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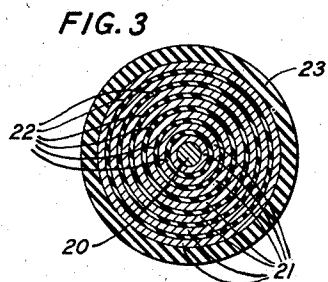
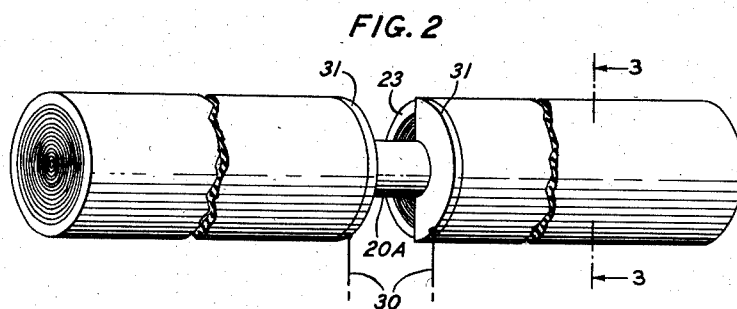
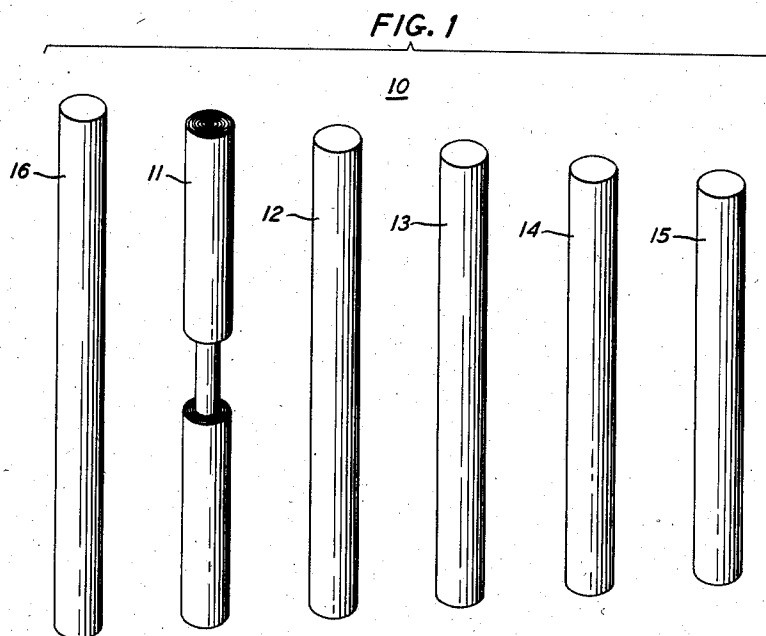
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2,841,792

DIRECTIONAL ARRAY EMPLOYING LAMINATED CONDUCTOR

Filed Dec. 29, 1951

2 Sheets-Sheet 1



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FIG. 4

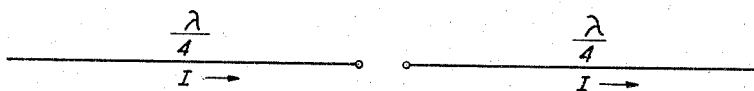


FIG. 5

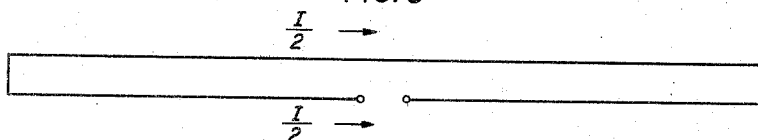
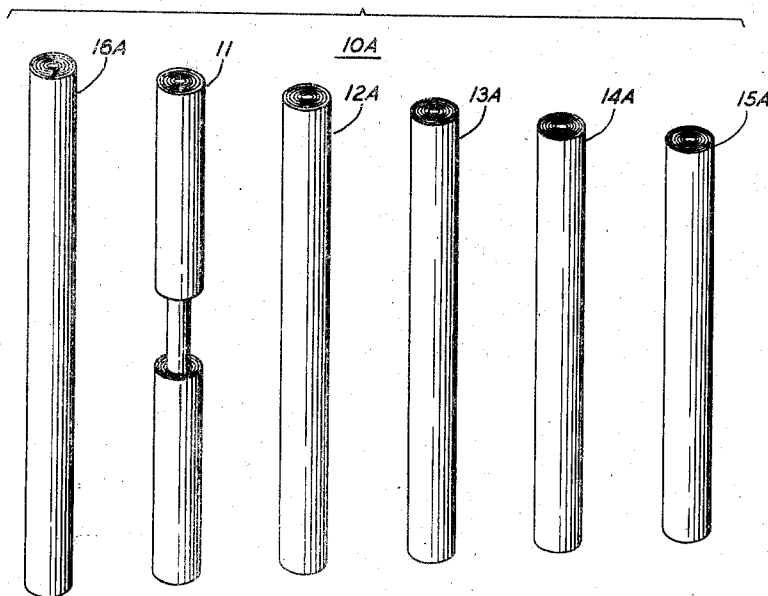


FIG. 6



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DIRECTIONAL ARRAY EMPLOYING LAMINATED CONDUCTOR

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Application December 29, 1951, Serial No. 264,102

8 Claims. (Cl. 343—819)

This invention relates to antenna systems and more specifically to directional antennas.

It is an object of this invention to improve the directional and gain characteristics of antenna arrays.

In a simple dipole antenna, power loss due to the resistance of conductors is usually unimportant. In directional arrays employing numerous dipoles with parasitic excitation, such as in Yagi arrays, for example, conductor dissipation may limit the directivity and gain obtainable.

In the usual Yagi array, such, for example, as is disclosed in an article by H. Yagi entitled "Beam transmission of ultra short waves" in the Proceedings of the I. R. E., volume 16, pages 715 to 741, inclusive, June 1928, one dipole or other driven element has applied thereto the signals to be radiated and the waves therefrom are given a directional pattern by means of a number of parasitic director elements arranged in a row in front of the driven element. One or more parasitic reflector elements have been used behind the driven element with such arrays.

The present invention is based on the discovery that the dissipation in the driven element, and in the reflector and director elements as well, can be reduced by employing laminated conductors with insulating coatings in place of solid elements. Moreover, the laminated construction of the driven element makes it possible to match the impedance of a transmission line feeding the driven element more closely to that of the array than in Yagi arrays employing solid conductor elements.

The theory of laminated conductors is described in a copending application of A. M. Clogston, Serial No. 214,393, filed March 7, 1951, now U. S. Patent No. 2,769,148. In the Clogston application, there is disclosed a "stack" comprising a multiplicity of thin, coaxially arranged, metal laminations insulated from one another by thin insulating layers and arranged so that the smallest dimension of each of the laminations is in the direction perpendicular to both the direction of wave propagation and the magnetic vector. Each metal lamination is preferably many times (for example 10, 100, or even 1000 times) smaller than the factor δ which is called one skin thickness or one skin depth. The distance δ is given by the expression

$$\sqrt{\frac{1}{\pi f \mu \sigma}} \quad (1)$$

where δ is expressed in meters, f is the frequency in cycles per second, μ is the permeability of the metal in henries per meter, and σ is the conductivity in mhos per meter. The factor δ measures the distance in which the current and field penetrating into a slab of the metal many times δ in thickness will decrease by one neper; i. e., their amplitude will become equal to

$$\frac{1}{e} = 0.3679 \dots$$

times their amplitude at the surface of the slab.

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It is pointed out in the Clogston application that when a conductor has such a laminated structure, a wave propagated along the conductor at a velocity in the neighborhood of a certain critical value will penetrate further into the conductor (or completely through it) than it would penetrate into a solid conductor of the same material, resulting in a more uniform current distribution in the laminated conductor and consequently lower losses. The critical velocity for the type of structure just described is determined by the thickness of the metal and insulating laminae and the dielectric constant of the insulating laminae in the composite conductors.

This invention will be more readily understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof, in which:

Fig. 1 is a schematic perspective view of an antenna array in accordance with the invention;

Fig. 2 is an enlarged view, in perspective and with portions broken away, of the driven element in the array of Fig. 1 and connections thereto;

Fig. 3 is a cross-sectional view taken in a plane through line 3—3 of Fig. 2;

Figs. 4 and 5 are schematic diagrams of a simple dipole and of a folded dipole used in explaining a feature of the present invention; and

Fig. 6 is a schematic perspective view of a modification of the arrangement of Fig. 1.

Referring more specifically to the drawings, Fig. 1 shows, by way of example for purposes of illustration, a Yagi antenna array 10 modified in accordance with the invention. As in arrays described in the above-mentioned Yagi article, the system 10 comprises a driven element 11, a group of director elements 12, 13, 14 and 15, and a reflector element 16. The axes of the various elements are preferably contained within a single plane or "curtain." The number of director and reflector elements shown is merely by way of example. Obviously a greater or smaller number of director elements can be used, if desired, and this applies also to reflectors since a plurality of such members can be used or such members omitted entirely. Each member 11 to 16, inclusive, is approximately a half wavelength long but they taper off somewhat in length reading from left to right from member 16 to member 15 as shown in Fig. 1. The spacings between the various members of the array 10 may vary somewhat but in general they are between a quarter and a half of a wavelength. Specific lengths and spacings of Yagi arrays and their manner of operation are discussed on pages 504 to 507, inclusive, of a textbook entitled "Radio Aerials," by E. B. Moullin, Oxford University Press (1949), and reference is made to this text as well as to the Yagi article mentioned above for such information.

A Yagi antenna system is a curtain array in which successive currents are made equal and opposite and spaced $\frac{1}{2} \lambda$ apart, and thus, under these conditions, the field tends toward zero along the normal to the curtain and N times that of one current in the plane of the curtain. In this respect the array of Fig. 1 is no different from any other Yagi array. However, in the usual Yagi array, conductor dissipation limits the directivity and gain obtainable. In order to reduce such conductor dissipation, the driven element 11 has been given a laminated structure as shown in Figs. 1, 2 and 3. As taught in the above-mentioned Clogston application, laminated structures in which the metal laminations thereof are made very small compared to the factor δ (skin depth), and in which the size and dielectric material between and around the metal laminations is chosen to give the appropriate velocity of propagation of waves in the

structure, have a much smaller power loss than solid structures of the same dimensions since the currents penetrate more deeply into the material instead of traveling near the surface thereof.

The member 11, as shown in Fig. 3, comprises a central core 20 (of metal or of dielectric material but which by way of example has been shown as metallic), a multiplicity of metallic laminations 21 which are made very thin compared to the factor δ , a multiplicity of insulating laminae 22 between the conductors, and an outer sheath 23 of dielectric material. Suitable materials for example, are: laminations 21—copper, silver or aluminum; laminations 22—polyethylene, polystyrene, quartz or polyfoam; sheath 23—an appropriate thickness of high dielectric constant material such as titanium dioxide. The laminated conductor is proportioned so that the optimum overall dielectric constant for the surrounding medium is not much greater than that of free space (perhaps one percent to 100 percent greater), the relative dielectric constant of the insulation 22 between metallic laminae 21 is made nearly unity and preferably the laminae 21 are made thin compared to the thickness of insulation 22.

The use of a laminated conductor as a driven element in the array also makes possible an effective impedance match between the transmission line 30, 30 feeding the member 11 and the array 10. In the usual Yagi array employing solid conductors either half wave dipoles as in Fig. 4 or folded dipoles as in Fig. 5 are used. The center impedance or feed point impedance of a half wave dipole is of the order of 75 ohms. In the folded dipole, the center impedance is approximately 300 ohms or four times the impedance exhibited by the straight dipole. Thus, assuming there is an equal division of current between the elements, the impedance changes as the square of the number of elements in the dipole. When the dipoles are replaced by laminated structures as in Fig. 2, the center impedance of the element 11 can be varied by changing the number of elements that are fed, leaving the remaining layers in parallel. Thus in Fig. 2, the central member 20A includes the core 20 and a number of layers 21 and 22. The plates 31 connect the laminations 21 not in the central member 20A to the transmission line 30, 30. This impedance matching is very important in Yagi arrays since the impedance looking into the array from the transmission line is varied as the number of elements in the array is changed.

Fig. 6 shows a modification of the arrangement of Fig. 1. In the array 10A of Fig. 6, the director elements 12A, 13A, 14A and 15A correspond to members 12, 13, 14, and 15 respectively in Fig. 1 except that in Fig. 6 the directors are laminated conductors instead of solid ones. Moreover, if desired, the reflector (16A) can also be laminated. The structures of the members 12A to 16A, inclusive, can be like the element 11 (except that there is no cutout portion in the center as in the member 11). This construction reduces substantially the radio frequency resistance.

In all the laminated structures of the arrays of Figs. 1 and 6, the materials and the thicknesses of the various layers are chosen so that the velocity of propagation of waves in the conductor is of the proper value to permit maximum penetration of currents and fields therein, as taught in the above-mentioned Clogston application and as explained in greater mathematical detail in the article "Reduction of skin effect losses by the use of laminated conductors," by A. M. Clogston, Bell System Technical Journal, volume 30, No. 3, July 1951, pages 491 to 529, inclusive.

It is to be understood that the above-described arrangements are illustrative of the principles of the invention.

Numerous other arrangements can be devised by those skilled in the art without departing from the spirit of the invention.

What is claimed is:

1. In a directional antenna array, a driven element and a director element, said driven element comprising a pair of composite conductors, each comprising a multiplicity of very thin metal films separated by insulating material and said composite conductors being spaced around different portions of a common axis, and means for applying signals to said two composite conductors at the ends thereof at which they are adjacent one another, said last-mentioned means comprising conducting means for making contact with a plurality of said metal films.
2. In combination, an elongated laminated conductor comprising a multiplicity of very thin metal layers separated by insulating material, the thin dimension of said layers being at right angles to the longitudinal axis of said conductor, and means for applying a signal to a fraction only of the total number of said metal layers at at least one point on each layer.
3. The combination as in claim 2 in which each of said metal layers is in the form of a cylinder.
4. In a directional antenna array, a driven element and a director element, said driven element comprising an elongated laminated conductor comprising a multiplicity of very thin metal layers separated by insulating material, the thin dimension of said layers being at right angles to the longitudinal axis of said conductor, and means for applying a signal to a fraction only of the total number of said metal layers.
5. In a directional antenna array, a driven element, a reflecting element, and a multiplicity of director elements, the axes of which are parallel to one another and are spaced apart coplanar with the axes of the driven element and the reflector element, said driven element comprising an elongated laminated conductor comprising a multiplicity of very thin metal layers separated by insulating material, the thin dimension of said layers being at right angles to the longitudinal axis of said conductor, and means for applying a signal to a fraction only of the total number of said metal layers.
6. In a directional antenna array, the combination of elements as claimed in claim 5 wherein each of said elements comprises a composite conductor.
7. In combination, an elongated laminated conductor comprising a multiplicity of very thin metal layers separated by insulating material, the thin dimension of said layers being at right angles to the longitudinal axis of said conductor, said conductor being coated with a dielectric material of high dielectric constant, and means for applying a signal to a fraction only of the total number of said metal layers.
8. In a directional antenna array, a driven element and a director element, said driven element comprising an elongated laminated conductor comprising a multiplicity of very thin metal layers separated by insulating material, the thin dimension of said layers being at right angles to the longitudinal axis of said conductor, said conductor being coated with a dielectric material of high dielectric constant, and means for applying a signal to a fraction only of the total number of said metal layers.

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