Nov. 15, 1966 R. R. CARMAN ET AL 3,286,259

UNFURLABLE REFLECTOR

Filed April 30, 1964 2 Sheets-Sheet 1

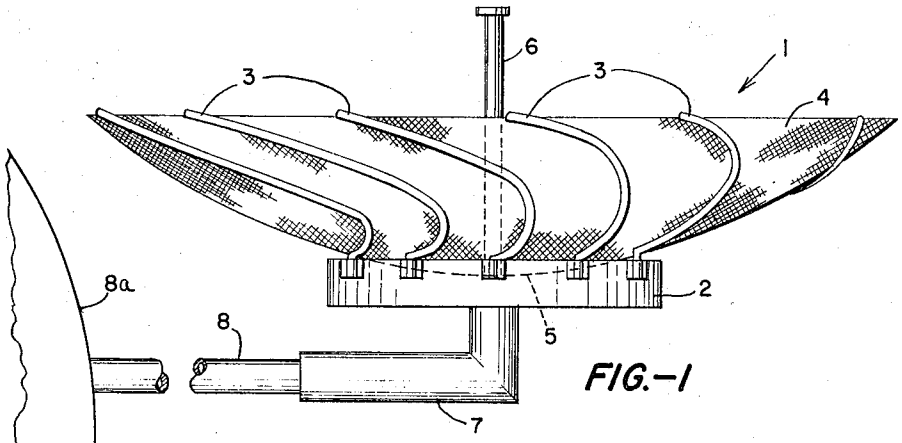


FIG.-1

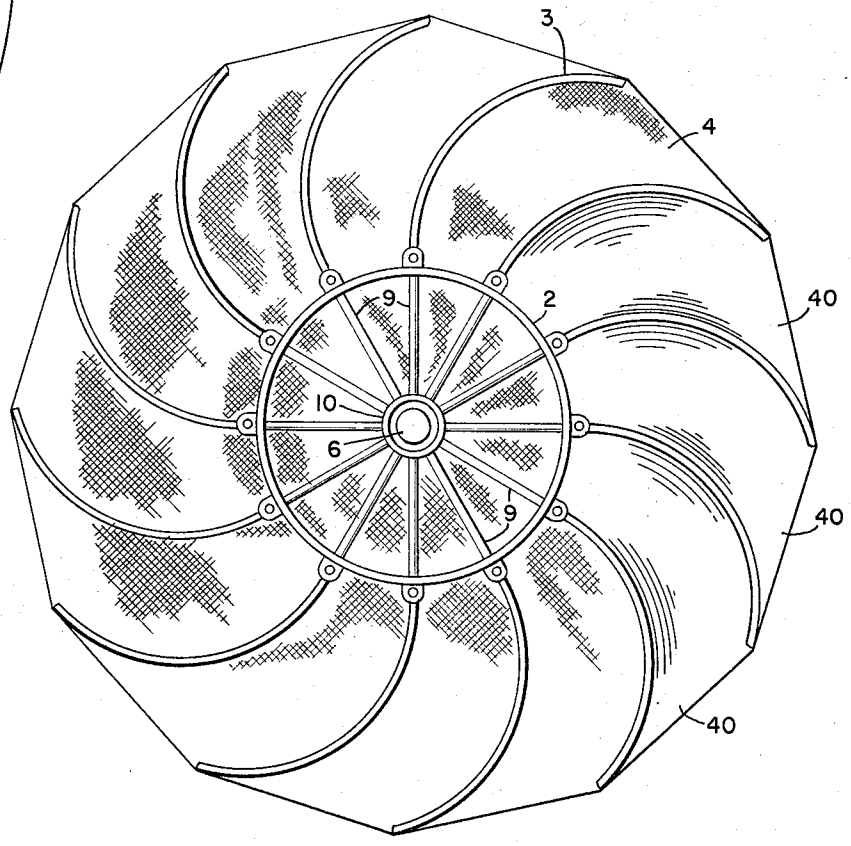


FIG.-2

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UNFURLABLE REFLECTOR

Filed April 30, 1964 2 Sheets-Sheet 2

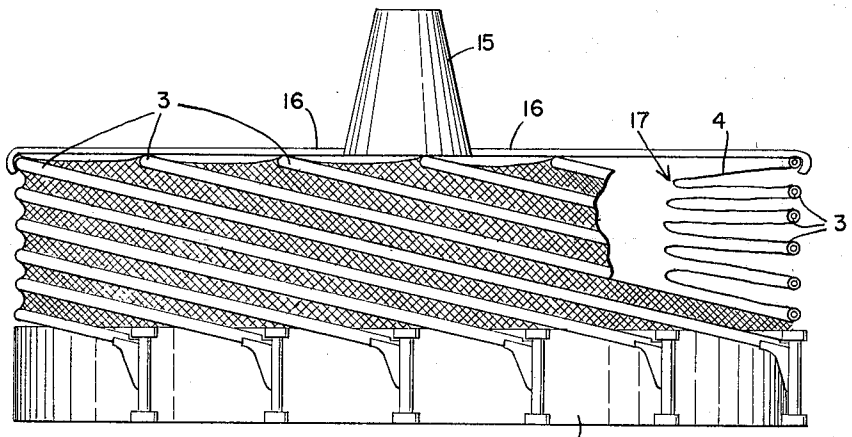


FIG.-3

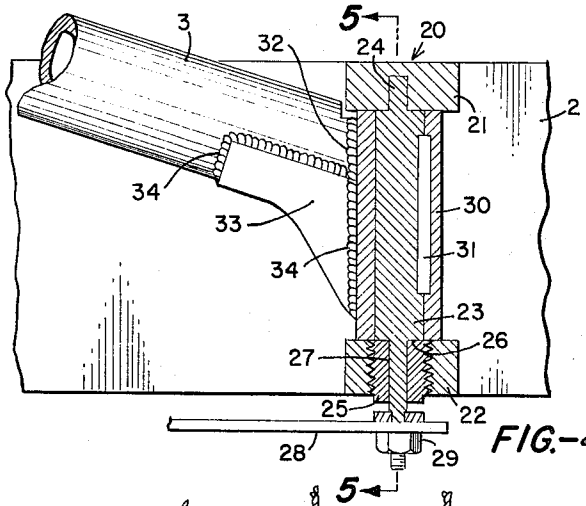


FIG.-4

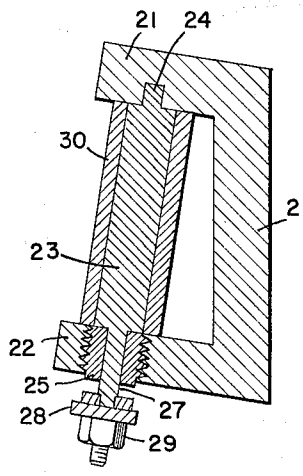


FIG.-5

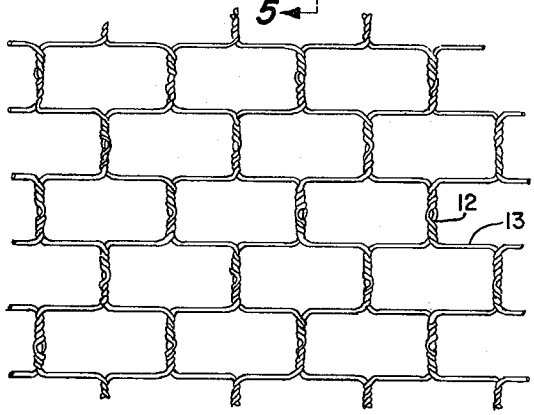


FIG.-6

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3,286,259

UNFURLABLE REFLECTOR

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Filed Apr. 30, 1964, Ser. No. 363,771
8 Claims. (Cl. 343—18)

This invention relates to an unfurlable reflector which may be used to reflect solar or electromagnetic wave energy, and more particularly to a unique application where the reflective surface unfurls laterally from a central hub to an extended diameter approximately three times the packaged diameter, and where the package size is small in height and compact in storage.

In many situations it is desirable to transmit signals, originating at a common point, along parallel paths. Conversely, it may also be desirable to collect signals travelling along parallel paths and concentrate them at a common point. In order to accomplish these aims a reflector device is used. A parabola has the distinguishing characteristic that it will reflect all parallel impinging signals to a common focal point and is probably the most desirable shape. Also, any signals originating at that point and impinging on the reflector will leave the reflector along parallel paths.

This type of reflector is particularly applicable to usage on space vehicles either in combination with a solar receiver or with a radar or radio-transmitter or receiver.

In the space situation, and many other situations, it may be desired to transport the reflector, such as launching it by suitable means to its desired location in space. Since the reflecting parabola is rather large and is difficult to transport through the atmosphere in its operative condition, it is necessary to collapse the parabola during flight or for any other transporting operation.

Various types of foldable or unfurlable parabolic reflectors for space vehicles have been developed, but these generally have involved utilizing a plurality of reflective surfaces folding up vertically or longitudinally around a central extending portion from a mounting hub. An example of this type of reflector is indicated in U.S. Patent No. 3,064,534. This type of reflector is open to the objection that the complicated rotation and positioning of the reflective surfaces does not achieve a true parabolic shape, and the upright positioning of the parabolic surfaces during transportation leaves them vulnerable to damage from gravitational effects or other large forces occurring during a rocket launch. A more compact, more durable unfurlable reflector is needed.

It is the general object of the invention to avoid and overcome the foregoing and other difficulties of prior art practices and meet the needs of the art particularly with regard to an RF antenna by the provisions of an unfurlable parabolic reflector wherein a plurality of curved ribs are pivotally mounted to the outer periphery of a substantially cylindrically shaped central hub so that they can fold out laterally like the petals of a flower to substantially increase the diameter of central hub, and with a reflective mesh screen operatively affixed to the ribs to form a substantially parabolically shaped dish when the ribs have been moved to the outwardly extended position.

A further object of the invention is to provide an unfurlable reflector utilizing a plurality of curved ribs pivotally mounted to the outer periphery of a cylindrically shaped hub wherein the ribs are mounted at an angle with respect to the hub so that upon lateral rotation to an inward position they stack one upon another to substantially conform to and extend the shape of the hub.

Another object of the invention is to provide an unfurlable reflector wherein the pivotally mounted ribs are

stacked upon each other to uniformly and solidly receive any thrust forces occurring during satellite launch to substantially eliminate the possibility of damage to the reflector during satellite launch.

A further object of the invention is to provide an unfurlable reflector which may utilize a flexible electromagnetic wave reflective cloth-like material as the reflective surface or may use large solid formed pieces to form the reflective surface without altering the physical construction of the supporting frame.

A further object of the invention is to provide an unfurlable reflector which unfolds laterally from a central hub so that no complex movements are involved, and wherein the construction is extremely simple, yet highly effective and generally reasonable in cost.

The aforesaid objects of the invention and other objects which will become apparent as the description proceeds are achieved by providing in a foldable reflector adaptable for a space environment the combination of a substantially cylindrically shaped hub having an electromagnetic wave reflecting top surface, pivot means operatively mounted at equally spaced points around the circumference of said hub substantially adjacent to the reflective top surface thereof, a plurality of ribs each having substantially the curvature of the circumference of the hub and being of about ½ the length thereof with one pivotally mounted to each of the pivot means, so that the pivotal plane of the ribs is in an angled relationship with respect to the reflective top surface of the hub so that the ribs stack on top of each other when pivoted inwardly, and said ribs defining a parabolic dish shape in combination with the top reflective surface of the hub when pivoted outwardly until the pivoted end thereof is substantially perpendicular to the circumference of the hub, means to pivot the ribs to the inwardly stacked position and to the outwardly parabolic dish position, and flexible reflective means operatively affixed to the ribs and adapted to fill the spaces between adjacent ribs to define a parabolic dished reflective surface when the ribs are moved outwardly to the parabolic dished position.

For a better understanding of the invention, reference should be had to the accompanying drawings, wherein:

FIGURE 1 is a side elevational view of the foldable reflector of the invention with the curved ribs in the outwardly extended position to define the parabolic dished shape;

FIGURE 2 is a plan view of the reflector of FIGURE 1 showing the relationship of the pivotal ribs to the central hub and how the reflective mesh is attached to form the parabolic dish;

FIGURE 3 is a side elevation partially broken away of the foldable reflector of FIGURE 1 with the ribs pivoted into the stacked position and a protective cover positioned over the central radiator to hold the ribs in stacked position while further illustrating in the broken away portion the folded relation of the flexible reflective screen;

FIGURE 4 is an enlarged broken away partially sectioned elevational view of one of the pivotal mountings for the curved ribs with the rib in the folded position;

FIGURE 5 is an enlarged sectioned side elevation of the pivotal mounting of FIGURE 4 taken on the line 5—5 thereof; and

FIGURE 6 is a broken away section of the flexible reflector screen showing the weave pattern therein to achieve the complex curvature desired.

While it should be understood that the foldable reflector of the invention may be adaptable to use on earth itself, it is particularly suited for being launched in conjunction with a satellite into an orbital pattern in space to provide either a radar-radio or solar reflective

surface as desired, and hence it has been so illustrated and will be so described. Particularly, the description is directed to the radar-radio reflective surface.

With reference to FIGURE 1 of the drawings, the numeral **1** indicates generally a foldable reflector comprising a substantially cylindrically shaped hub **2** pivotally mounting a plurality of curved ribs **3** at equally spaced distances around its periphery. The ribs **3** have operatively affixed thereto a lightweight wire mesh **4** which describes a parabolic dish shape as defined by the ribs **3** and the hub **2**. Any suitable convenient means can be utilized to attach the wire mesh **4** to the ribs **3** and the hub **2**. The invention anticipates that the wire mesh **4** will be made from a screen material in the form of Invar, and of a particular orthotropic weave to allow for proper stretching during furling operation to conform to the parabolic shape as more fully described hereinafter. The top surface of hub **2** is so formed to continue the parabolic dish shape of the screen **4** and forms a reflective surface as indicated by the dotted line **5**. A radiating feed **6**, at the focal point, is operatively mounted to the center of the hub **2** in order to provide for radar or radio radiation and reception from the reflective surface defined by the wire mesh **4**. A support frame **7** is provided to mount the hub **2** centrally, and this may be made to telescope onto a frame **8** which generally will be affixed to a space craft **8***a*. Apparatus (not shown) may be utilized to effect relative movement between the support frame **7** and the frame **8** affixed to the space craft. Thus, the entire reflector assembly may be moved outwardly from the space craft **8***a* a sufficient distance to allow the ribs **3** to be moved to the extended position thus unfurling the reflector without interference with the space craft.

FIGURE 2 provides a plan view of the relationship of the curved ribs **3** to the hub **2**. Note that a plurality of strengthening beams **9** support the hub **2** to a central frame **10** to which the support frame **7** may be attached. The invention contemplates that the ribs **3** will be pivotally mounted to the hub **2** at equally spaced points around the outer circumference thereof. The invention further contemplates that each rib **3** shall be formed from a radius substantially equal to the radius of the hub **2**, and having a length of substantially ½ the cirmumference of the hub **2**. In this manner, when the ribs are moved to the outwardly or extended position, as indicated in FIGURE 2, the pivotal end is substantially perpendicular to the circumference of the hub **2** thereby extending the diameter of the reflector to about three times the diameter of the hub **2**. When the ribs **3** have come to a pre-determined open position and locked as indicated in FIGURE 2, the reflective wire mesh is properly stretched into a substantially true parabolic dished shape.

As clearly seen in FIGURE 1, the parabolic dish shape as defined by the curved ribs **3** offers a complex curvature of the wire mesh **4**. A conventionally woven wire mesh will not achieve this complex contour as flexible extensions in the warp and woof directions are not possible. Thus, the invention comtemplates that a wire mesh, as indicated in FIGURE 6 will be utilized. This type of wire mesh will permit alternate stretching in a vertical and a horizontal direction because a plurality of vertical connection strands, indicated generally by numeral **12** alternately connect the horizontal strands indicated generally by numeral **13**. This type of rectangular weave allows in excess of 100% elongation in the warp direction with a consequent shortening in the woof direction without yielding of the wire elements. This type of material will readily stretch one way or the other to provide the proper contours of the wire mesh **4** into the parabolic dished shape upon extension of the ribs **3**.

FIGURE 3 illustrates the foldable reflector in the stacked position where the ribs **3** have been pivoted inwardly towards the hub so that they tend to come into engagement with the outer surface of the hub. However, the ribs **3** are mounted at a somewhat inclined angle with relation to the plane of the hub so that they stack one upon another as clearly indicated in FIGURE 3. Note that a protective cover **15** may be placed over the center of the stacked ribs **3** to protect the antenna **6**, and that arms **16** extending from the cover **15** hook over the ends of the ribs **3** to securely latch the stacked assembly into a fixed position. The cover **15** would be affixed to the hub **2** in a convenient manner. The right hand side of FIGURE 3 is broken away to show that the reflective wire mesh **4** tends to fold inwardly into a plurality of folds indicated generally by numeral **17** when the ribs are rotated inwardly to the stacked position.

It is an important feature of the invention that the ribs **3** be pivotally mounted to the hub **2** so that upon rotation to the outwardly extended position they provide a true parabolic dish shape with reference to the hub **2** as shown in FIGURE 1, when moved to the inward position they readily stack on top of each other as illustrated in FIGURE 3. This pivotal mounting is shown in enlarged cross section in FIGURE 4, and is indicated generally by numeral **20**. The pivotal mounting includes a pair of mounting brackets **21** and **22** operatively affixed to the hub **2** by convenient means such as welding, bolting or integrally forming therewith. A rotational pin **23** is slidably received through the bottom mounting plate **22** and has a smaller machined end **24** journalled in the upward support plate **21**. A locking nut **25** removably screwed into the bottom support plate **22** operatively engages a lower shoulder **26** of the pin **23** to securely hold it in rotatable position between the upper and lower support plates **21** and **22**. A smaller machined end **27** of the pin **23** rotatably passes through the locking nut **25** and has an operating lever **28** operatively secured thereto by bolt means **29**. The lever means **28** is adapted to be rotatable in the horizontal plane to rotate the pin **23**. A sleeve **30** is slidably received over the pin **23** and locked into position therewith by a key **31**. One of the ribs **3** is operatively secured to the sleeve **30** by convenient means such as welding at **32**. In order to insure a proper structural relationship between the rib **3** and the sleeve **30**, a brace support **33** is operatively welded as at **34** therebetween. Thus, rotation of the lever **28** provides rotation of the rib **3** from the stacked position indicated in FIGURE 3 to the extended position indicated in FIGURES 1 and 2, or vice versa. Suitable means (not shown) such as pulleys or levers attached to the hub **2** through the mounting frames **7** and **8** may be utilized to actuate the lever **28**. The invention contemplates that every pivot means **20** will be actuated simultaneously to move to and/or from the stacked or extended positions.

Another important feature of the invention is illustrated in FIGURE 5 where it is seen that the pin **23** is actually mounted at an angle with respect to the hub **2**. This insures that the ribs **3** move downwardly into the stacked position when they are rotated in that direction and are actually moving somewhat upwardly when rotated to the extended position to insure the proper parabolic shape and stretching into position of the wire mesh **4**. The downward movement into the stacked position further compresses the height of the folded package. The precise angular relationship of the pin **23** as defined by the support flanges **21** and **22** in relation to the hub **2** can vary between about one and about fifteen degrees depending upon the desired parabolic shape and the size of the reflective surface It should also be understood that the pivotal mounting of the ribs does not need to be angled as indicated in FIGURE 5 in order to accomplish the objectives of the invention. However, each rib **3** must be mounted at an upwardly directed angle with relation to the hub **2**, as indicated in FIGURES 3 and 4 to insure that the ribs actually do stack when moved to the inward position.

While the invention has been illustrated and described as utilizing a wire mesh **4** as the reflective surface for the purpose of lightening the weight and minimizing inter-

ference with solar energy, rigid accurately contoured petals formed to the shape between adjacent ribs **3** in the extended position, and indicated by sections **40** in FIGURE 2, may be operatively affixed to each rib **3**. These solid sections **40** may be adapted to slide laterally over each other when the ribs are moved to the closed position and to form the desired parabolic shape when the ribs are moved to the extended position. This type of a solid reflective surface would probably be most adaptable for use as the reflective surface for a solar reflector, but could also provide a high frequency RF antenna.

Thus, it is seen that the objects of the invention have been achieved by providing a foldable reflector utilizing a plurality of ribs **3** pivotally mounted at equally spaced points on the outer peripheral surface of a hub **2** so that the ribs open laterally from a stacked position substantially extending the hub **2**, as indicated in FIGURE 3, to an extended position where the pivoted ends are substantially perpendicular to the circumference of the hub **2** to form a parabolic dished reflective surface. The ribs **3** are pivotally mounted at an angle with respect to the hub **2** to provide the parabolic shape and insure they will form a stacked relationship when they are moved inwardly towards the hub **2**. Further, the pivotal mountings may be angled so that the ribs moved downwardly to compress the vertical height of the reflector in the stacked position and move upwardly to insure the proper parabolic shape when the ribs are moved to the extended position. Generally, the invention contemplates that Invar metal will be used for the wire mesh and rib tubing to reduce any heat distortion and to increase strength at a reduced weight.

The simple mechanical structure of the apparatus utilizes no complex movements and the stacked relationship of the ribs in the folded position provided a compact structure which rests upon itself and is adapted to receive great thrusts in the vertical direction upon launch without any possible structural damage. This design is adaptable to repeated erection and storage, launching, and any assembly or positioning movements in space. The angled pivotal mounting of the curved ribs **3** is designed to maintain mechanical strength and insure surface accuracy that will provide a long efficient life time of operation. The utilization of the wire mesh adaptable for stretching in the warp and woof direction insures adherence to the complex surface of the parabolic shape.

While in accordance with the patent statutes only one best known embodiment of the invention has been illustrated and described in detail, it is to be particularly understood that the invention is not limited thereto or thereby, but that the inventive scope is defined in the appended claims.

What is claimed is:

1. In a foldable reflector adaptable for a space environment the combination of

a substantially cylindrically shaped hub having an electromagnetic wave reflective top surface,

pivot means operatively mounted at equally spaced points around the circumference of said hub substantially adjacent to said reflective top surface thereof,

a plurality of ribs each having substantially the curvature of the circumference of said hub and being of about ½ the length thereof with one rib pivotally mounted to each of said pivot means so that when pivoted inwardly the ribs tend to come into engagement with the outer surface of said hub except that the pivotal plane of the ribs is in an angled relationship with respect to the reflective top surface of said hub so that said ribs stack on top of each other when pivoted inwardly, and said ribs defining a parabolic dished shape in combination with said top reflective surface of said hub when pivoted outwardly so that the pivoted end thereof is substantially perpendicular to the circumference of said hub,

means to pivot said ribs to the inwardly stacked position and to the outwardly parabolic dished position, and

flexible reflective means operatively affixed to said ribs and adapted to fill the spaces between adjacent ribs to define a parabolic dished reflective surface when said ribs are moved outwardly to the parabolic dished position.

2. In a foldable reflector adaptable for a space environment the combination of

a substantially cylindrically shaped hub having a parabolic shaped reflective top surface,

pivot means operatively mounted at substantially equally spaced points around the circumference of said hub substantially adjacent to said reflective top surface thereof,

a plurality of curved ribs with one pivotally mounted at its end to each of said pivot means adapted to pivot laterally with relation to said hub to stack on top of each other when pivoted toward said hub and define a parabolic dished shape in combination with said top reflective surface of said hub when pivoted away from said hub,

means to pivot said ribs to the stacked position and to the parabolic dished position, and

flexible reflective means operatively affixed to said ribs and adapted to fill the spaces between adjacent ribs to define a parabolic dished reflective surface when said ribs are moved away from the hub to the parabolic dished position.

3. In a foldable reflector adapted for a space environment the combination of

a substantially cylindrically shaped base hub having a parabolic shaped reflective top surface,

a plurality of curved radial ribs pivotally mounted at one end to equally spaced points on the circumference of said hub, said ribs having a curvature substantially equal to the curvature of said hub and extending approximately ½ the length of the circumference thereof, so that said ribs describe a continuation of the parabolic shaped reflective top surface of said hub when said ribs are pivoted to an extended position where the ends of said ribs are substantially normal to the circumference of said hub, and said ribs adapted to stack on top of each other when pivoted toward said hub to an inward position to essentially conform to the cylindrical shape of the hub,

means to move the ribs from the inward position to the extended position,

flexible wire mesh reflector means connected between each rib and said hub adapted to be fully stretched to describe a continuation of the parabolic shaped reflective top surface of the hub when said ribs are moved to the extended position, and

receiving means operatively mounted at the center of said hub and extending along the axis of said parabolic shape of said wire mesh reflector means to lie on the focal point of said reflector means.

4. In a foldable reflector adapted for space environment the combination of

a substantially flat cylindrically shaped base hub having a parabolic shaped reflective top surface,

a plurality of curved radial ribs each pivotally mounted at one end to separate equally spaced points on the circumference of said hub so that said ribs describe a parabolic shape in combination with the reflective top surface of said hub when said ribs are pivoted laterally away from said hub to an extended position,

means to hold said ribs in a packaged position when they are moved laterally from the extended position to lie substantially adjacent to said hub,

means to move the ribs to the packaged position and to the extended position, and

flexible wire mesh reflector means connected between adjacent ribs and said hub adapted to be fully stretched to describe a parabolic shape with the reflective top surface of said hub when said ribs are moved to the extended position.

5. A foldable reflector as set forth in claim 4 which includes the pivotal mounting of the ribs being in angled relation to the longitudinal axis of the base hub so that the ribs move downwardly when moved away from said hub until the pivotal ends are substantially normal to the circumference of said hub.

6. A foldable reflector as set forth in claim 4 except that solid reflective materials are operatively secured to the ribs and adapted to fill the spaces therebetween when said ribs are moved to the extended position, and said solid materials are adapted to slide over each other to form layers when said ribs are moved to the packaged position.

7. In a foldable reflector adapted for a space environment the combination of

a flat circularly shaped base hub having a parabolic shaped reflective top surface,

a plurality of curved ribs each pivotally mounted at one end to separate equally spaced points on the circumference of said hub so that said ribs describe a parabolic shape in combination with the reflective top surface of said hub when said ribs are pivoted laterally away from said hub to an extended position,

means to store said ribs in a packaged position when they are pivoted laterally to lie adjacent said hub wherein the pivotal mounting of the ribs is angled in relation to the longitudinal axis of the hub so that the vertical height of the reflector is compressed as the rib moves downwardly when moved laterally towards said hub into the packaged position,

means to move the ribs to the packaged position and to the extended position, and

reflector means connected between adjacent ribs and said hub adapted to describe a parabolic shape with the reflective top surface of said hub when said ribs are moved to the extended position.

8. A foldable reflector as set forth in claim 7 except that a plurality of sheets of solid reflective materials adapted to fill the spaces between adjacent ribs are provided so that a sheet is operatively secured to each rib so that a parabolic surface is achieved when said ribs are moved to the extended position, and said solid sheets are adapted to slide over each other in layers when said ribs are moved to the packaged position.

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