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SPHERICAL REFLECTOR WITH LENS TO CONVERT TO PARABOLIC SURFACE

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EQUIVALENT PARABOLIC
REFLECTING SURFACE
 $F/D = 0.35$

FIG. 2.

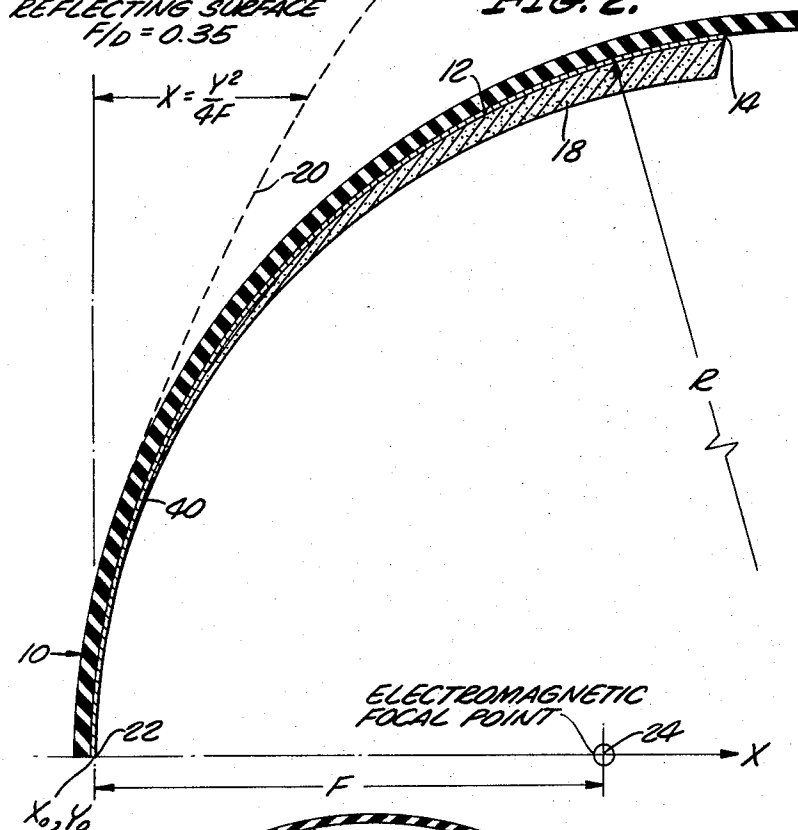


FIG. 1.

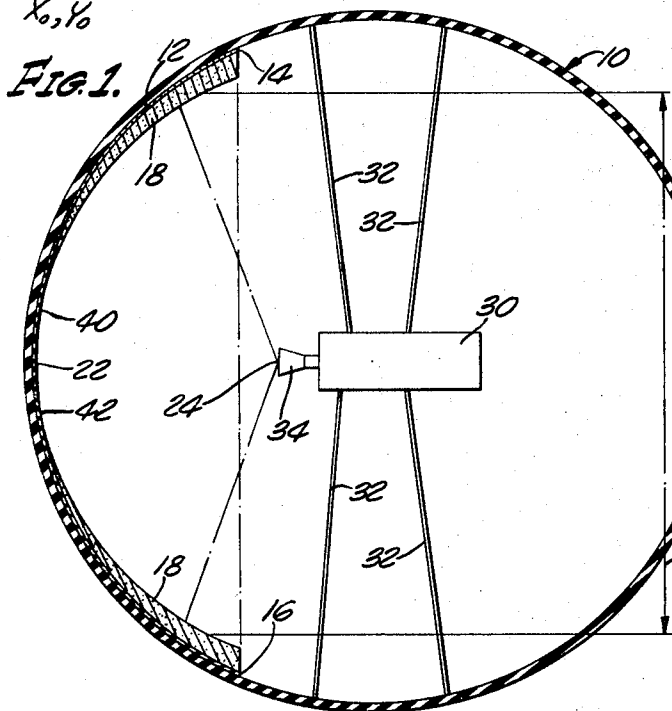
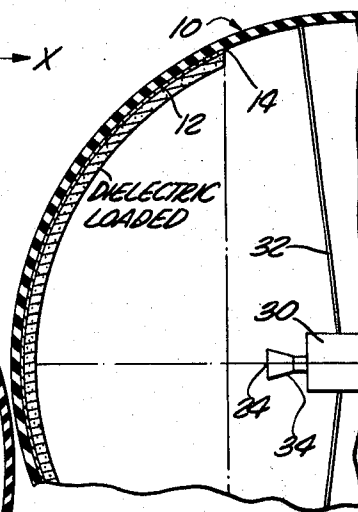


FIG. 3.



WAVE FRONT

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ABSTRACT OF THE DISCLOSURE

A spherical shell of elastic dielectric material has a portion of its internal surface coated with a thin metallic spherical shaped reflecting coating which in turn is coated with an elastic dielectric material such that in effect a parabolic reflecting surface results. The entire assembly may be compacted into a small space and when the compacting forces thereon are released as, for example, in outer space the elasticity of the dielectric materials causes the assembly to assume its normal spherical appearance and capability of serving as a parabolic antenna.

The present invention relates to improvements in antenna construction and is particularly useful in the attainment of a reflecting surface for microwave frequencies in space environment.

Briefly, the construction described herein involves a spherical shell of elastic material with an inner surface portion of the shell being provided with a reflecting surface over which a dielectric material is coated such that such dielectric coating in effect, changes the spherical reflecting surface to an equivalent parabolic reflecting surface. Such spherical shell is of a material which is essentially transparent for electromagnetic waves at the frequency of operation of the antenna. Such material is preferably an elastic foam material as is also the dielectric coating whereby the composite antenna structure, so defined, is elastic and may be compacted to occupy a relatively small storage space when not in use and which may automatically self-expand (upon release of compacting forces) to its operating condition.

It is therefore a general object of the present invention to provide an antenna construction of this general character.

A specific object of the present invention is to provide an antenna which may be packaged into a small volume for purposes of space transportation and yet which may be deployed in a space environment into a semi-rigid operable condition.

Another specific object of the present invention is to provide means and techniques whereby in effect a spherical reflecting antenna surface may be converted into a parabolic reflecting antenna surface, the same being accomplished in general by providing various means of radiation phase front correction or retardation.

Another specific object of the present invention is to provide an antenna of this character which is enclosed in an expandable space radome structure such that solar environmental conditions may be controlled.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. This invention itself, both as to its organization and manner of operation, together with further objects and advantages thereof, may be best understood by reference to the following description taken in connection with the accompanying drawings in which:

FIGURE 1 is essentially a transverse sectional view of an antenna embodying features of the present invention.

FIGURE 2 demonstrates in enlarged form a portion

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of the antenna shown in FIGURE 1 together with various mathematical relationships.

FIGURE 3 is a view similar to that illustrated in FIGURE 2 but of an alternative construction.

As illustrated in FIG. 1 the antenna is essentially spherical in outward appearance and is defined by a spherical shell 10 preferably of elastic material such as, for example, foam material, such material being transparent at those frequencies of electromagnetic waves energy which is either received or transmitted by the composite antenna structure.

A portion of the inner surface of the shell 10 is coated with a metallized reflector surface 12, such surface defining a portion of a sphere of the same internal radius as the shell 10; and such reflecting surface is illustrated as extending between the points 14 and 16 in FIGURE 1.

This reflecting surface 12 is a thin coating which may be applied as, for example, by metal spraying an internal portion of the shell 10 or by affixing thereto as, for example, by cement, a thin layer of metal foil.

Coated on the reflector surface 12 is a dielectric material 18 which is preferably flexible plastic foam material.

The purpose of this foam material 18 is to introduce a delay in the transmission of electromagnetic wave energy such that incremental portions of the reflecting surface 12, in effect, are displaced rearwardly to the left as indicated in FIG. 2 to form an equivalent reflecting surface 20 which is parabolic.

In accordance with the relations set forth also in FIG. 2 wherein R is the internal radius of the shell 10 and also the radius of the reflector 12; the distance F is the focal distance of the parabolic reflector 20 and is measured from the 0,0 coordinate 22 to the electromagnetic focal point 24 of the parabolic reflector 20. In the example illustrated, the ratio of F/D is equal to 0.35 where D is the diameter of the actual reflector 12. The equation for the parabola 20 may thus be defined by the equation $x=y^2/4F$.

FIG. 1 illustrates also electronic and positioning equipment 30 supported by guy wires 32 an internal portion of the shell 10. The positioning equipment 30 serves to position and maintain the horn structure 34 at the focal point 24 in essentially a Newtonian type antenna arrangement.

It will be evident to one skilled in the art that the antenna arrangement instead of being of the Newtonian type may be of any other particular desired type as, for example, of the Cassegrain type in which latter case a hyperbolic reflector may be supported internally of the shell 10 by guy wires of dielectric material and the antenna feed may be located also inside of the shell 10 in a Cassegrain configuration.

Because the effective reflecting surface is parabolic, i.e., transformed from a spherical reflecting surface into a parabolic reflecting surface, the wavefront from the antenna as indicated in FIG. 1 is perpendicular to the axis of the parabola.

This conversion of a spherical surface into a paraboloid is primarily electromagnetic in nature and is accomplished by the application of dielectric materials.

It is well known that a dielectric material retards an electromagnetic wave passing through it, and has an index of refraction defined as the square root of the material's dielectric constant. This material causes a modification of phase. In other words the dielectric material retards the phase front of electromagnetic radiation in an amount depending upon its thickness. As illustrated in FIGS. 1 and 2, a central portion extending between the points 40 and 42 need not be covered with the dielectric material since in that central region the spherical reflector surface and the desired effective parabolic reflector surface are essentially coincident. Indeed

with a ratio of F/D of 0.225, the parabolic curve and the curve of constant radius are coincident over substantially 60% of the radial y coordinate. This means that for a 10 foot diameter sphere, a six foot diameter area of the sphere could be used as a parabolic reflector when the ratio of F/D is equal to 0.225.

This ratio decreases when the F/D ratio is increased to, for example, 0.35 as illustrated in FIG. 2.

In FIG. 2 the dielectric material 13 is gradiently applied to the inner surface of the reflector 12 and continuously increases in thickness as the spacing of the spherical reflector from the $x-x$ axis increases in the y coordinate. The physical thickness of the dielectric d , is related to the electrical thickness, ϕ , in one way wave or ray traversal in accordance with the following equation:

$$\phi = \frac{2\pi d}{\lambda_0} \sqrt{\frac{\epsilon'}{\epsilon_0}} \sin^2 \theta$$

where:

λ_0 is the electromagnetic free space wavelength
 ϵ'/ϵ_0 is the complex dielectric constant of the medium
 θ = the angle of electromagnetic incidence

Using this equation and considering also the geometry of the spherical reflecting surface and also Snell's law which defines the optical path through the material in terms of its refractive index, one is able to trace various rays so that they all have the same phase, i.e., are delayed in the required amount at the time they reach the plane wavefront indicated in FIG. 2.

FIG. 2 indicates that there is an apparent element of magnification in that the actual spherical reflector diameter is less than the equivalent parabolic reflector as described by the electromagnetic ray path. This, however, cannot be regarded as a gain since the projected aperture at a certain dissipation factor of the dielectric material must be taken into consideration.

Since the ray correcting refractive medium is a dielectric material, it possesses some value of attenuation due to the dissipation factor which, in plastic foam and titanate materials, is usually quite small. The power lost by dissipation is considered to have only minor effect upon antenna gain or directivity.

In the arrangement shown in FIG. 2 the foam material used to impart a delay is a homogeneous material and hence its thickness increases, the material being thicker, the greater its displacement from the $x-x$ axis. Instead of using a homogeneous material the same may be loaded with an element which has a very high dielectric constant and low dissipation factor such as barium titanate. In this case the dielectric loading is such that the layer may be constant in thickness but yet there is a resultant dielectric constant which is the product of the ratio of dielectrics per unit volume so as to obtain the same result as in FIG. 2, i.e., a greater delay at locations further from the $x-x$ axis. This is illustrated in FIG. 3 wherein the dielectric material is illustrated as being of constant thickness and with the same being loaded in different amounts with barium titanate as described above.

Many advantages result from the fact that the antenna is spherical in shape and is of flexible material.

The entire spherical radome structure and the equivalent parabolic reflector can be made flexible and therefore collapsible for efficient packaging. When the packaged antenna structure is released, the elastic memory of the materials expand the sphere into its original shape thus deploying the antenna into its operating condition. To obtain full elastic recovery, a pressurization process may be used to smooth out any creasing and wrinkling of the structural material which might have occurred when in its folded and collapsed state.

Once full memory of the sphere's elastic material has been restored, the spherical structure maintains its spheri-

cal geometry precisely in the space environment following any perforation and depressurization by meteorites. Using flexible plastic foam which has a very low dielectric constant and dissipation factor, and also using flexible plastic laminate skins, which also have a relatively low dielectric constant dissipation factor, the wall of the spherical shell can be constructed to act as a radome which is of course very desirable in this application.

In each of FIGS. 2 and 3 the radiation retarding material is continuously gradated outwardly from the central portion of the actual reflecting surface so as to produce an increasingly greater retardation to radiation the greater the perpendicular distance such retarding material is located from the central axis which passes through such central portion. In FIG. 2 this gradation is accomplished by increasing the thickness and in FIG. 3 is accomplished by having the dielectric constant of the material increase progressively with increase in distance from the $x-x$ axis.

While there has been described what is at present considered the preferred embodiment of the invention, it will be understood that various changes and alterations may be made therein without departing from the essence of the invention and is intended to cover herein all such changes and alterations as come within the true scope and spirit of the annexed claims.

I claim:

1. An antenna structure including a spherical shell of radiation transparent material; said spherical shell having an axis passing through its center; a spherically shaped radiation reflecting surface on an internal portion of said shell and having its central portion intersected by said axis and symmetrically disposed around said axis; said reflecting surface having an area which is not greater than one half of the internal surface area of said shell; radiation retarding material on said reflecting surface and continuously gradated outwardly from said central portion and said axis to produce an increasingly greater retardation to radiation the greater the perpendicular distance such retarding material is located from said axis.

2. An antenna structure as set forth in claim 1 in which said radiation transparent material and said radiation retarding material are elastically deformable to occupy a space substantially less than the volume of said shell upon application of forces radially inwardly to said spherical shell and being capable of returning to its original form upon release of said forces.

3. An antenna structure as set forth in claim 1 in which said radiation retarding material is so gradated that it is substantially homogeneous and has an increasingly greater thickness the greater the perpendicular distance the same is located from said axis.

4. An antenna structure as set forth in claim 1 in which said radiation retarding material is so gradated that it has substantially the same thickness but is non-homogeneous.

5. An antenna structure as set forth in claim 1 in which said material is so gradated that said spherically shaped radiation reflecting surface is transformed effectively into a paraboloid having its focal point lying on said axis.

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ELI LIEBERMAN, Primary Examiner.

U.S. CL. X.R.

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