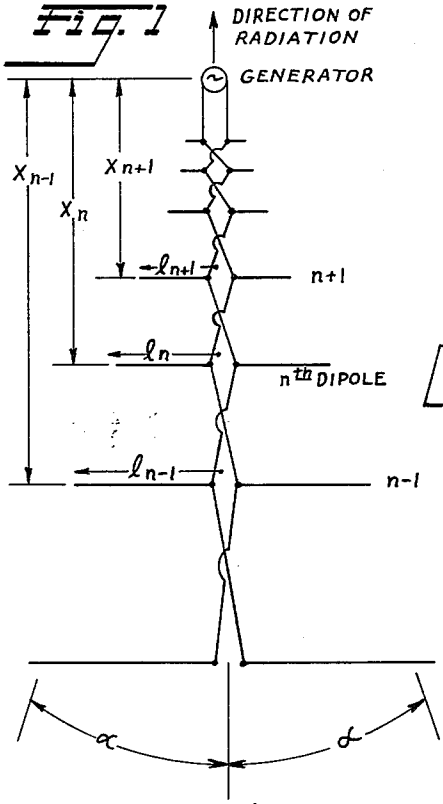
Nov. 5, 1963 E. B. COLE, JR 3,110,030

CONE MOUNTED LOGARITHMIC DIPOLE ARRAY ANTENNA

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Fig. 1



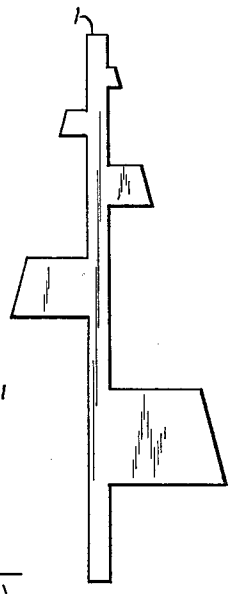


Fig. 2A

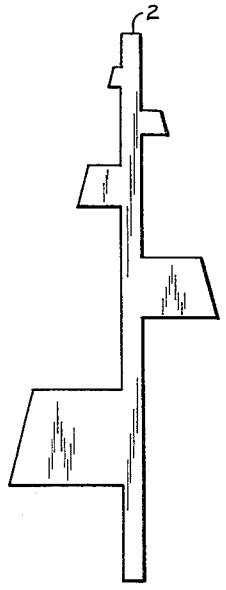


Fig. 2B

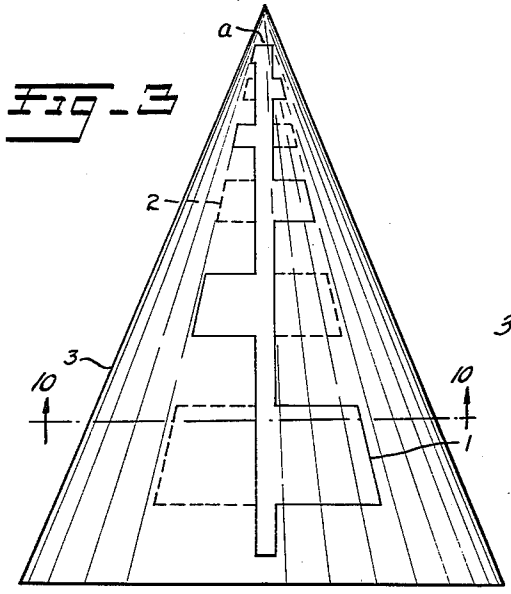


Fig. 3

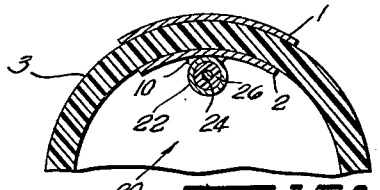


Fig. 10A

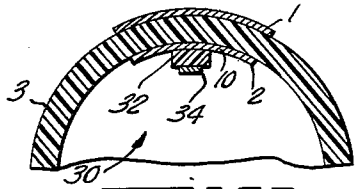


Fig. 10B

ANTENNA MOUNTED ON DIELECTRIC HEAD

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CONE MOUNTED LOGARITHMIC DIPOLE ARRAY ANTENNA

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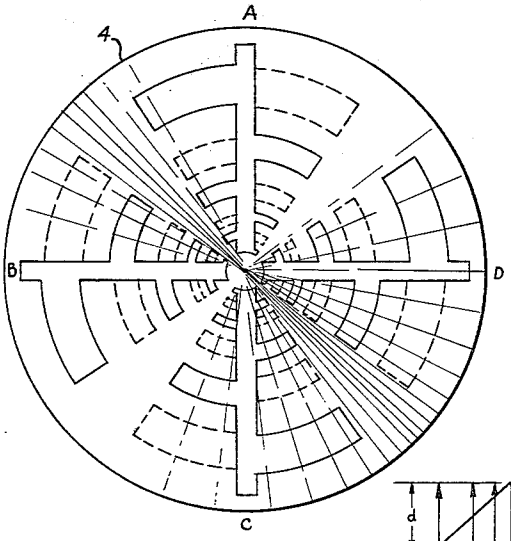
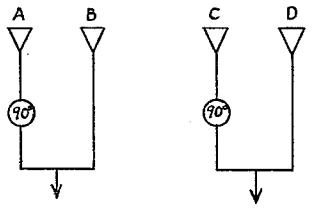


Fig. 4

Fig. 5



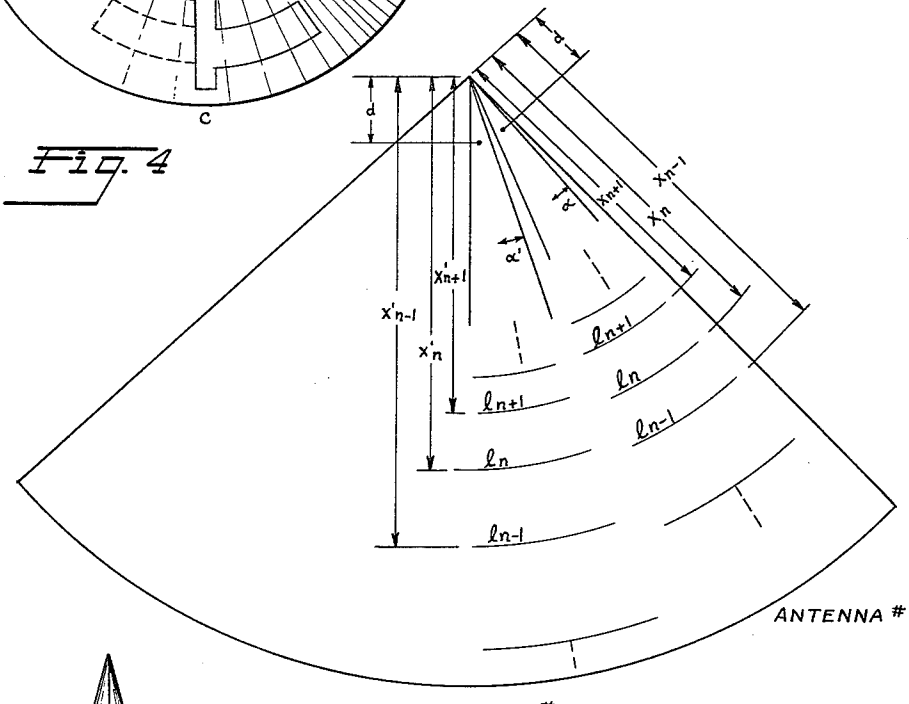


Fig. 6B

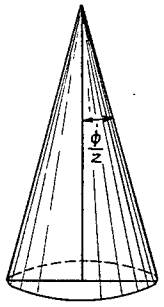


Fig. 6A

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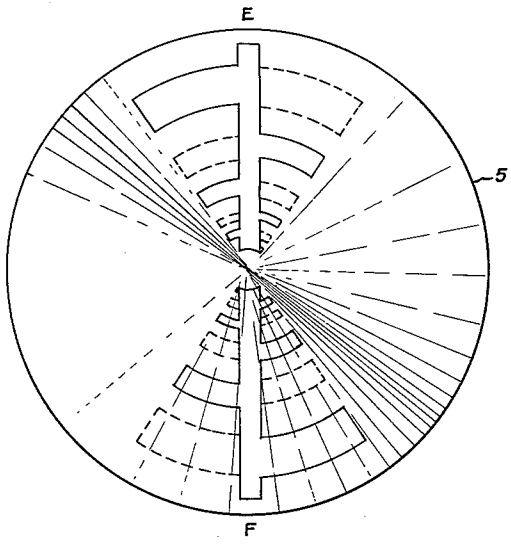


Fig. 7

Fig. 8

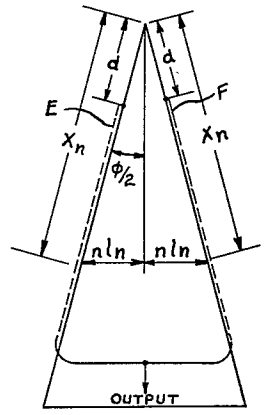
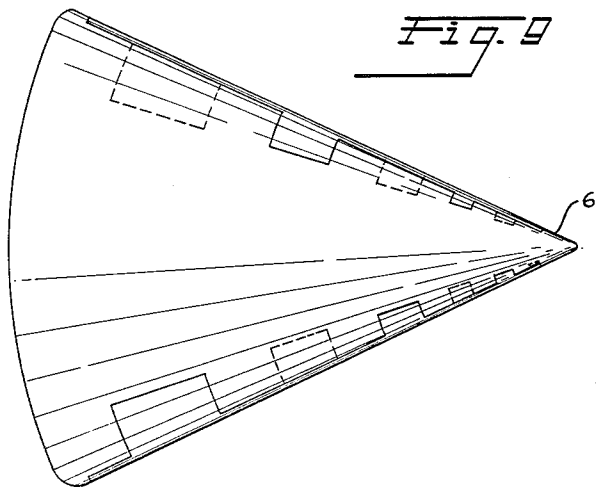


Fig. 9



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United States Patent Office 3,110,030 Patented Nov. 5, 1963

3,110,030

CONE MOUNTED LOGARITHMIC DIPOLE ARRAY ANTENNA

Elwood B. Cole, Jr., Baltimore, Md., assignor to Martin-Marietta Corporation, a corporation of Maryland

Filed May 25, 1961, Ser. No. 112,690
6 Claims. (Cl. 343—792.5)

The present invention relates to antenna units for use on an aerodynamic vehicle. More particularly, the invention relates to dipole array antennae which are integrally formed with a tapered conical surface of an aerodynamic vehicle so as to form a composite unit which does not impair the aerodynamic characteristics of the vehicle.

It is an object of the present invention to provide antennae which are specially adapted to be structurally associated with an aerodynamic vehicle, such as, for example, a guided missile.

It is a further object of this invention to provide antennae which are supplied by a transmission line utilizing an aerodynamic dielectric cone wall as a part thereof.

It is a more specific object of this invention to provide electrically balanced antennae which are formed by bonding symmetrical halves in juxtaposed relation to opposite sides of an aerodynamic cone wall of dielectric material.

It is an additional object of this invention to provide antennae which produce a directional beam toward the apex of an aerodynamic nose cone.

It is also an object of a modified embodiment of this invention to provide antennae which produce circular polarization along the axis of an aerodynamic vehicle.

A still further object, achieved by a further modified embodiment of this invention, is to provide antennae connected to produce a constant monopulse or interferometer response over a wide band of frequencies.

Previous directional antennae intended to produce broad axial radiation coverage in association with aerodynamic vehicles have employed either antenna elements such as, for example, phased slots arranged on the external surface of the vehicle or directional elements such as, for example, dipole arrays housed within the vehicle and aligned with the vehicle axis installed behind a transparent radome. The slot solution requires a multiplicity of antennas and is somewhat wasteful of energy in directions other than those desired. The second example occupies substantial internal volume and is subject to certain electrical errors caused by reflections from the surfaces of the radome. Either example is effective only over a narrow band of frequencies.

Such difficulties are obviated by the present invention which provides a frequency independent antenna which is formed with a series variable width, flat strips which are contoured to conform to the surface of a cone. The antenna is formed from two symmetrical halves fed by a transmission line in such a way that the problems of flection and conservation of space are minimized. The individual antenna dipoles are broadened in order to make the response of a given element at a particulary frequency less susceptible to variation. The dipoles are connected together to produce the phase shift necessary for the operation of antennae such as those disclosed herein.

The present invention will be more fully understood by reference to the drawings and the accompanying detailed description in which:

FIG. 1 illustrates the geometry and basic parameters of logarithmic periodic dipole array antennae;

FIGS. 2*a* and 2*b* are plan drawings of symmetrical flat elements of a modified logarithmic periodic dipole array antennae forming a part of the subject invention;

FIG. 3 illustrates the preferred embodiment of this invention wherein an aerodynamic nose cone is illustrated

in side elevation with the applied elements shown in solid and dotted line;

FIG. 4 is an elevational view of an aerodynamic nose cone as viewed from the apex with antennae associated therewith constituting a second embodiment of this invention;

FIG. 5 illustrates schematically the supply circuitry for the antennae of FIG. 4;

FIG. 6*a* is a perspective view of a right circular cone which forms the basis for a geometrical and parametrical analysis of the antenna of FIG. 4;

FIG. 6*b* is a flat development of the cone of FIG. 6*a*;

FIG. 7 is an elevational view of an aerodynamic nose cone as viewed from the apex with antennae mounted thereon constituting a third embodiment of this invention;

FIG. 8 is a side elevational view of a cone corresponding to the cone of FIG. 7; and

FIG. 9 is a perspective view of an aerodynamic nose cone with its associated antennae.

FIG. 10A is a cross-section taken along line 10—10 of FIG. 3 showing details of the transmission line of the present invention.

FIG. 10B is a cross-section taken along line 10—10 of FIG. 3 depicting an alternate form of the transmission line of the present invention.

Referring now to FIG. 1, dipoles $n-1$, n, $n+1$, etc. represent the dipoles of a logarithmic periodic dipole array antenna. The n^{th} dipole of this array has a length of l_n and lies distance of x_n from the apex of the triangular envelope. The remainder of the dipoles have lengths of l_{n+1}, l_{n-1}, etc. and are a distance of x_{n+1}, x_{n-1}, etc. from the apex. The lengths of the respective dipoles increase as the distance between each of the dipoles and the apex increases. In this manner, the tips of the dipoles lie along straight lines extending from the apex to the opposite end of the array. With such an arrangement, the two imaginary lines formed by the dipole tips form equal included angles α with the array axis. In addition, there is a 180 degree phase transposition in the balanced transmission line between adjacent dipoles. This latter function is necessary to create end-fire radiation in the direction indicated. End-fire radiation is well-known in the are and relates to radiation along the axis of an antenna array.

With further regard to FIG. 1 and in view of the above discussion, the following relationship holds true:

$$\frac{l_n}{x_n}=\tan\alpha$$

The following definition has been established for convenience:

$$\frac{l_{n+1}}{l_n}=\frac{x_{n+1}}{x_n}=\tau$$

Therefore, any logarithmic periodic dipole array antenna exhibits constant τ and α. Each of the dipoles may be considered to resonate at a single frequency and the device is essentially frequency independent as τ approaches unity. Each successive dipole in the antenna array is resonant at a slightly higher frequency than the preceding dipole. At any given frequency, the non-resonant dipoles act as directors and reflectors and thereby increase directivity. That is, the radiation of the antenna array as a whole is beamed along the antenna longitudinal axis. Accordingly, for a fixed value of τ, it then becomes apparent that the operating band-width of the antenna is primarily a function of the number of dipoles used.

The symmetrical antenna elements of FIGS. 2*a* and 2*b* illustrate the antenna design in conformity with the theory discussed above. Considering either of these figures, there is shown a longitudinally extending relatively narrow strip 1 or 2 each of which is provided with a longitudinal-

ly spaced series of laterally offstanding half-dipoles of progressively shorter length from bottom to the top thereof. The corresponding half-dipoles of each of the antenna elements are of equal size and the tips thereof form equal and opposite angles in relation to their respective longitudinally extending supporting strip.

In order to form an antenna constituting the first preferred embodiment of this invention, the symmetrical elements **1** and **2** are suitably attached to a dielectric cone **3** as best shown in FIG. 3. In this view, the symmetrical elements **1** and **2** are arranged in aligned pairs with the narrow strips extending longitudinally of the cone externally and internally thereof, respectively, each of said strips being provided with a longitudinally spaced series of laterally offstanding half-dipoles of progressively shorter length from the base toward the apex of the cone. In addition, this strip arrangement conforms to the tapered surface of the cone. The half-dipoles of the elements are in relative staggered relation. The dipoles of the resulting antenna array are supplied by an electrically balanced transmission line consisting of the two longitudinally extending supporting strips and the dielectric cone wall. This transmission line is, in turn, energized by either a conventional unbalanced coaxial cable or a strip line. In FIGURE 10A is shown a coaxial cable **20** having a shield **22**, a center conductor **24** and an insulating dielectric **26** therebetween, utilized as an energizing feed line. The shield is soldered or otherwise suitably bonded to the longitudinally extending support strip **10** of the antenna element designated as **2** which is bonded to the interior surface of cone **3**. The coaxial center conductor extends through the cone wall adjacent to the apex thereof and is soldered to antenna half **1** at the point *a*. An alternate means for energizing the integral electrically balanced transmission line is shown in FIGURE 10B. Here, a strip transmission line **30** is depicted wherein the interior longitudinal support strip **10** of the antenna element **2** is utilized as a flat ground strip. Bonded to the strip **10** is a strip of insulating dielectric **32** to which is bonded a narrow conducting strip **34**. This narrow conducting strip is coupled, through the cone wall adjacent to the apex thereof, to the antenna half at the point *a*. The 180 degree phase transposition between the adjacent dipoles necessary for end-fire radiation is achieved by feeding each successive dipole from opposite sides of the feed line. The end-fire radiation of the antenna array produces a directional beam projected toward the dielectric cone apex, with negligible radiation in the opposite direction. Accordingly, it will be appreciated that an aerodynamically clean integral nose cone-antenna structure has been achieved.

The second embodiment of this invention is exemplified by the structure shown in FIG. 4. In this modification, antenna arrays A, B, C and D are arranged in space quadrature on missile cone **4**. Each of these arrays is similar to the array formed by antenna elements **1** and **2** shown in FIG. 3 and previously described. These antenna arrays are end-fire devices which are installed on the surface of a missile cone. Antenna arrays A and B combine to form one composite antenna array while antenna arrays C and D combine to form a second composite antenna array. Each of the two arrays, A and B, for instance, is responsive to linear polarization in the plane of the dipoles. As noted hereinbefore, each of the two arrays is mounted on adjacent quadrants of the supporting cone **4** to provide a response to two orthogonal linear polarizations. Because of the design difference, any dipole of array A, for instance, will lead by 90 degrees in electrical phase the corresponding dipole of array B, for electromagnetic energy arriving at the composite array from a direction along or near the cone axis. Arrays C and D are mounted on the two remaining quadrants of the cone and function in the same manner as arrays A and B to form a second composite antenna array. The individual array outputs, e.g., A and B, differing in electrical

phase by 90 degrees, are combined in a common output such as that shown in FIG. 5. It will now be recognized by those conversant with the art to which this invention pertains, that the requirements of time and space quadrature have been fulfilled and each composite array will respond optimally to circularly polarized signals of the same sense of circular polarization arriving from an axial direction. The geometrical displays of FIGS. 6*a* and 6*b* illustrate the above functions of this modification. The dipoles of arrays A and B (FIG. 4), for instance, are of equal length and yet the position of a particular dipole of array B lags by 90 degrees in electrical phase behind the corresponding dipole of array A, at the frequency at which the particular dipole is responsive. Therefore, at a given frequency within the antenna band, the common output is fed quadrative voltages from two orthogonally oriented antenna elements. The following relationship holds true with respect to FIGS. 6*a* and 6*b*:

$$x'_n = x_n + \frac{l_n}{\cos\frac{\phi}{2} + \sqrt{\epsilon}(1-d)}$$

where ϵ=relative dielectric constant of transmission line dielectric material.

The third embodiment of the present invention is illustrated in FIG. 7. FIG. 8 provides a graphic study of the theoretical explanation of the antenna function of this embodiment of the invention. Two identical arrays, E and F, are mounted in a diametrically opposed relation on a dielectric cone **5**. The antennas may be either linearly or circularly polarized according to the first and second modifications of this invention, respectively. The arrays are connected so as to produce a monopulse or interferometer response in the plane containing the axes of the two arrays.

The monopulse pattern is due to both phase and amplitude differences, and it is taken at the carrier frequency level by adding the two antenna signals through equal lengths of transmission line at a common junction. Since one array is physically out of phase to incoming energy with respect to the other array, the addition of out-of-phase signals at the common junction is effectively subtractive. If

E'=angular field strength response of array E in the monopulse plane,

F'=angular field strength response of array F in the monopulse plane,

d=physical spacing between corresponding dipoles,

λ=wavelength, and

θ=angle of wave front arrival in the monopulse plane measured from the cone axis, then

$$\text{Monopulse response} = E'^2 + F'^2 - 2E'F' \cos(2\pi d/\lambda \sin\theta)$$

Since the array patterns E' and F' are similar in shape, but offset in opposite directions from the cone axis due to the slope of the cone, the pattern crossover occurs along the cone axis and the null of the monopulse pattern is aligned with the cone axis.

If E' and F' remain constant over a wide frequency range (a basic property of the logarithmic periodic dipole array), and d/λ remains constant, the same monopulse pattern can be maintained over that range. It is, therefore, only necessary that $\sin\theta/2 = n \tan\alpha$ for d/λ to remain constant over the frequency range. According to FIG. 8:

$$\frac{nl_n}{x_n} = \sin\phi/2$$

$$\frac{l_n}{x_n} = \tan\alpha$$

Therefore,

$$\sin\phi/2 = n\tan\alpha$$

where,

ϕ=total included cone angle,
α=antenna parameter shown in FIG. 1, and
n=number of half-wavelength spacings desired at all frequencies.

It thus appears that a wide band constant monopulse pattern response has been provided. It would, of course, be possible to utilize a dual plane monopulse configuration with the addition of a second pair of arrays similar to E and F and lying in a plane perpendicular to the plane containing antenna E and F. This second pair of arrays would function in the same manner as antennae E and F to produce a second monopulse pattern.

While particular embodiments of the present invention have been illustrated, it should be clearly understood that it is not limited thereto since many modofiications may be made in the several elements employed and in their arrangement and it is contemplated by the appended claims to cover any such modifications as fall within the spirit and scope of the invention.

I claim:

1. An aerodynamic vehicle broad frequency band antenna assembly comprising a hollow dielectric cone with inner and outer surfaces, first, second, third and fourth logarithmic periodic dipole array antennas, each of said arrays being disposed at spaced quadrature points on said cone, each of said arrays comprising first and second symmetrical elements, said first element of each array being mounted on said inner surface and said second element being mounted on said outer surface, an integral electrically balanced transmission line utilizing said cone wall as a part thereof common to said first and second symmetrical elements, said first and second elements constituting each of four said logarithmic periodic dipole array antennas.

2. A broad frequency band antenna assembly is described in claim 1 wherein each dipole of said second array lags in electrical phase each corresponding dipole of said first array and, further, wherein each dipole of said fourth array lags in electrical phase each corresponding dipole of each third array, a feed network for said first and second arrays constituting a composite array, a feed network for said third and fourth arrays constituting a second composite array, whereby the said composite antenna arrays function to produce a circular polarization response along the longitudinal axis of said cone.

3. An aerodynamic vehicle broad frequency band antenna assembly comprising a hollow dielectric cone with inner and outer surfaces, first and second symmetrical logarithmic periodic dipole array antennas, said arrays being disposed diametrically opposite on said cone, each of said arrays comprising first and second symmetrical dipole arrangements, said first dipole arrangement of each array being mounted on said inner surface and said second dipole arrangement being mounted on said outer surface, integral electrically balanced transmission lines common to each of said first and second arrays.

4. A broad frequency band antenna assembly as described in claim 3, wherein said first antenna array is connected in and out of phase arrangement with said second antenna array and, further, wherein the combined function of said arrays produces a constant monopulse or interferometer pattern.

5. An aerodynamic vehicle broad frequency band antenna assembly comprising a hollow dielectric cone with inner and outer surfaces, first and second symmetrical elements of a logarithmic periodic dipole array antenna, said antenna elements each comprising a plurality of parallel, closely spaced, half-dipoles which are mounted on a supporting strip and which extend from either side of said strip in a uniform staggered arrangement, said antenna elements further constituting an arrangement wherein each successive half-dipole is progressively larger as the distance from the apex of said cone to a particular one of said half-dipoles increases, said plurality of oppositely disposed half-dipoles having tips which form a pair of lines on either side of said supporting strip with the included angles formed by said lines and by said supporting strip being equal, said first antenna element being mounted on said inner surface and said second element being mounted on said outer surface, an integral electrically balanced transmission line consisting of said first and second supporting strips and said dielectric cone as parts thereof, supported by said inner and outer surfaces respectively and connected to said first and second elements for transmitting a flow of electrical energy to and from said elements which together constitute a logarithmic periodic dipole array antenna, said transmission line being energized by a coaxial cable, said coaxial cable including a shield, a center conductor, and an insulating dielectric, said shield being bonded to said first supporting strip, and said center conductor being bonded to said second supporting strip.

6. An aerodynamic vehicle broad frequency band antenna assembly comprising a hollow dielectric cone with inner and outer surfaces, first and second symmetrical elements of a logarithmic periodic dipole array antenna, said antenna elements each comprising a plurality of parallel, closely spaced, half-dipoles which are mounted on a supporting strip and which extend from either side of said strip in a uniform staggered arrangement, said antenna elements further constituting an arrangement wherein each successive half-dipole is progressively larger as the distance from the apex of said cone to a particular one of said half-dipoles increases, said plurality of oppositely disposed half-dipoles having tips which form a pair of lines on either side of said supporting strip with the included angles formed by said lines and by said supporting strip being equal, said first antenna element being mounted on said inner surface and said second element being mounted on said outer surface, an integral electrically balanced transmission line consisting of said first and second supporting strips and said dielectric cone as parts thereof, supported by said inner and outer surfaces respectively and connected to said first and second elements for transmitting a flow of electric energy to and from said elements which together constitute a logarithmic periodic dipole array antenna, said transmission line being energized by a strip transmission line, said strip transmission line constituting a flat ground strip, a narrow conducting strip and an insulating dielectric, said flat ground strip being the same as said first supporting strip and said narrow conducting strip being bonded to said second supporting strip.

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