Nov. 17, 1970 W. I. BERKS ET AL 3,541,569

EXPANDABLE PARABOLIC REFLECTOR

Filed March 8, 1968 2 Sheets-Sheet 1

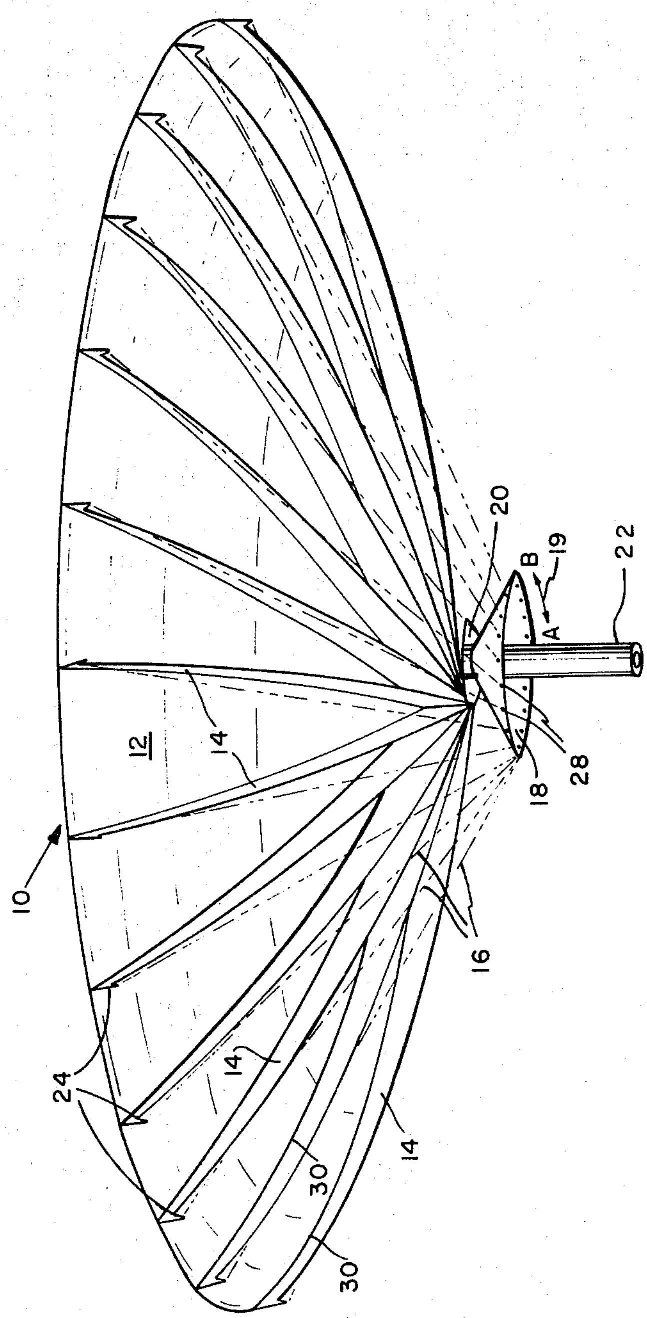

Fig. 1

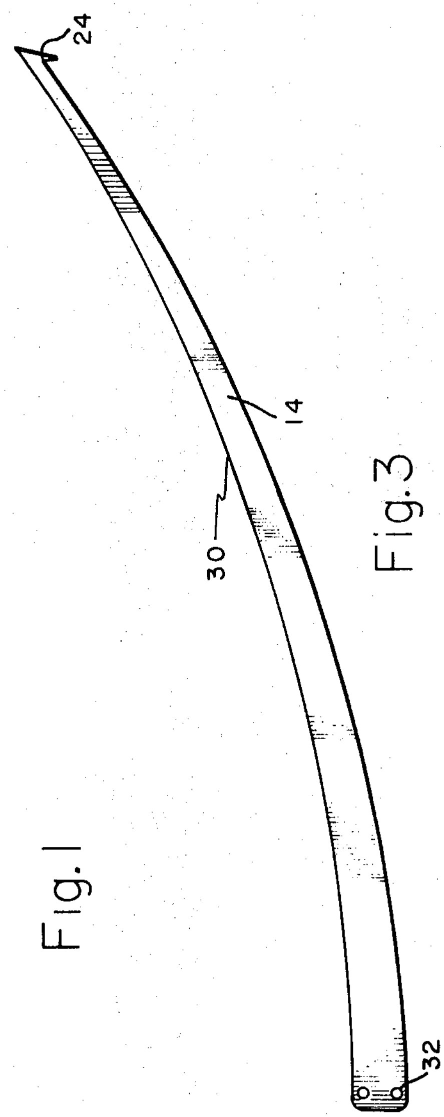

Fig. 3

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EXPANDABLE PARABOLIC REFLECTOR

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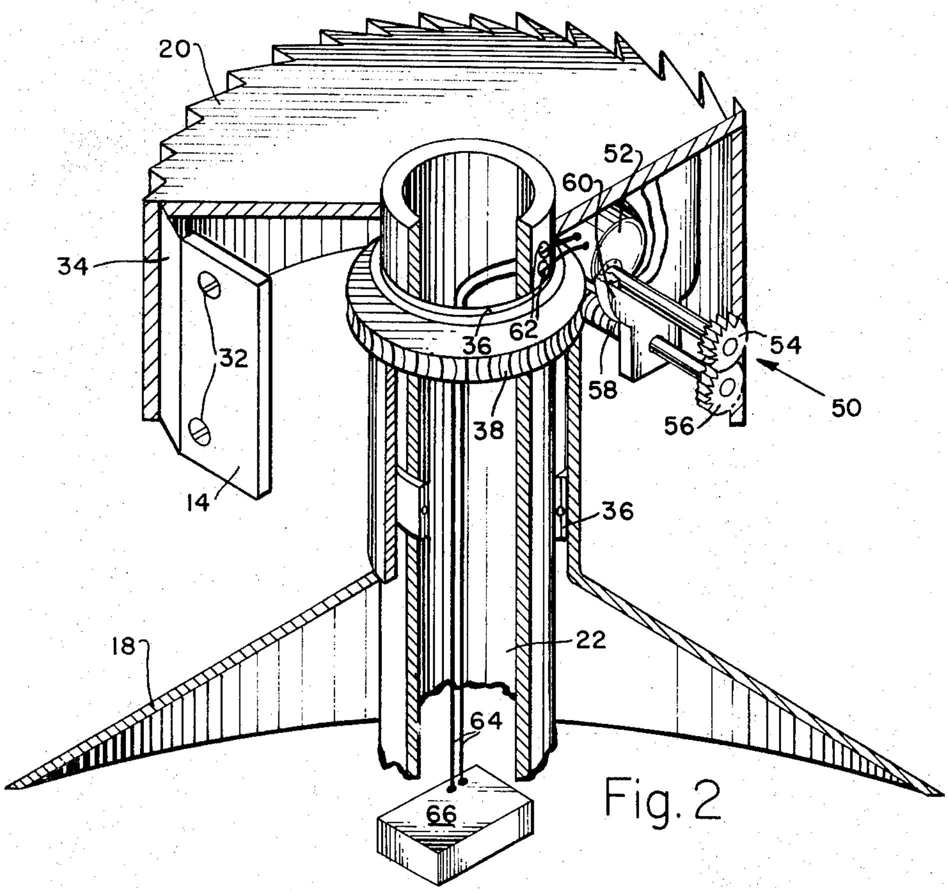

Fig. 2

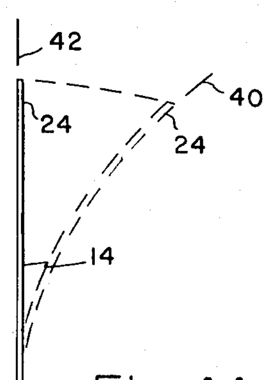

Fig.4A

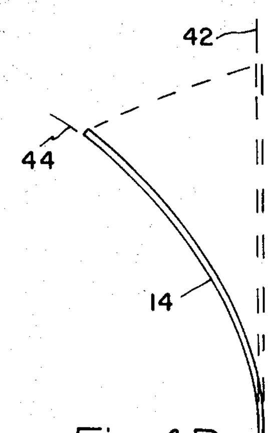

Fig.4B

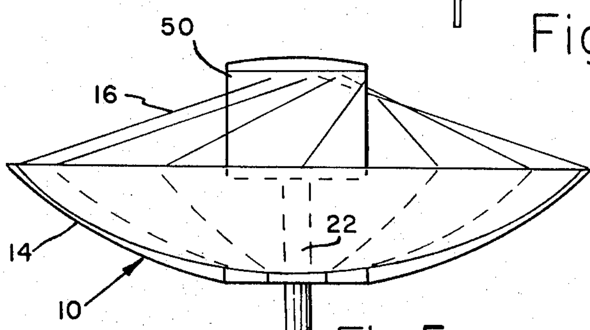

Fig.5

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3,541,569

EXPANDABLE PARABOLIC REFLECTOR

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U.S. Cl. 343—915 6 Claims

ABSTRACT OF THE DISCLOSURE

The device of this invention is an expandable parabolic reflector which is comprised of a plurality of rib members radially extending from a relatively fixed central member, with each of the members shaped to form a skeleton structure of a parabolic reflector. A thin collapsible sheet of conductive material attached and stretched between the rib members forms the reflector surface. A spindle member is rotatably mounted to the central member and cables, or wires, are extending from points spaced on the outer surface of the spindle to the outermost tips of the rib members. Means are also provided for rotating the spindle member with respect to the central member to wind the cables and in turn the rib members and reflector around the central member. To expand the reflector, the spindle is rotated in an opposite direction unwinding the cable and allowing the spring action of the ribs to open the reflector material between the ribs. The spindle continues to rotate thus increasing the tension on the cables and stretching the reflector into the desired shape.

BACKGROUND OF THE INVENTION

This invention pertains to the field of parabolic reflectors and, more particularly, to a parabolic type reflector which may be collapsed and expanded when desired. Parabolic reflectors find their most common use in the communications field as antennas. In the present-day scientific world, spacecraft must be provided with various types of antennas in order to communicate with various ground areas. Where increasing data requirements demand higher gains and hence larger antennas, size and volume limitations of launch vehicle fairings often require that such antennas be capable of being folded to a small fraction of their open diameter and total volume with their deployment occurring after orbit has been achieved.

One of the prior art devices consists of umbrella-type antennas which have rigid ribs that are extended in a manner similar to an umbrella. The umbrella antenna is disclosed in a paper entitled "The Development of High Gain Deployable Antennas for Communications Satellites," AIAA Paper No. 66–306, by S. A. Milliken, Hughes Aircraft Co., El Segundo, May 1966.

Another foldable antenna design consisting of a series of spirally-formed fiber glass rods which support a metallic-rooted plastic mesh is disclosed in the article "Lightweight Antenna for Space Vehicles," Product Engineering, Nov. 22, 1965, page 60. The expanding of the antenna is accomplished by utilizing the elastic energy of the fiber glass rods and controlling the rate of opening with a braking device.

The reflector of this invention differs from the prior art devices in that no heavy mechanical linkages, such as those used on the umbrella-type reflectors, are used and in that the reflector is expanded with elastic energy and rigidly stretched in the open position to provide a relatively stable paraboloid focal point and corresponding paraboloid of revolution.

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SUMMARY OF THE INVENTION

In the preferred embodiment of this invention, a substantially cylindrical central member has mounted on its periphery a plurality of rib-like members which extend radially from the central member. Each of the rib members is shaped to form the skeleton structure of a parabolic reflector. A thin collapsible sheet of conductive material is attached and stretched between the rib members to form a parabolic reflector. A spindle member is rotatably mounted to the central member and cables or wires are extending from points spaced on the outer periphery of the spindle to the outermost tips of the rib members. Means are provided for rotating the spindle member with respect to the central member to wind the cable and in turn the rib member and the reflector around the central member. To expand the reflector the spindle member is rotated in an opposite direction until the reflector is expanded. The spindle member is then further rotated such that the cable now pulls the rib members stressing the reflector material forming it into a rigid parabolic shape.

Accordingly, it is an object of the present invention to provide an improved expandable reflector.

It is a further object of the present invention to provide a reflector which may be folded into a relatively small space.

It is another object of the present invention to provide a reflector which is relatively rigid in its expanded position.

The aforementioned and other objects of the present invention will become more apparent when taken in conjunction with the following description and drawings, throughout which like characters indicate like parts, and which drawings form a part of this application.

BRIEF DESCRIPTION OF THE THE DRAWINGS

FIG. 1 is a perspective view of the preferred embodiment of the invention;

FIG. 2 is a perspective view in partial cutaway of a portion of the embodiment illustrated in FIG. 1;

FIG. 3 illustrates a structural member utilized in the embodiment shown in FIG. 1;

FIG. 4*a* and FIG. 4*b* are top views of the structural member illustrated in FIG. 3; and

FIG. 5 illustrates a second embodiment of the invention.

BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, wherein the expandable reflector **10** is shown in its fully expanded position. The reflector **10** consists of a plurality of flexible ribs **14** which are fixedly attached and extend radially from a central core member **20**. The ribs are relatively thin and flexible in the plane defined by the reflector surface but in the plane perpendicular to the reflector surface the ribs are fairly wide and rigid. In the embodiment shown in FIG. 1, the ribs **14** are symmetrically disposed about the outer periphery of the central member **20**. This symmetry need not be maintained for all types of reflectors. Each of the rib members **14** has a surface **30** formed into the shape of a parabola, or other desired shape, so as to form a skeleton structure to which a conductive reflective flexible covering may be attached. A central hollow shaft member **22** extends vertically through the central core member **20** along the axes defining the focus of a paraboloid. The spindle member **18** resembling an inverted funnel is rotatably mounted to the shaft member **22**. Cables **16**, or flexible wires, extend from points **24** on the tips of each of the rib members **14** to corresponding points **28** on the periphery of the spindle member **18**.

In operation, the reflector **10** may be collapsed by rotating the spindle member **28** in the direction A indicated by the double headed direction arrow **19**. With the spindle rotating in this direction, the cables **16** are wound around the outer surface of the spindle member pulling the tips of the structural rib members **14** towards the central shaft **22**. This process continues until the structural rib members are compactly wound around the central core member **20**. The spindle member is shaped in the form of an inverted funnel to provide varying degrees of torque to pull the tips **24** efficiently towards the center. For example, in the fully extended position shown in FIG. 1, the torque required to initially move, and start, the tip members in toward the central core member **20** is relatively low. The moment arm transmitting the torque to the cable is then equal to the distance between the periphery of the spindle member **18** and the central axis of the shaft **22**. As the cable **16** is wound onto the funnel, the cable slides up towards the narrow portion of the spindle thereby decreasing the distance between the central axis of shaft **22** and the outer surface or torque transmitting surface of the spindle member **18**. The winding of the cable will decrease in speed but the force applied thereto will increase. This particular feature automatically takes care of the increase in resistance caused by the spring constant of the structural rib members and the normal folding resistance in the conductive reflector material **12**. To release the reflector in a controlled manner, the spindle is rotated in the B direction of the double action arrow **19**. A point will be reached where further unwinding of the spindle will not extend the tip members **24** any farther. By rotating the spindle **18** past this point, the cable **16** will attempt to extend the tip members even farther thereby stretching or placing the structural rib members in a stressed condition forming a substantially rigid structure that is capable of defining the focus point of the paraboloid with a relatively high degree of accuracy. The flexible material used for the reflector **12** may be a continuously reflective medium such as metallic coated plastic film, or a conductive mesh material affixed to the structural rib members **14** by any suitable means such as a contact type cement. In FIG. 1, each of the structural rib members **14** is provided with an individual cable to help collapse and extend that member. It is not necessary that each of the structural ribs have such a cable arrangement. For example, every second rib could have such a cable with the reflective material providing the necessary torque transmittal to the adjacent rib to collapse and controllably extend that rib.

Referring to FIG. 2, the central core member **20** and the spindle member **18** are shown partially cut away. The outer periphery of the central core member **20** is formed into the shape of a series of saw tooth steps **34**. The plurality of structural rib members **14** are recessed onto or into these steps and affixed to the central core member **20** by means of fasteners **32** which may be bolts or a welding process. The shaft member **22** is hollow and extends upward to the central portion of the central core member **20** and is fixedly attached to the central core member **20**. The spindle member **18** resembling the inverted funnel is rotatably attached to the shaft member **22** by means of race-type ball bearings **36**. A worm gear **38** is fixedly attached to the spindle member **18**. A screw gear **58** when rotated drives the worm gear which in turns drives the spindle member **18** about the central axes of the shaft **22**. The screw gear **58** is connected to the electric motor **52** by the wheel gears **54** and **56**. The motor **52** is fixedly attached to the central core member **20** by means of brackets **60** or other suitable apparatus.

Opening **62** are provided in the shaft **22** for the electrical leads **64** which are connected to the motor **60** and to the power source **66**. The power source **66** may be batteries, or solar cells, or any other power source adequate to drive the motor **52**.

FIG. 3 illustrates one of the structural rib members **14** more clearly defining the parabolic curvature **30**. The tip **24** having the opening for attaching the cables **16** and the openings **32** for attaching the rib members to the central housing member **20**. As shown, the portion of the rib which is attached to the central housing is relatively thick as compared to the tip. By slimming the rib member down as it approaches the tip, a considerable savings in weight can be achieved. The structural rib **14** may be formed in many shapes; two of which are shown in FIGS. *4a* and *4b*. In FIG. *4a*, the rib is formed with a curvature corresponding to moving the tip **24** to the position defined by the line **40** and forming the rib in an unstressed position at this point such that when no pressure is applied, the rib will remain fixed at the point **40**. As the reflector is then expanded, the rib tip **24** is forced into the position defined by the line **42**. The spring tension in the rib **14** attempts to return the rib to the position **40** and thereby maintains a constant tension or pressure which tends to begin the folding phase of the collapsible reflector as soon as the spindle begins to unwind about the shaft. Referring now to FIG. *4b*; in this figure the rib member **14** is initially formed along the dotted position indicated by the line **42**. As the reflector is expanded and tension is applied to the tip, the rib unfolds and assumes the position defined by the line **44**.

Referring to FIG. 5, the expandable reflector shown therein is similar to the embodiment illustrated in FIGS. 1 to 4 except that in this embodiment the shaft **22** extends upward from the reflector towards the focus point and a cylindrical central member **50** is mounted for rotation about the axis **22** in a similar manner as was mounted the spindle **18**. Wires, or cables **16** extend from peripheral points about the central member **50** to tips of the rib members **14**. In operation, the central cylindrical member **50** is rotated about the axis **22** to wind on its outer surface the cables **16** which in turn pull the rib member **14** upwards and around the axis **22**. In this particular embodiment, because the focuse point of the antenna is licated somewhere within the central rotating member **50**, the member **50** and its associated components should be made of a dielectric material which will not hamper the reception of electromagnetic radiation.

While there has been shown what are considered to be the preferred embodiments of the present invention, it will be manifest that many changes and modifications may be made therein without departing from the essential spirit of the invention. It is intended, therefore, in the annexed claims, to cover all such changes and modifications as may fall within the true scope of the invention.

What is claimed is:

1. An expandable structure comprising in combination:
- a central member;
- a shaft extending through said central member;
- a plurality of rib members fixedly attached to said central member and extending radially therefrom, wherein said rib members are shaped to form a parabolic skeleton;
- a spindle member rotatably mounted to said shaft;
- a plurality of cables extending from the tips of said rib members to the outermost surface of said spindle member;
- a collapsible sheet of conductive material attached between each of said rib members, said conductive material when stretched between said ribs forming a parabolic reflector, the focal point of which lies along the axis of said shaft and positioned at a point corresponding to the position of said spindle; and

means for rotating said spindle member about said shaft.

2. The invention, according to claim **1**, wherein said spindle member is shaped as a funnel to provide a varying torque to said tip members.

3. The invention, according to claim 1, wherein said spindle member is made of a dielectric type material.

4. The invention, according to claim 1, wherein said rib members in the expanded position extend radially from said central member along substantially straight lines.

5. The invention according to claim 1, wherein said rib members in the expanded position extend radially from said central member along substantially curved lines.

6. The invention, according to claim 1, wherein said rib members are made from material exhibiting spring-type properties.

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135—20; 343—840