and is of relatively high attenuation. In order to achieve low attenuation, the section 15, 16 should be of reasonably low effective resistance per unit length and may be, for example, copper wire of the gauge ordinarily used in antennae. Section 17, 18, on the other hand, should be of relatively small gauge wire having a relatively high effective resistance per unit length and may be, for example, of stainless steel approximately 20 mils in diameter. By reference to the simplified formula for the attenuation constant A given above, it may be shown that the section 17, 18 has a high attenuation per unit length compared with section 15, 16.

The impedance matching device 16, 17 is necessary in this arrangement in order to realize the full benefit of the bottle-neck effect because a direct connection between the copper wire of section 15, 16 and the stainless steel wire of section 17, 18, said wires having widely different surge impedances, would introduce an abrupt impedance irregularity at the junction of the wires. Such an impedance irregularity would reflect a considerable part of the energy attempting to pass through the junction. This effect is not harmful where the radiation is arriving in the desired direction, i. e., from the front, because then it would act merely to reduce the energy contribution of the high attenuation section 17, 18 which is purposely negligibly small. However, it may be very harmful and, to whatever extent it exists, it tends to defeat the proper functioning of my invention where the radiation is arriving in the undesired direction, i. e., from the back. What I aim to do is to force the undesired radiation picked up by the collector to make a round trip to the extreme outer end and back whereby it is reduced to negligible proportions by being subjected twice to the high attenuation of the section 17, 18. Obviously, when there is an abrupt impedance irregularity at the junction of wires a considerable part of the undesired radiation is reflected back over the low attenuation section 15, 16 without having been forced to travel first to the outer end. Under these conditions much of the discrimination between front and back radiation would be lost.

In order to overcome this difficulty I employ the relatively simple impedance matching device 16, 17. It comprises two of the stainless steel wires used in section 17, 18 connected in parallel to the end of the copper wire 16, being spaced at this point so that the surge impedance of the spaced stainless steel wires approximately matches that of the copper wire. After a short run, the stainless steel wires come together at a point 17 where they are joined to the outer section 17, 18. This graduates the impedance from a value equal to the surge impedance of the copper wire to a value equal to the surge impedance of the stainless steel wire, thus effecting a substantially reflectionless junction.

Generally, where it is desired to join two wires, one of which has a substantially different surge impedance than the other, in such a manner that there is negligible reflection, I construct the impedance matching device with the wire having the higher surge impedance connecting the spaced ends to the wire of lower surge impedance and the joined ends to the wire of higher surge impedance. The impedance matching device is, therefore, an isosceles triangle constructed of the wire having the higher surge impedance and having a relatively short base and small angle at the vertex, the base being of such a length that the spaced wires have a surge impedance equal to that of the wire of lower surge impedance. The base is connected to the wire of lower surge impedance and the vertex to the wire of higher surge impedance. In practice the height of the triangle is equal to a plurality of wave lengths where the antenna is used for short wave transmission or reception and the base is very short as compared to the wave length used.

In actual practice I make section 15, 16 substantially horizontal and about a quarter wave length above the earth's surface and five to ten wave lengths long, the impedance matching device about two wave lengths long and section 17, 18 four to six wave lengths long. In order to determine approximately the best angle at which to run the collectors I find that it is desirable to add about two wave lengths to section 15, 16 on account of penetration into the outer sections.

What I claim is:

1. A directional antenna system comprising a transmission line, and two antenna wires connected therewith and forming a V, the portions of the wires nearest the line having a lower attenuation constant than the portions farthest from the line.

2. An antenna system comprising a transmission line, and antenna wires connected therewith and forming a plurality of parallel V's, the portions of the wires nearest the line having a lower attenuation constant than the portions farthest from the line.

3. An antenna system comprising a transmission line, and antenna wires connected therewith and forming a V, one section of each wire nearest the line having lower attenuation constant than another section, and impedance matching devices between the two sections of each wire.

4. An antenna system comprising a transmission line, and antenna wires connected therewith and forming a plurality of parallel V's, one section of each wire nearest the line having lower attenuation constant than another section, and impedance matching devices between the two sections of each wire.

5. In a transmission system, wires of relatively low and high impedance, and an impedance matching device between said wires consisting of an isosceles triangle of relatively high impedance wire the height of which is great and the base of which is of small length as compared to the wave length at which transmission is effected.

6. A unidirectional antenna system for radiant action with respect to a desired direction, comprising two substantially linear wires of different resistance per unit length disposed end to end along a line obliquely inclined to said desired direction and coupled to each other at their adjacent ends to constitute a conductor of varying attenuation along its length and a transmission line coupled to that end of said conductor which has the lower attenuation.

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