NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

November 19, 1970

REPLY TO
ATTN OF: GP

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for
Patent Matters

SUBJECT: Announcement of NASA-Owned U. S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code USI, the attached NASA-owned U. S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U. S. Patent No. : 3,521,290

Government or Corporate Employee : U.S. Government

Supplementary Corporate Source (if applicable) : NA.

NASA Patent Case No. : XGS-09190

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:
Yes ☐ No ☒

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of . . ."

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Enclosure
Copy of Patent cited above

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COSATI 22B

July 21, 1970 H. BAHIMAN ET AL 3,521,290

SELF-ERECTING REFLECTOR

Filed June 16, 1967 2 Sheets-Sheet 1

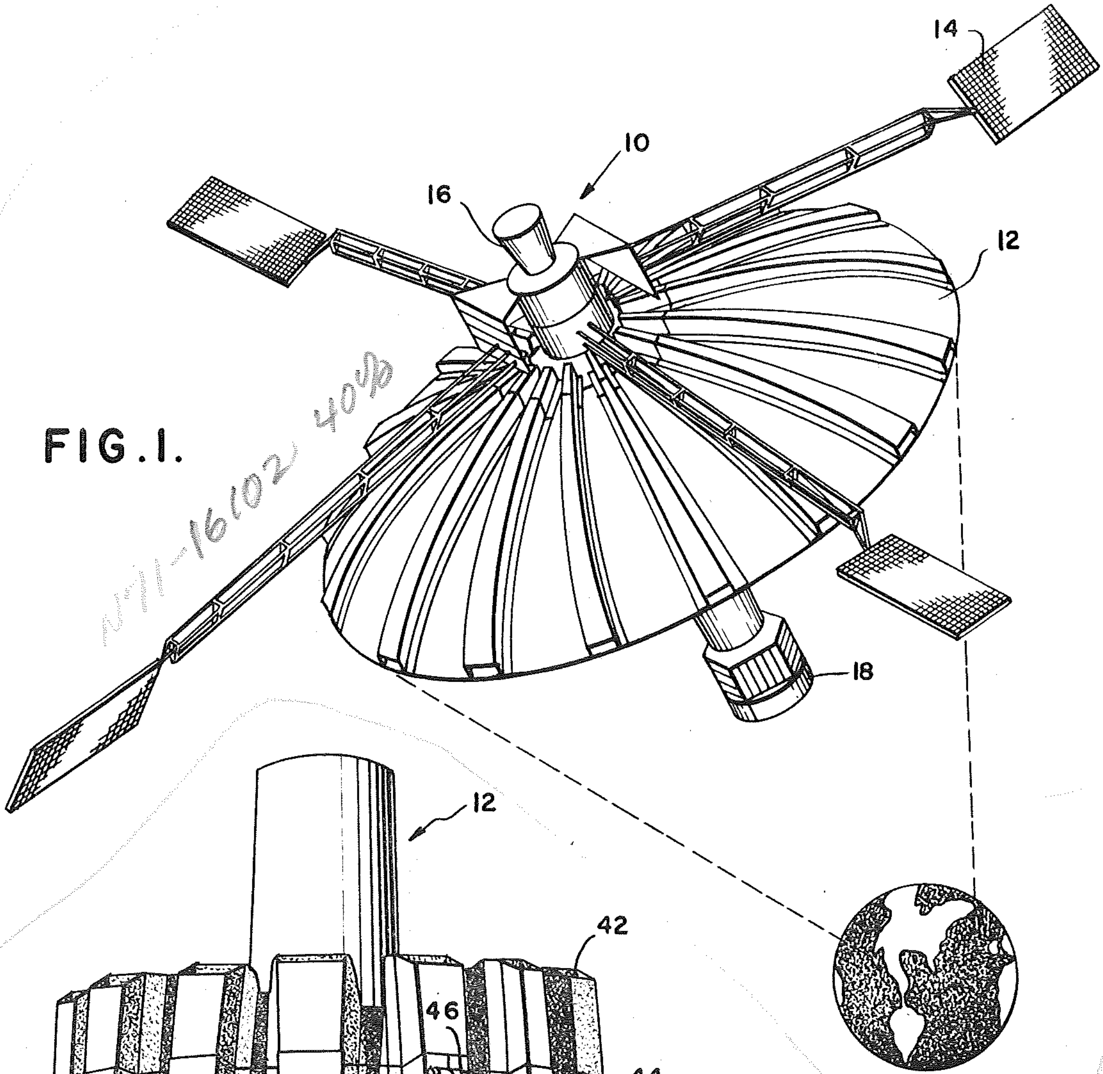

FIG. 1.

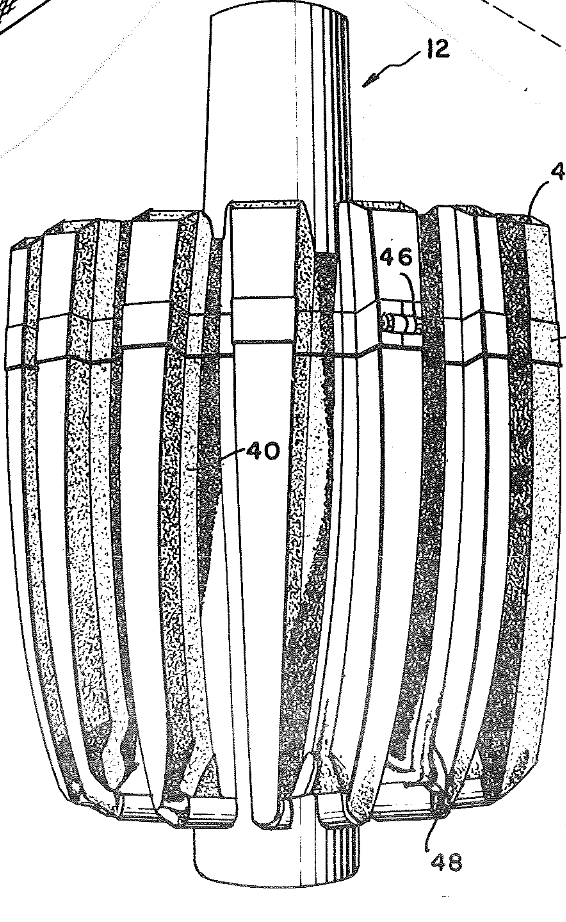

FIG. 5.

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SELF-ERECTING REFLECTOR

Filed June 16, 1967 2 Sheets-Sheet 2

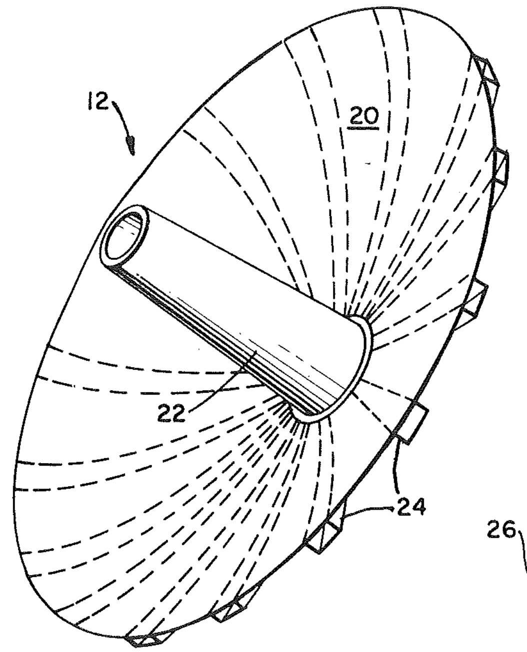

FIG. 2.

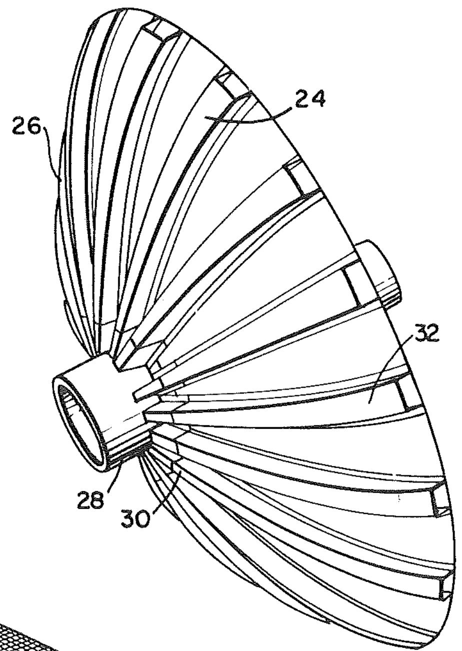

FIG. 3.

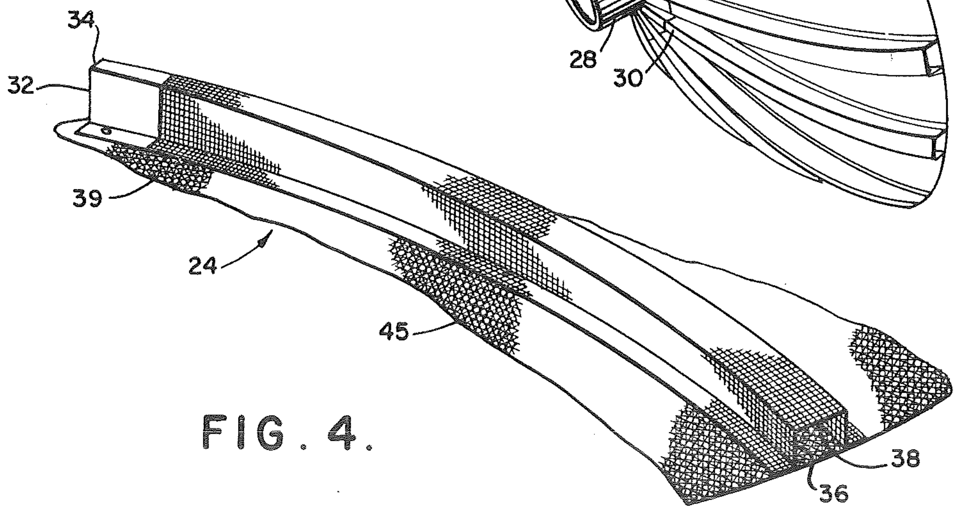

FIG. 4.

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SELF-ERECTING REFLECTOR

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Filed June 16, 1967, Ser. No. 647,298
Int. Cl. H01q 15/20
U.S. Cl. 343—915 6 Claims

ABSTRACT OF THE DISCLOSURE

A collapsible antenna structure having a reflector of a continuous high modulus mesh with a plurality of radially extending mesh ribs integrally attached to the convex side thereof.

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates generally to erectable structures and more particularly to self-erectable antenna elements which are designed to be packaged as low volume units and deployed to an expanded operational shape.

In many electronic applications, an antenna is employed to transmit energy towards a distant position. The antenna generally has a radiator which transmits the energy and a reflector which serves to direct or collimate the energy into a desirable pattern. The reflector is usually considerably larger than the radiator or any other component in the antenna.

Recently it has been proposed to anchor in synchronous orbit about the earth, satellites having as an element thereof an antenna reflector capable of receiving from and transmitting to different ground stations. This presents a unique problem, for the height of such synchronous orbits is approximately 23,000 miles. Operation over such great distances requires a reflector of considerable size in terms of wavelengths of the radio frequency to obtain the required gain characteristics. It is most important that the reflector be of a true shape. Even small deviations (with respect to the large reflector) from the ideal reflector shape would severely distort the wave pattern and hence reduce the required efficiency of the antenna.

One prior art proposal for attaining large utilizable surface areas from lightweight structures of minimum bulk involves inflating these structures with a pressurized gas upon their being ejected from a carrier vehicle and placed in orbit about the earth. This proposal, however, is very susceptible to damage from micrometeroid punctures which result in collapse of the structure due to loss of the inflating medium.

To solve the problem of loss of inflation medium once in orbit, another prior art solution utilizes the inherent stiffness of the inflatable structure's skin material to maintain the desired configuration. These devices, however, must sacrifice part of the payload weight and bulk to provide the inflation medium source. Additional problems which render this approach undesirable include finding a reliable way of discarding the structure container, staying within the permitted geometrical tolerance of the ideal shape (due to variations of solar radiation on exposed surfaces), and "pumpkinoiding" (the effect of pressure differentials created by reinforcement at the seams).

Another prior art approach comprises what might generally be called the mechanical technique. These systems consist of rigid geometrical shapes which are segments of a desired erected structure surface. The segments

are stacked or flexed slightly, depending on the deployment mechanism, into a minimum volume for the package configuration. Deployment may be powered by springs, compressed gas, electrical solenoids or motors. Although the rigidity of these devices is high and the erected structures are less susceptible to distortion it is only possible to approximate the ideal shape desired. Additionally, high deployed to package volume ratios are not possible, and the relatively great weight of the systems limits the allowable payload.

U.S. Pat. No. 3,217,328 is an example of a prior art solution employing a plurality of flexible ribs upon which a flexible grid type of metalized covering material is attached which is to be deployed under slight tension in the erected state. The flexible ribs are bent in an inward radial direction along with their reflection material covering, and restrained in an appropriate manner for the packaged condition. Since the reflective material is attached to the backup rib structure only at specific points the resultant reflective surface is made up of single curved surfaces which only approximate the ideal curved surface desired. Also, since the reflecting material is under tension through the discrete attachment points, any creep exhibited could easily result in permanent distortion of the reflective surface.

Another prior art approach is represented by U.S. Pat. No. 3,202,998 wherein antenna elements are formed from an open cellular flexible foam which is compressed to a packaged condition and, due to the inherent recovery properties of the foam, returns to approximate its original shape when the packaging restraint is removed. Such devices, however, are not suited to large antenna components such as reflectors which must radiate over great distances because in practice it is highly difficult to achieve the necessary close tolerances which must be maintained. Tolerances of a small fraction of an inch over the entire curved surface of a large diameter reflector must be attained in order to produce an element effective to produce a highly directive beam of energy over distances as great as 23,000 miles. The foam material above discussed recovers to only a percent of its original dimensions and could not conform to the necessary close tolerances.

The present invention combines the advantageous features of the aforementioned prior art proposals while minimizing the disadvantages thereof.

Accordingly, an object of the present invention is the provision of a new and improved erectable article of manufacture.

Another object of the instant invention is the provision of a self-erectable space structure.

A further object of the present invention is the provision of a novel self-erectable reflector assembly for antennas utilizable on space satellites operating up to and beyond synchronous orbits.

With these and other objects in view, as will hereinafter more fully appear, and which will be more particularly pointed out in the appended claims, reference is now made to the following description taken in connection with the accompanying drawings in which:

FIG. 1 is a perspective view of the invention in its intended environment,

FIG. 2 is a perspective view of the front surface of the invention in its deployed state,

FIG. 3 is a perspective view of the rear surface of the invention in its deployed state,

FIG. 4 is an enlarged fragmentary view of a portion of the invention as shown in FIG. 3, and

FIG. 5 is a perspective view of the invention in its packaged condition.

Briefly described, the invention comprises a collapsible antenna structure including an annular base member, a feed support, and a reflector of a continuous high modulus mesh attached to the base and having a plurality of radially extending ribs of the same high modulus mesh material integrally formed on its convex surface.

FIG. 1 depicts the reflector of this invention in an operational mode. As shown, the satellite 40 has been launched into a synchronous orbit, that is, at a height of approximately 23,000 miles and at such a speed that it revolves at the same rate as the earth and thus appears to remain fixed with respect thereto. Thus, at a terrestrial point beneath the satellite the reflector 12 will appear stationary in space. So located, reflector 12 can thus act as a collector to receive electromagnetic signals from the earth and as a radiator-director to illuminate, as shown by the dashed lines, a delineated portion of the earth's surface. Solar paddles 14, by collecting energy from the sun, drive batteries within the main housing 16 of the satellite to power the feed 18. Although shown in a synchronous orbit this antenna system, as further described below, may be employed in orbits up to and beyond those of the synchronous altitude.

Additionally, it is to be understood that the satellite configuration upon which the reflector of this invention may be employed is not limited to that shown in FIG. 1. For example, a nuclear power source could be used in place of the solar paddles shown and a variety of stabilization techniques such as gravity-gradient, pulsed-jet, or spin stabilization are possible.

FIGS. 2 and 3 depict the reflector 12 in its deployed or operational condition. The principal material of the reflector is a high modulus mesh 20 which includes a fiberglass grid core impregnated with a flexible resin system upon which a metallic coating is deposited. The reflecting properties of the system and the rigidity of the overall device are enhanced if two layers of fiberglass core material are employed and the grids of two layers are oriented 45 degrees with respect to one another before the resin coating is applied.

The resin system applied over the fiberglass core consists of a cured polysulfide liquid polymer. This polymer imparts a high degree of flexibility to the overall system and makes possible the low volume packaging configuration which will be discussed below. Over the polysulfide resin a coating of aluminum is vacuum deposited to both the concave and convex sides of the composite mesh structure to provide the necessary reflective and ultraviolet protection characteristics.

As seen in FIG. 2 the reflector 12 assumes in its deployed condition a true parabolic shape. Central element 22, schematically shown, represents the feed cone or support which could be one of several configurations but does not form a part of this invention. Radial ribs 24, as described below, are seen along the periphery of the reflector surface which, excepting the feed support cone 22, forms a continuous parabola.

As more clearly seen in FIG. 3 the convex side 26 of the reflector surface has a plurality of radial ribs 24 uniformly spaced thereabout. In the embodiment illustrated fifteen ribs are used. In order to securely base the ribs 24 and to provide an attachment for the feed support cone 12 a light rigid hub 28 is provided. The hub may be constructed of a light metal such as aluminum.

The ribs themselves are constructed of the same mesh material as the reflector surface although it is desirable to use an additional layer of fiberglass core material to increase rigidity. It is extremely important, however, that the ribs be of the same composition as the reflector shell in order to avoid dissimilar rates of expansion and other characteristics which would result in undesirable stress concentrations within the assembly. Assembly of the ribs to the parabolic shell is accomplished by bonding with the same resin system used to coat the fiberglass core. Subsequent curing effects an integral bond between the ribs and convex reflector surface. If desired, the ribs may be woven to the shell surface with fiberglass thread prior to application of the resin bond.

As seen in FIG. 3 the hollow ribs are secured to rigid flange members 30 and proceed radially along the convex reflector surface. More specifically, referring to FIG. 4, rib 24 in the area of attachment to hub 28 is relatively high as at 32 and narrow in width as at 34. As the rib progresses to the outer periphery of the reflector surface it decreases in height as shown at 36 and increases in width as at 38. The progressively increased rib width provides greater rigidity along the outer periphery of the reflector surface where the distance between successive ribs is greatest. The high narrow portion of the rib at the apex of the reflector allows packaging as described below. Additionally, the use of ribs tapered in this manner minimizes the total necessary weight of the system.

FIG. 4 also illustrates as shown at 39 the alignment of the two layers of fiberglass core material as described above. Thus, the grid of one layer is oriented 45 degrees with respect to the grid of the second thereby increasing the effective reflecting surface of the entire system.

FIG. 5 shows the reflector system in its packaged condition as it would appear before insertion into a launch vehicle shroud. The method of packaging consists of introducing straight radial folds 40 in the mesh reflector as its outer periphery is moved away from the apex of the parabola and inwards toward the focal point. The convoluted folded periphery 42 is clamped and held in position with a tension ring shown schematically at 44. This ring could take any of several forms but could include a series of spaced explosive bolts 46 (only one shown) to be fired to release the reflector once it has separated from the launch vehicle and entered a preselected orbit.

Of special interest is the configuration of the ribs 24 in the packaged condition. Although the ribs themselves contribute greatly to the stiffness of the overall structure in radial vertical planes of the upright parabola, these ribs may be flexed sideways for folding as seen at 48. This transverse flexing removes the increased moment of inertia contributed by the ribs in the deployed condition which then allows folding and packaging of the composite structure.

Thus it is seen that the combination of the flexible mesh composition described with the tapering radial ribs provides a sufficient degree of flexibility to allow folding the entire system to a configuration such as that of FIG. 5 without introducing a permanent set into the surface of the reflector. The stored elastic strain energy allows the reflector to spring to its deployed configuration upon release of the applied restraining force. The result is a lightweight, high gain, large aperture, easily packaged and deployed antenna system which, due to its homogeneous mesh composition, is substantially immune to distortion from temperature and pressure gradients.

A six-foot diameter parabolic model of the invention as above described was constructed and tested for accuracy and surfaces tolerences. Male molds for both the ribs and parabolic shell were fabricated and carefully hand finished to an estimated tolerance of ± 5 mils from the theoretical configuration. Two layers of fiberglass cloth oriented 45 degrees as described above were placed over frames larger in area than the mold surface to be covered. (Three layers were used for the rib elements.) The edges of the cloth were lightly constrained to the frames by taping.

The oriented glass layers were then impregnated with a thinned polysulfide liquid polymer consisting of approximately one part toluene and one part PR–1201–Q, a liquid polymer compound available from the Products Research Company of Gloucester City, N.J. The material was blotted to remove excess resin and blown with air to eliminate bridging at the interstices. The composition was then immediately draped over the male molds and hand shaped to conformation.

Curing was accomplished by raising the temperature to 160° F. for approximately 72 hours. During this period clamping was applied to a small area of the outer tips of the rib mold to prevent bridging of the material in the area of compound curvatures. Similar clamping was applied to the extreme outer periphery of the reflector shell. Assembly of the ribs to the parabolic shell and then to the metal hub was accomplished by bonding with the same resin system. The metal hub was fabricated by spinning an aluminum sheet to a parabolic surface. The rib sockets were formed by compression molding of similar aluminum sheet.

Upon completion of the bonded assembly, the composite mesh structure was processed with a metallizing lacquer to provide a suitable substrate for vacuum metal deposition. Aluminum was then vacuum deposited to both the concave and convex sides of the assembly to provide the necessary reflective and ultraviolet protection characteristics. Finally, an RF feed support structure was fabricated and bonded to the central metal hub.

The completed assembly exhibited good flexibility and was packaged (substantially as shown in FIG. 4) and successfully deployed in a one *"g"* field. Pattern measurements taken at an X-band frequency of 7.6 gigahertz resulted in a gain of 38 decibels. Measurements of surface tolerances after testing showed a maximum deviation from the mold of no greater than 50 mils for an estimated 5 percent of the area and no greater than 10 mils for the remaining 95 percent.

In order to further enhance the deployment and subsequent rigidity of the configuration without a significant increase in weight, a flexible, elastic material such as a sponge or foam rubber could be poured or otherwise deposited within the hollow rib structure. Such material would be sufficiently flexible to allow folding of the ribs during packaging but would return to its original deployed contour upon release of the restraining force. This addition could become especially important in terrestrial applications where the one *"g"* field might tend to collapse the hollow rib structure.

Another contemplated modification is the construction of a complete, continuous reflector composed entirely of the mesh composition described above. That is, the central metallic hub **28** could be eliminated by applying additional layers of fiberglass core material in the area of the apex of the reflector surface. The mesh ribs could then be anchored in this reinforced area.

Although the embodiment illustrated is directed to use of reflector on a space satellite, the system lends itself equally well to ground communications systems. The packaging characteristics of the reflector along with its light weight make it especially attractive for use in transportable tactical communication systems and the open mesh configuration reduces wind loads encountered in ground use.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A collapsible antenna structure comprising:
(a) an annular base member;
(b) a feed support attached to and extending from said base member;
(c) a reflector attached to the periphery of said base member, said reflector constructed of a continuous high modulus mesh having deposited thereof a metallic reflective coating;
(d) a plurality of radially extending ribs integrally attached in a continuous manner throughout their lengths to the convex surface of said reflector and extending from the periphery of said base member to the outer periphery of the reflector surface, said ribs being flexible about said base to fold said antenna into a packaged configuration and induce elastic strain energy in said ribs; and
(e) means for retaining said antenna in a packaged configuration such that when said means is released the stored elastic strain energy in said ribs causes said antenna to automatically deploy.

2. The antenna structure of claim **1** wherein:
said ribs increase in width progressively from approximately the apex of the reflector surface to the outer periphery thereof,
and wherein said ribs are constructed of the same mesh material as the reflector surface.

3. The antenna structure of claim **2** wherein:
said ribs decrease in height progressively from approximately the apex of the reflector surface to the outer periphery thereof.

4. The antenna structure of claim **2** wherein said mesh is a fiberglass grid core impregnated with polysulfide liquid polymer, and wherein said reflective coating is vacuum deposited aluminum.

5. The antenna structure of claim **3** wherein:
said fiberglass core consists of two layers of fiberglass cloth having the grid of one layer oriented 45 degrees with respect to the grid of the other.

6. The antenna structure of calim **2** wherein said ribs are filled with a flexible, elastic material.

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