United States Patent

Low et al.

[15] **3,680,144**

[45] **July 25, 1972**

[54] SINGLY-CURVED REFLECTOR FOR USE IN HIGH-GAIN ANTENNAS

[72] Inventors: **George M. Low**, Acting Administrator of the National Aeronautics & Space Administration with respect to an invention of; **Arthur C. Ludwig**, 4823 Grand Ave., Lacanada, Calif. 91011

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[21] Appl. No.: **112,988**

[52] **U.S. Cl.** **343/781**, 343/837, 343/840, 343/915

[51] **Int. Cl.** **H01q 15/20**

[58] **Field of Search** 343/781, 840, 837, 915

[56] **References Cited**

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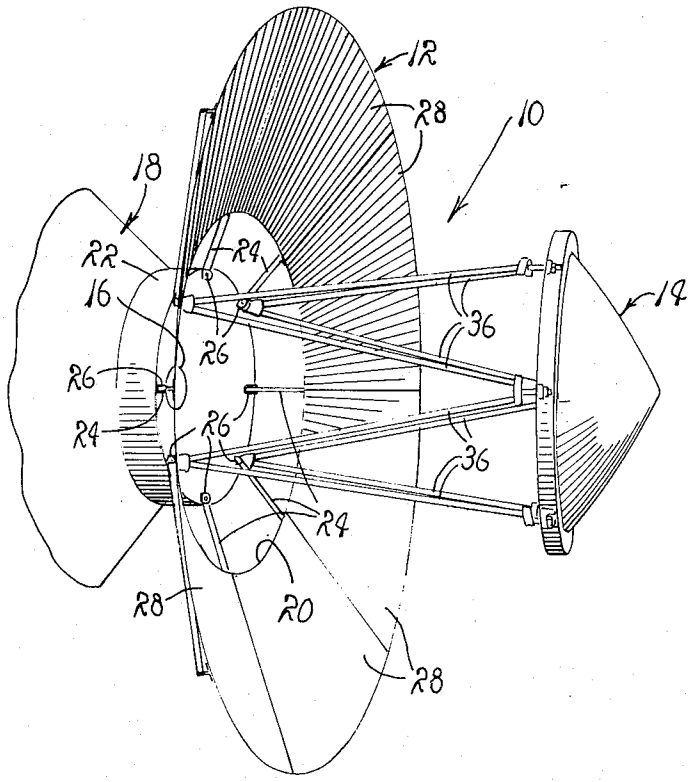
Primary Examiner—Eli Lieberman

Attorney—Monte F. Mott, Paul F. McCaul and John R. Manning

[57] **ABSTRACT**

A furlable antenna particularly suited for use aboard spacecraft. The antenna is characterized by an improved reflector plate conforming to a frusto-conical configuration combined with a point-source feed and a secondary reflector having a reflective surface conforming to a figure of revolution generated by rotating a segment of a parabola about an axis parallel the ray path of the intermediate rays, whereby the antenna can be stowed in a furled configuration without substantially reducing its efficiency.

6 Claims, 11 Drawing Figures



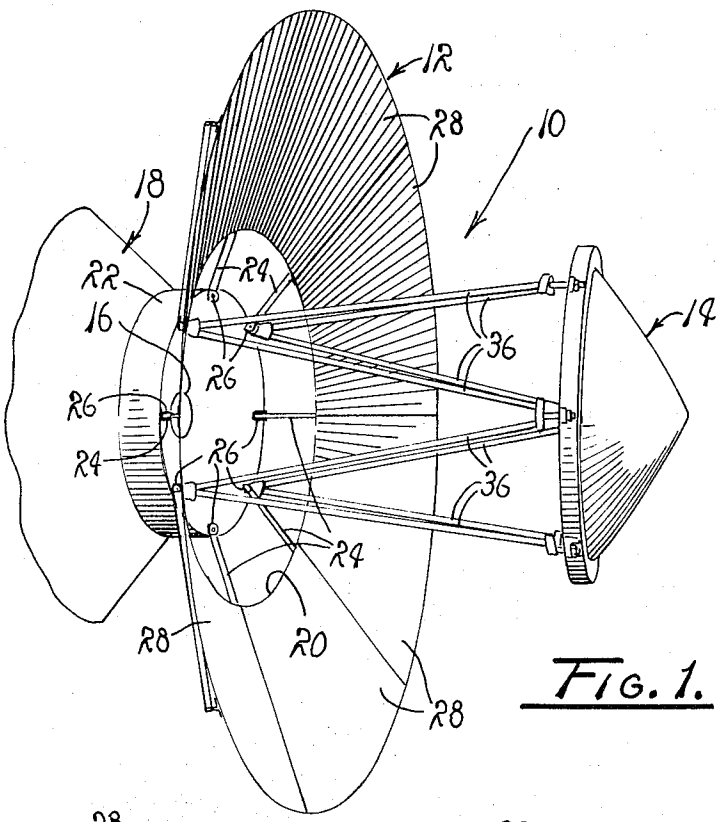


FIG. 1.

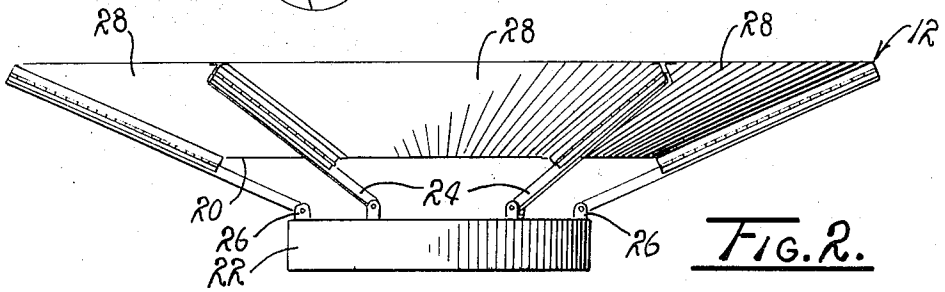


FIG. 2.

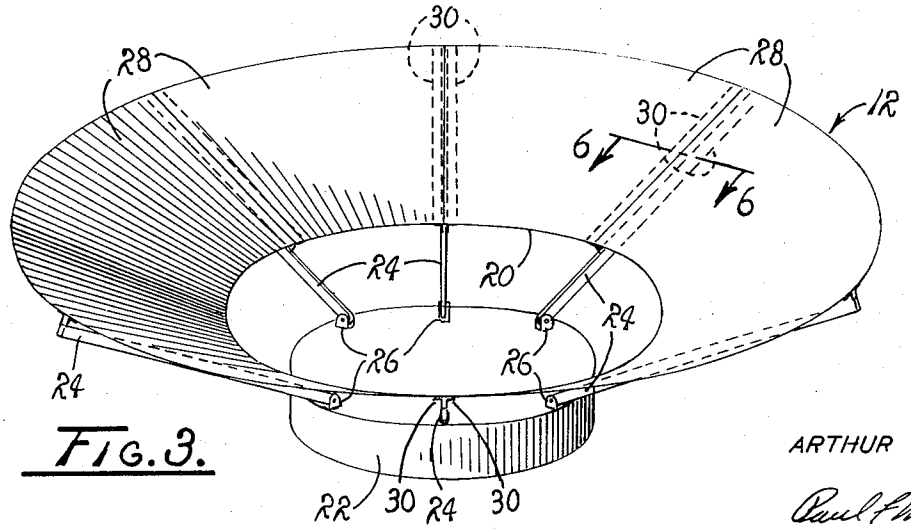


FIG. 3.

ARTHUR C. LUDWIG
INVENTOR
Paul F. McCord
Monte F. Mott
ATTORNEYS

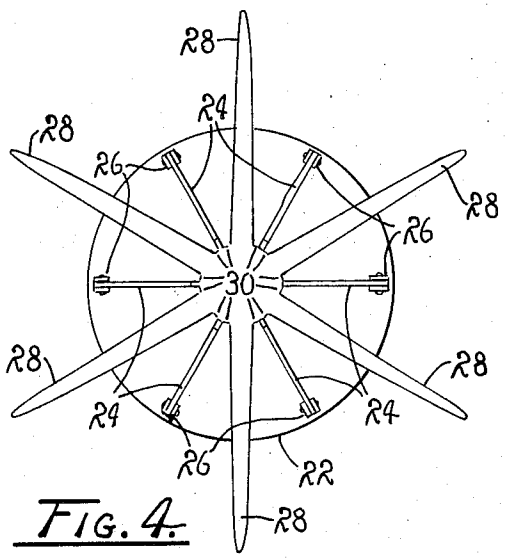


FIG. 4.

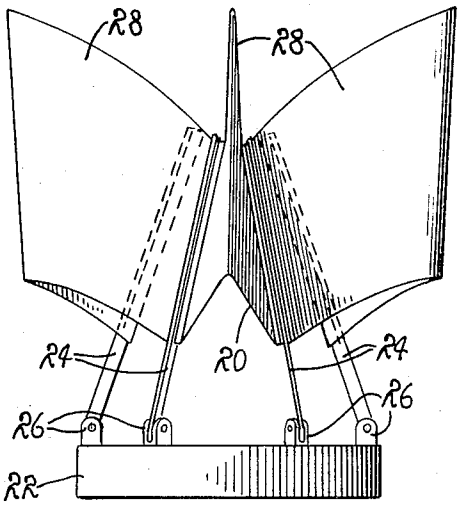


FIG. 5.

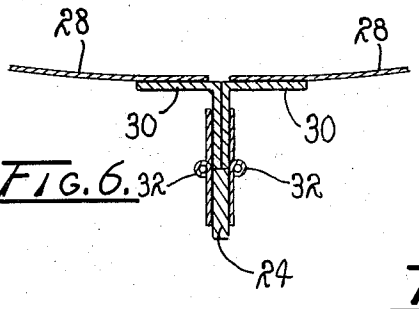


FIG. 6.

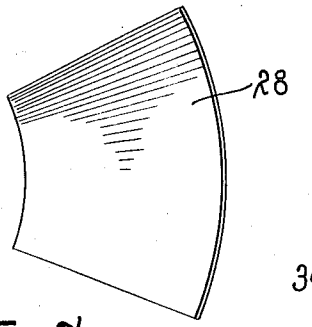


FIG. 7.

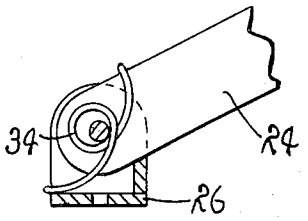


FIG. 9.

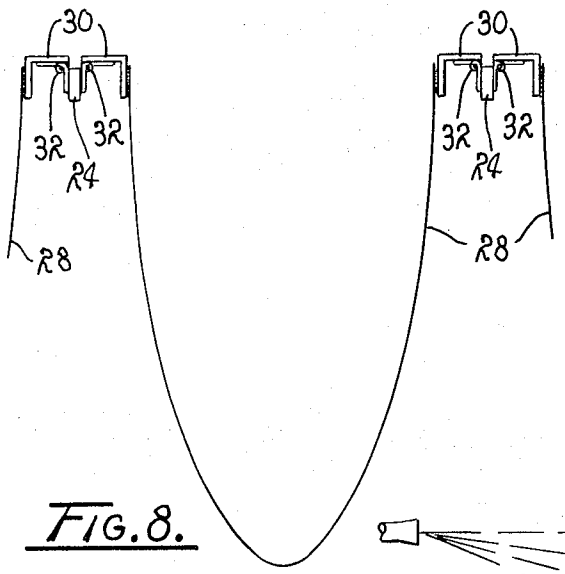


FIG. 8.

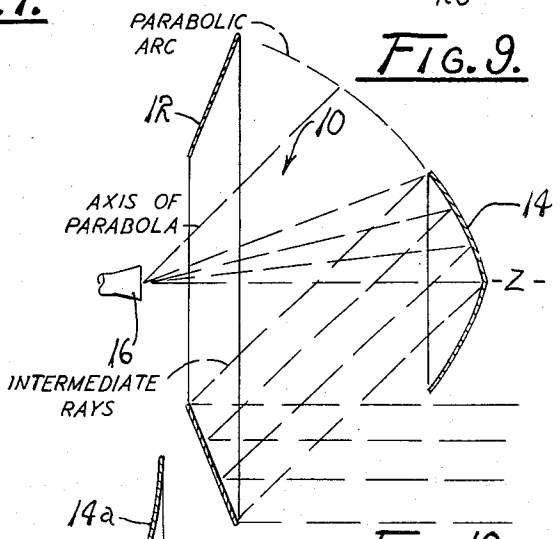


FIG. 10.

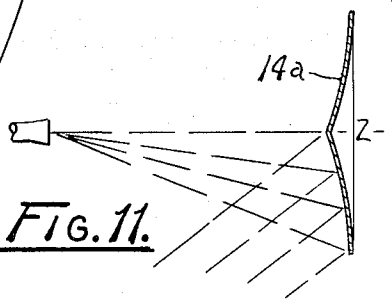


FIG. 11.

ARTHUR C. LUDWIG
INVENTOR
Paul & Paul
Monte & Mott
ATTORNEYS

SINGLY-CURVED REFLECTOR FOR USE IN HIGH-GAIN ANTENNAS

ORIGIN OF INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 Stat. 435; 42 USC 2457).

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention generally relates to high-gain antennas for use aboard spacecraft, and more particularly to an improved primary reflector plate capable of being pleated to a furled configuration and subsequently deployed into a frusto-conical configuration.

2. Description of the Prior Art

Where a high-gain antenna is to be employed aboard a spacecraft, it is highly desirable to reduce the bulk of the antenna during launch, for purposes of accommodating limited shroud dimensions as well as to protect the antenna from the deleterious effects of the high-G environment normally encountered during launch. Of course, large antennas necessarily must be capable of being readily erected into desired shapes having illumination characteristics dictated by prevailing RF (Radio Frequency) requirements.

Doubly-curved, rigid surfaces cannot be folded. For this reason, parabolic antenna reflecting surfaces larger than those that can be designed with petals must employ some form of a compliant structure, such as those of a rib and mesh design. A number of types have been built, tested, and used. However, such antenna tends to suffer the common deficiency, mainly that of chording in both radial and circumferential directions. Consequently, a mesh cannot be made to assume a configuration which is truly parabolic. In order to meet this imposed combination of parameters it has been suggested that large reflectors be segmented into petals so that these petals could be stowed in various overlapped configurations. Of course, the structure required in deploying the petals tends to be rather complex and massive and thus tends to reduce the feasibility of such structure.

It is the consensus of those engaged in designing antennas that while singly-curved surfaces are particularly desirable from a structural standpoint, such are not desirable from an RF standpoint, primarily because of the poor focusing characteristics of such surfaces. Therefore, there currently exists a need for a practical high-gain antenna capable of being stowed and subsequently deployed into a practical and operatively efficient configuration.

OBJECTS AND SUMMARY OF THE INVENTION

It is therefore an object of the instant invention to provide an improved high-gain antenna which overcomes aforementioned difficulties and disadvantages.

Another object is to provide an improved reflector for use in a high-gain antenna.

Another object is to provide a singly-curved reflector for use with a high-gain antenna of the type commonly found aboard spacecraft and the like.

Another object is to provide a primary reflector plate having a reflective surface defining a frustum particularly suited for use with a point-source feed and a secondary reflector having a reflective surface conforming to a figure of revolution of a segment of a parabolic curve.

It is another object to provide in a high-gain antenna of the type employing a two-reflector system, a primary reflector plate having good electrical properties and greatly simplified structure whereby the primary reflector plate can be furled for stowage and unfurled into an efficient configuration.

These and other objects and advantages are achieved through the use of an antenna including a point-source feed, a secondary reflector and a primary reflector having an operable frusto-conical configuration, including a singly-curved reflective surface fabricated from a furlable, impervious sheet of metal, supported in an operative configuration by structure which permits the plate to be stowed aboard spacecraft in a furled configuration and deployed therefrom into a practical, operative configuration.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a fragmented perspective view of a high-gain antenna which embodies the principles of the present invention, depicting a primary and a secondary reflector operatively associated in a deployed configuration.

FIG. **2** is a side view of the primary reflector shown in FIG. **1**.

FIG. **3** is a perspective of the primary reflector shown in FIGS. **1** and **2**.

FIG. **4** is a top plan view of the primary reflector shown in FIGS. **1** through **3** illustrating a pleated configuration assumed by the reflector when it is supported in its furled configuration by pivotal ribs.

FIG. **5** is a side elevation of the primary reflector shown in FIGS. **1** through **4**, also illustrating a furled configuration for the reflector.

FIG. **6** is a detailed view taken generally along line **6**—**6** of FIG. **3** illustrating one manner in which adjacent gores can be coupled with the pivotal ribs.

FIG. **7** is a detailed view of one of the gores illustrating its preformed configuration.

FIG. **8** is a detailed, enlarged view illustrating a pleated configuration assumed by a single gore when the primary reflector is in the furled configuration illustrated in FIGS. **4** and **5**.

FIG. **9** is a detailed view depicting one manner in which the ribs employed in supporting the primary reflector are urged into an operative disposition for unfurling and deploying the reflector plate.

FIG. **10** is a schematic view depicting the approximate ray optics behavior of the antenna system of the instant invention.

FIG. **11** is a schematic view depicting optics behavior of a modified form of the secondary reflector.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings wherein like reference numerals designate like or corresponding parts throughout the several views, there is shown in FIG. **1** a high-grain antenna **10** which embodies the principles of the instant invention.

The antenna **10** includes a primary reflector **12**, a subreflector, hereinafter referred to as secondary reflector **14**, and a point-source antenna feed **16** operatively associated with the secondary reflector. The antenna **10** has particular utility in celestial space communication systems and accordingly is supported by suitable structure, generally designated **18**. Since the structure **18** employed in mounting the antenna **10** forms no specific part of the instant invention, a detailed description thereof is omitted in the interest of brevity. However, it is to be understood that the structure **18** can be of a type capable of supporting a high-gain antenna in a projected disposition relative to an operative spacecraft. As such, the structure **18** and the antenna **10** are appropriately matched in order to facilitate a desired orientation and operation of the antenna.

As illustrated in FIG. **10**, both of the reflectors **12** and **14** include a reflective surface conforming to a figure of revolution generated about the Z axis of the antenna **10**. In practice, the primary reflector **12** is a singly-curved plate having a reflective conical configuration, while the secondary reflector **14** is a plate having a reflective surface conforming to a figure of revolution generated by rotating a segment of a parabolic curve. Since the behavioral characteristics of the reflectors of the type herein employed are well known, a detailed discussion of such characteristics is omitted in the interest of brevity. As is well known, a singly-curved surface tends to focus in one dimension only and will convert a plane wave to a cylindrical

or conical wave converging toward a line segment. However, by utilizing a secondary reflective surface generated by rotating about the axis Z, FIG. 10, a segment of a parabola, having an axis paralleling the ray path of the intermediate rays of reflected energy, it is possible to employ a "point-source" feed rather than a more complex "line-source" feed.

As also illustrated in FIGS. 1 and 10, the primary reflector 12 is provided with a concentric opening having a diameter approximately equal to its radius. Consequently, the illuminated portion of the primary reflector is such that the antenna 10 has a maximum gain which is approximately 75 percent of the maximum gain achievable through the use of a reflector of a full circular aperture of the same diameter. Since the normal loss encountered is 3 to 6 percent in a conventional system, due to illumination blockage, the relative potential gain of the antenna illustrated is about 75 to 78 percent of the potential value for such reflectors. In practice, the actual gain of this reflector is approximately the same as conventional reflectors.

Mounted within the opening 20 is the antenna feed 16. As herein employed, the term "feed" is defined as any device that couples energy between free space and a transmission line. Since feed designs are matters well within the skill of the art and form no specific part of the invention, a detailed description of the feed 16 also is omitted. However, it is to be understood that the primary reflector 12, the secondary reflector 14, and the feed 16, in effect, establish a conical-Gregorian antenna system by which incident plane wave energy can be refocused to a point.

Of course, the secondary reflector 14 can be of an inverted configuration, as depicted at 14*a*, FIG. 11, and employed in a Cassegrainian configuration wherein the rays strike the outer surface of the reflector.

Turning now to FIGS. 2 and 3, it is noted that the primary reflector 12 is supported by an annular base 22 having extended therefrom a plurality of rigid ribs 24. The ribs 24 are spaced at equi-distances about the periphery of the base 22 and are pivotally coupled thereto through suitable pivot blocks 26. The blocks 26 are of a suitable design which serve to pivotally couple the ribs 24 to the base 22 in a manner such that the ribs can be displaced pivotally in planes bisecting the base.

The primary reflector 12, in effect, is a singly-curved plate formed of a plurality of segments or preformed gores 28, FIG. 7, fabricated from a flexible, imperforate sheet stock such as a suitable thin-gauge metal, including stainless steel, aluminum and the like. In order to assure that the plate 12 is caused to assume a frusto-conical configuration, the gores 28 preferably are pre-stressed and strained in a manner such that when deployed in the reflector 12, the reflector is caused to assume a frusto-conical configuration having a singly-curved surface.

Each of the gores 28 is suspended and secured between a pair of the ribs 24, FIGS. 6 and 8. Where desired, right-angle hinge plates 30 are coupled to the ribs 24 through the suitable hinges 32, including piano hinges and the like. Of course, the manner in which the gores 28 are secured to the hinge plates 30 and the hinges 32 secured to the ribs 24 can be varied as is found practical. However, these structural components can be bonded quite suitably, employing high-performance polymeric materials.

When deployed, the reflector 12 assumes a rigid, frusto-conical configuration so that its reflective surface defines a frustum. This, of course, requires the ribs 24 to be forced outwardly toward a common plane, radiating from the base 22. However, due to the fact that the reflector 12 is of a conical configuration, the ribs 24 do not assume a coplanar relationship.

While any practical actuator can be employed in urging the ribs outwardly to their deployed disposition, a torsion spring 34 mounted within each of the blocks 26, FIG. 9, serves quite satisfactorily for this purpose. In some instances, it may be deemed practical to employ a rack-and-pinion drive, or similar power train for forcing the ribs 24 into a deployed disposition relative to the base 22.

As best illustrated in FIGS. 4 and 5, the reflector 12 is furled by simultaneously pivoting the ribs 24 toward a common point located on the axis of the base 22. Such displacement of the ribs 24 normally is manually achieved and serves to fold each of the gores 28 in a manner such that the reflector 12 is configured to a series of adjacent pleats. Hence, by drawing the distal ends of the ribs 24 into close proximity, the reflector 12 is pleated and thus caused to assume a furled condition particularly practical in spacecraft launching operations. Of course, for practical considerations the ribs are secured by suitable means, now shown, in close proximity for securing the reflector in its furled condition.

In order to unfurl and thus deploy the primary reflector 12 from its pleated configuration, the distal ends of the ribs 24 are released and in response to forces applied by the torsion spring 34 they simultaneously are caused to pivot outwardly toward a coplanar relationship. This pivotal displacement of the ribs 24 deploys the reflector 12 into an unfurled condition and fully expanded configuration. The forces applied by the springs 34 serve to tension the gores 28 for thus causing the hinge plates 30 to pivot into an abutting relationship, as best illustrated in FIG. 6.

As shown in FIG. 1, a plurality of extended support struts 36 are utilized for supporting the secondary reflector 14 in an operative relationship with respect to the primary reflector 12. It is preferred that the struts 36 be of a length sufficient to permit the ribs 24 to be pivoted inwardly beneath the secondary reflector 12. While not shown, it also is to be understood that the secondary reflector 14 is supported at predetermined distances from the feed 16 for thus appropriately positioning the secondary reflector 14, relative to the primary reflector 12. This can be accommodated by including within each of the struts 36 a screw-threaded jack or similar device, not designated, which accommodates axial adjustment and alignment of the secondary reflector with respect to the antenna axis as well as the feed 16. Also, while not shown, it can be appreciated that the feed 16 preferably is supported by an adjustable mount which accommodates an axial repositioning of the feed relative to the antenna axis.

OPERATION

It is believed that in view of the foregoing description, the operation of the device will be readily understood and it will be briefly reviewed at this point.

With the antenna 10 assembled in the manner hereinbefore described it is associated with a given spacecraft. The ribs 24 are pivotally displaced toward the axis of the antenna 10 for simultaneously folding the gores 28 to impart to the primary reflector 12 a pleated configuration. In this configuration the antenna 10 is enclosed within a protective shroud, not shown, preparatory to launch. Preferably, the distal ends of the ribs 24 are positioned in the vicinity of the peripheral surface of the secondary reflector 14 and operatively secured in this position, by any suitable means not shown.

Once launched, the shroud is removed and the ribs 24 are released. Under the influence of the springs 34 simultaneously acting on the ribs 24, the reflector 12 is unfurled and deployed into an operative frusto-conical configuration. As the reflector is unfurled, its reflective surface is caused to define the frustum of a cone coaxially related to the axis of the secondary reflector 14. In this configuration the primary reflector 12 presents a singly-curved surface to the reflective surface of the secondary reflector 14, whereupon an instant plane wave can be focused at the feed 16. Due to the capability of the reflector 12 to be unfurled from a stowed condition, the primary reflector can be fabricated from imperforate materials into operatively efficient reflectors of practical dimensions.

In view of the foregoing, it is to be understood that the instant invention is embodied in a conical-Gregorian high-gain antenna which provides a practical solution to problems encountered in developing systems capable of establishing communication with spacecraft employed in deep space exploration.

Although the invention has been herein shown and described in what is conceived to be the most practical and preferred embodiment, it is recognized that departures may be made therefrom within the scope of the invention, which is not to be limited to the illustrative details disclosed.

What is claimed is:

1. An antenna comprising:

A. a base having an annular configuration;

B. a point-source feed operatively associated with said base;

C. a plurality of substantially rigid ribs fixed to said base and extended therefrom;

D. a reflector plate of an annular configuration supported by said ribs and having a reflective surface conforming to a frustum; and

E. a sub-reflector coaxially related to said plate and operatively associated with said point-source feed and said plate having a reflective surface conforming to a figure of revolution of a segment of a parabolic curve.

2. The antenna of claim 1 wherein said plate includes a plurality of arcuate gores suspended between said ribs and having a common radius of curvature.

3. The antenna of claim 2 wherein each of said gores is fabricated from impervious sheet stock and includes a singly-curved reflective surface.

4. The antenna of claim 1 wherein the reflector plate is fabricated from flexible sheet stock of impervious material and said ribs are pivotally coupled with said base and displaceable between a stowed position wherein the plate is caused to assume a pleated configuration, and an operative position wherein the reflector plate is caused to assume an expanded frusto-conical configuration.

5. In a high-gain antenna adapted to be deployed into an operative configuration and furled into a stowed configuration, a reflector comprising an annular plate having a singly-curved reflective surface formed of a plurality of flexible, thin-gauge metal sheets defining a frustum when deployed into an operative configuration and a sinuously curved reflective surface when furled into a stowed configuration, and means for alternately supporting said reflector in said deployed and stowed configurations.

6. The reflector of claim 5 wherein said means for supporting said reflector includes a base and a plurality of substantially rigid ribs pivotally supported by said base.

* * * * *