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(54) **Ultra light weight thin membrane antenna reflector**

Antennenreflektor aus ultraleichter, dünner Membran

Réfecteur d'antenne en une membrane ultra légère et mince

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800-803, ORIKASA ET AL. 'SIDELOBE  
SUPPRESSION OF MESH REFLECTOR  
ANTENNA BY NON-REGULAR INTERVALS'**

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## Description

**[0001]** The present invention relates generally to light weight reflectors to be used with antennas, and more specifically to very light weight reflectors associated with satellite antennas formed from a tri-axial fabric, which is capable of undergoing some deformations due to accelerations and minor contacts, and returning to the original configuration after the deformation.

**[0002]** Reflector technology has always been an important consideration in antenna design. Since the cost of a launch is tied closely to the mass of the satellite, the weight of the antenna is at a premium. It is also important that the reflector be able to survive the extreme environment of launch and orbit conditions. These include high G-forces, acoustic noise and extreme temperature. So called "shaped" surfaces for reflectors are also highly desirable, in which reflector surfaces are intentionally distorted during manufacture so that regions of the radiation emanating from the reflector surface can be precisely controlled.

**[0003]** There have been a considerable number of reflector designs which have involved interwoven fabric of one type or other. One example is illustrated in U.S. Patent No. 4,092,453, issued to Jonda on May 30, 1978. The interweaving of a plurality of the strands of the fabric is oriented perpendicularly to other strands (the weave is bi-axial). While this interweaving process does provide for significant strength improvements over the prior art methods, the material of this patent suffers from having different strength characteristics when force is being applied to the fabric at different orientations. For example, when the force is being exerted parallel to the orientation of some of the strands of the fabric, the reflector will exhibit a greater resistance against deformation and deflection than when the force is being applied in the plane of the fabric, yet at some angle to the strands of the fabric.

**[0004]** Both U.S. Patent No. 4,868,580, issued September 19, 1989 to Wade and U.S. Patent No. 4,812,854, issued March 14, 1989 to Boan et al. illustrate different interweaving patterns for the fabric reflector from the perpendicular weave described in Jonda; both of these prior art weaves will under certain situations exert a greater resistance to applied stress, for a given weight than Jonda. These weaving configurations still exhibit different characteristics when a constant force is applied at different orientations to the fabric, within the general plane of the fabric.

**[0005]** Another reflector which utilizes interwoven fabric is illustrated in U.S. Patent No. 4,635,071, issued on January 6, 1987 to Gounder et al. The strands of fabric in each ply of fabric is oriented parallel to all of the other strands in that ply of fabric. There are multiple plies of fabric, each of the ply is oriented approximately sixty degrees to the other plies of fabric. The strands of fabric which are oriented in different directions are not intertwined. Also, utilizing fabric with more than one ply leads

to extra material expense and manufacturing challenges.

**[0006]** US Patent No. 5,070,914, issued Dec. 10, 1991 to Fukuta et al discloses the production of a multi-axial (at least tri-axial) intertwined fabric, which produces substantially constant resistance against deflection when the forces are applied within the plane of the material, applicable to the production of a lightweight, resilient reflectors which are associated with antennas to be used in spacecraft and in other applications. However, no suitable lightweight supports for such fabrics are disclosed.

**[0007]** The present invention relates to an antenna reflector and support including a plurality of strands of fabric, in which a plurality of strands which are oriented along distinct axis are intertwined with respect to each other and is supported solely by an outer support ring attached by spaced support members to the inner ring of a lightweight support structure. The multi-axial fabric is at least tri-axial.

**[0008]** According to an aspect of the present invention, there is provided an ultra lightweight thin membrane space antenna reflector which is reflective of high frequency radiation, including microwaves, and has a low coefficient of thermal expansion, comprising a support member having bonded thereto a membrane of a single ply fabric woven of high modulus fibers and pre-impregnated with a toughened resin, the single ply fabric being woven from fibers which are orientated along at least three distinct axes and are intertwined with respect to each other to provide the fabric with quasi-isotropic strength properties whereby it possesses the same strength and distortion-resistance in substantially all directions, characterised in that the support member comprises an outer ring and a rear support portion, comprising an inner ring connected to and supporting the outer ring by means of a plurality of spaced support members, the membrane being attached only to, and supported only by, the outer ring.

**[0009]** In order that the invention and its various other preferred features may be understood more easily, some embodiments thereof will now be described, by way of example only, with reference to the drawings, in which:-

Figure 1 illustrates a perspective view of one embodiment of spacecraft (14) containing an antenna (12) and an associated reflector (10) constructed in accordance with the present invention,

Figure 2 illustrates a side view of one embodiment of reflector (10) constructed in accordance with the present invention to be utilized in conjunction with the spacecraft (14) illustrated in Figure 1,

Figure 3 illustrates a perspective view of a support (18) of the reflector of Figure 2,

Figure 4 illustrates a side view of the support (18) of Figure 3,

Figure 5 illustrates an exploded view of one embod-

iment of multi-axial fabric used in the reflector of Figure 2, and

Figure 6 illustrates a similar view to Figure 5 of a prior art bi-axial fabric weave.

**[0010]** While the present disclosure describes a reflector used on conjunction with a spacecraft, this application (and the specific configuration of the reflector) and materials is intended to be illustrative and not limiting in scope. The present invention is meant to apply to any reflector which is to be utilized with any space or terrestrial application, whether it is associated with antennas or any other structure where reflectors are utilized. The present disclosure, however, is especially suited to spacecraft applications since it provides a very lightweight, durable, and resilient structure.

**[0011]** The present invention is concerned with an ULTRA-light weight thin membrane reflector 10, suitable for use with an antenna 12 on a spacecraft 14 (in the illustration, a satellite) as illustrated in Figure 1. The spacecraft also has vanes 15 which do not form a part of the present invention. The thin membrane reflector 10, as illustrated in Figure 2, comprises a support 18 including an outer ring 20 and a rear support portion 22. Also included in the thin membrane reflector 10 is a thin membrane 24 which is formed from a fabric 26 containing a multitude of strands, as described below. A typical size of the thin membrane reflector 10, when properly supported, is typically within the range of 1 to 3 meters, but may be any size which is desired, and applicable, and may be deployed.

**[0012]** Exploded perspective and side views of the support 18 are illustrated in Figures 3 and 4, respectively. The support is formed from the outer ring 20 and the rear support portion 22. Both the outer ring and the internal support portion are configured to support the thin membrane 24 (illustrated in Figure 1) in a planar, parabolic, hyperbolic, or any other geometric shape as is desired for the specific application. The support is attached to the spacecraft utilizing any well known and suitable type of fastener affixed to a connection portion 29. The outer ring 20 preferably has a core formed from a graphite honeycomb structure to provide a strong and lightweight structure and also provide a very low thermal expansion: even though any light weight material (usually synthetic) which has a very low coefficient of expansion may be used. Such synthetic materials may be formed using any well known manufacturing technique, but foam molds have been found to be appropriate.

**[0013]** The reason why the coefficient of thermal expansion is so critical in satellite applications is the intense temperature variation between the side of the reflector which is facing the sun compared to the side of the reflector which is in the shade. The spacecraft temperature variation ranges from 130 degrees centigrade in the sun to minus 180 degrees centigrade in the shade. with this temperature variation. It is preferred, if not essential, that the coefficient of thermal expansion be ap-

proximately 1 part expansion per million parts for each variation of one degree centigrade, if the satellite reflector can be reliably used in communication applications. Larger or smaller coefficients of expansion may be required for satellite reflectors with different applications.

**[0014]** The thin membrane 24 is attached only to, and supported only by, the outer ring 20. The rear support portion 22 includes a plurality of support members 32 and an internal ring 33. The outer ring 20 is supported by the plurality of support members 32 (preferably at least six) which are also affixed to, and supported by, the internal ring 33. The rear support portion consists of uni-directional and spread fabric formed preferably from a graphite composition which has a high modulus and low coefficient of thermal expansion. Such materials, and manufacturing techniques, as described previously relative to the outer ring 20 may also be applied to the internal ring 33 and the support members 32. The rear support portion 22 is formed from a minimal number of tubular integrated parts, being designed for a minimal weight. Multi-layer insulation may also be applied to protect all or part of the reflector and support structure from the thermal environments experienced in orbit. The front surface of the thin membrane 24 is left uncovered to avoid the thermal effects of paint, or other covering.

**[0015]** As illustrated in Figure 5, the thin membrane 24 is a single ply membrane (in the approximate range from 0.010" to 0.040" thick) of high modulus (preferably graphite) fiber 40 applied as a tri-axial open weave fabric which is pre-impregnated with a toughened resin. Such membrane dimensioning is usually applied to be reflective to radiation of the microwave spectrum. Even though the above membrane material dimension range is inapplicable in the visible light or other short wavelength electro-magnetic spectrum (the radiation would pass through the membrane and/or deflect at random angles off the individual fibers), the radiation from microwave radiation will interface with the 0.010" to 0.040" thick membrane as if it were a continual material. It is envisioned that the woven thin membrane of the present invention would therefore be most applied to microwave applications.

**[0016]** Even though this disclosure is directed towards a triaxial weave, it is envisioned that any multi-axial weave may be used, as long as the multi-axial is at least tri-axial. In a tri-axial weave as illustrated in Figure 5, for example, sets of fibers are oriented along three coplanar axes 42a, 42b, 42c with each axis forming an intersecting angle of approximately sixty degrees to each other axis. The fibers oriented along each axis are interwoven with fibers which are not oriented in the same axis.

**[0017]** The advantages of a multi-axial weave as illustrated in Figure 5 is illustrated in comparison to a prior art bi-axial weave as illustrated in Figure 6. The bi-axial weave will exhibit considerably higher deflection resistance when a distorting force F1 is applied in a direction substantially parallel to one of the axes 46, 48 as com-

pared to when a distorting force F2 is applied at an angle 50a, 50b to both of the axes. The tri-axial weave of the present invention as illustrated in Figure 5 will display a much more uniform deflection resistance when regardless of whether a distorting force F3 is applied substantially parallel to one of the axis 42a, 42b, 42c; or a distorting force F4 is applied at a non-zero angle 54a, 54b, 54c to each of the three axis 42a, 42b, 42c since the distorting force F4 usually is closer to parallel to one or more of the axes than F2 would be. This uniformity of deflection resistance (the material is quasi-isotropic in the plane of the fabric) not only ensures that the thin membrane will undergo a more constant deflection when a random force is applied to the fabric, but also ensures that the fabric will be able to resist the type of force which would likely cause permanent distortion to the thin membrane 24. The tri-axial weave also ensures that a desired resistance against a force applied from any direction can be met without providing a substantial increase in weight to the thin membrane 24.

**[0018]** The described configuration of thin membrane reflector 10 is ultra-light, and is suitable for use as an antenna reflector for the communications satellite 14. The fabric of the thin membrane 24 is very light, thermally stable, durable, responsive and provides a reflective surface at radio frequencies (RF) and microwave frequencies. The fabric can be easily molded as a planar surface, a parabola, a hyperbola, or any other desired surface. The thin membrane 24 is deformable under the types of forces (either G-forces or contact forces) which the thin membrane reflector 10 is likely to encounter when the spacecraft is being launched or deployed.

**[0019]** It is also possible that the thin membrane 24 may be formed in some peculiar configuration to form a so called "shaped" surface. Such shaped surfaces are configured such that radiation may be reflected off the surface of the membrane in a desired manner. For example, of the thin membrane reflector 10 is-being used to apply radiation across a land-mass, it would be desired to confine the direction which the radiation is being directed to within the outlines of the landmass (which would usually be an irregular shape). It may be desirable to alter the configuration of the thin membrane 24 such that a higher percentage of the transmitted or received radiation is being directed to or from the desired location. "Shaping" the membrane can assist in the above applications, among others. One advantage of the present invention compared to other more rigid reflectors relative to shaping is that the shape of the thin membrane 24 present system is easier to manufacture. Certain prior art reflectors, since they are thicker and relatively rigid, are typically more difficult to shape precisely.

**[0020]** Being able to produce a thin membrane 24 of only one ply improves the thermal stability both by lowering the thermal mass of the thin membrane reflector 24 and by lowering the coefficient of thermal expansion (CTE) to almost zero, and also simplifies the manufacturing process considerably. The open weave of the fab-

ric permits acoustic vibrational forces (pressure exerted by sound waves) to be relieved through the membrane surface. The acoustic vibration environment experienced during the launch of the satellite 14 is a critical design constraint for large light weight surfaces such as the thin membrane reflectors 10.

## Claims

1. An ultra lightweight thin membrane space antenna reflector (10) which is reflective of high frequency radiation, including microwaves, and has a low coefficient of thermal expansion, comprising a support member (18) having bonded thereto a membrane (24) of a single ply fabric woven of high modulus fibers and pre-impregnated with a toughened resin, the single ply fabric being woven from fibers which are orientated along at least three distinct axes and are intertwined with respect to each other to provide the fabric with quasi-isotropic strength properties whereby it possesses the same strength and distortion-resistance in substantially all directions, **characterised in that** the support member (18) comprises an outer ring (20) and a rear support portion (22), comprising an inner ring (33) connected to and supporting the outer ring (20) by means of a plurality of spaced support members (32), the membrane (24) being attached only to, and supported only by, the outer ring (20).
2. A reflector (10) as claimed in claim 1 in which the support (18) has a honeycomb structure.
3. A reflector (10) as claimed in claim 1 or 2, wherein the multi-axis fabric is molded into a geometric shape, and the outer ring (20) is affixed to the shaped fabric at a plurality of spaced points.
4. A reflector (10) as claimed in any one of the preceding claims, wherein the outer ring member (20) is formed from graphite.
5. A reflector (10) as claimed in any one of the preceding claims, wherein the outer ring member (20) comprises a honeycomb structure.
6. A reflector as claimed in claim 5, wherein the outer ring member comprises a material having a low thermal expansion.
7. A reflector (10) as claimed in any one of the preceding claims, wherein at least a portion of the support (18) is molded.
8. A reflector (10) as claimed in claim 7, wherein the support (18) is molded by means of a foam mold.

9. A reflector (10) as claimed in any one of the preceding claims, wherein said fabric is molded in a parabolic shape.
10. A reflector (10) as claimed in any one of claims 1 to 8, wherein said fabric is molded in a planar shape.
11. A reflector (10) as claimed in any one of claims 1 to 8, wherein the reflector is molded in a hyperbolic shape.
12. A reflector (10) as claimed in any one of the preceding claims, wherein the fibers comprise a high modulus graphite fiber.
13. A reflector (10) as claimed in any one of the preceding claims, wherein fibers are interwoven.
14. A reflector (10) as claimed in any one of the preceding claims, further comprising multi-layer insulation which is applied to protect all or part of the reflector (10) from the thermal environments experienced in orbit.

#### Patentansprüche

1. Ultraleichter Raumantennenreflektor (10) mit dünner Membran, der Hochfrequenzstrahlung einschliesslich Mikrowellen reflektiert, und einen niedrigen thermischen Expansionskoeffizienten aufweist, umfassend ein Trägerelement (18) mit einer daran angebrachten Membran (24) aus einem einlagigen Gewebe, das aus Hochmodulfasern gewoben und mit einem Verstärkungsharz vorimprägniert ist, wobei das einlagige Gewebe aus Fasern gewoben ist, die entlang mindestens dreier bestimmter Achsen orientiert und miteinander verschlungen sind, um das Gewebe mit quasi-isotropen Festigkeitseigenschaften auszubilden, wodurch es dieselbe Festigkeit und Verwindungsfestigkeit in im wesentlichen allen Richtungen aufweist, **dadurch gekennzeichnet, dass** das Trägerelement (18) einen äusseren Ring (20) und einen hinteren Trägerteil (22) aufweist, der einen inneren Ring (33) aufweist, der mit dem äusseren Ring (20) verbunden ist und ihn stützt mittels einer Vielzahl von beabstandeten Trägerelementen (32), wobei die Membran (24) nur am äusseren Ring (20) befestigt ist und nur von ihm getragen wird.
2. Reflektor (10) nach Anspruch 1, in dem der Träger (18) eine Wabenstruktur aufweist.
3. Reflektor (10) nach Anspruch 1 oder 2, worin das multiaxiale Gewebe in eine geometrische Form geformt ist und der äussere Ring (20) am geformten Gewebe an einer Vielzahl von beabstandeten

Punkten befestigt ist.

4. Reflektor (10) nach einem der vorhergehenden Ansprüche, worin das äussere Ringelement (20) aus Graphit gebildet ist.
5. Reflektor (10) nach einem der vorhergehenden Ansprüche, worin das äussere Ringelement (20) eine Wabenstruktur aufweist.
6. Reflektor nach Anspruch 5, worin das äussere Ringelement ein Material umfasst, das eine niedrige thermische Expansion aufweist.
7. Reflektor (10) nach einem der vorhergehenden Ansprüche, worin mindestens ein Teil des Trägers (18) geformt ist.
8. Reflektor (10) nach Anspruch 7, worin der Träger (18) mittels einer Schaumform geformt ist.
9. Reflektor (10) nach einem der vorhergehenden Ansprüche, worin das Gewebe in eine Parabelform geformt ist.
10. Reflektor (10) nach einem der Ansprüche 1 bis 8, worin das Gewebe in eine planare Form geformt ist.
11. Reflektor (10) nach einem der Ansprüche 1 bis 8, worin der Reflektor in eine Hyperbelform geformt ist.
12. Reflektor (10) nach einem der vorhergehenden Ansprüche, worin die Fasern eine Hochmodulgraphitfaser umfassen.
13. Reflektor (10) nach einem der vorhergehenden Ansprüche, worin die Fasern verwoben sind.
14. Reflektor (10) nach einem der vorhergehenden Ansprüche, ferner umfassend mehrschichtige Isolierung, die zum Schutz des ganzen oder eines Teils des Reflektors (10) vor den im Weltraum anzutreffenden thermischen Umgebungsbedingungen angebracht ist.

#### Revendications

1. Réflecteur d'antenne spatiale à membrane mince extrêmement légère (10) réfléchissant le rayonnement de haute fréquence, y compris des micro-ondes, et ayant un faible coefficient de dilatation thermique, comprenant un élément support (18) ayant, liée à celui-ci, une membrane (24) d'un tissu en une seule épaisseur tissé avec des fibres de module élevé et imprégnées à l'avance d'une résine de durcissement, le tissu à une seule épaisseur étant tissé

à partir de fibres qui sont orientées au moins le long de trois axes distincts et sont entrelacées les unes par rapport aux autres pour constituer le tissu avec des propriétés de solidité quasi-isotropes de façon qu'il possède les mêmes solidité et résistance à la déformation sensiblement dans toutes les directions, **caractérisé en ce que** l'élément support (18) comprend une bague externe (20) et une partie de support arrière (22), comprenant une bague interne (33) reliée à et supportant la bague externe (20) au moyen d'une pluralité d'éléments support espacés (32), la membrane (24) étant fixée seulement à, et supportée seulement par, la bague externe (20).

2. Réflecteur (10) selon la revendication 1, dans lequel le support (18) a une structure en nid d'abeilles. 15
3. Réflecteur (10) selon la revendication 1 ou 2, dans lequel le tissu multiaxial est moulé en une forme géométrique et la bague externe (20) est fixé au tissu mis en forme en une pluralité de points espacés. 20
4. Réflecteur (10) selon l'une quelconque des revendications précédentes, dans lequel l'élément de bague externe (20) est fait de graphite. 25
5. Réflecteur (10) selon l'une quelconque des revendications précédentes, dans lequel l'élément de bague externe (20) comprend une structure en nid d'abeilles. 30
6. Réflecteur selon la revendication 5, dans lequel l'élément de bague externe comprend un matériau ayant une faible dilatation thermique. 35
7. Réflecteur (10) selon l'une quelconque des revendications précédentes, dans lequel au moins une partie du support (18) est moulée.
8. Réflecteur (10) selon la revendication 7, dans lequel le support (18) est moulé au moyen d'un moule de mousse. 40
9. Réflecteur (10) selon l'une quelconque des revendications précédentes, dans lequel ledit tissu est moulé en une forme parabolique. 45
10. Réflecteur (10) selon l'une quelconque des revendications 1 à 8, dans lequel ledit tissu est moulé en une forme plane. 50
11. Réflecteur (10) selon l'une quelconque des revendications 1 à 8, dans lequel le réflecteur est moulé en une forme hyperbolique. 55
12. Réflecteur (10) selon l'une quelconque des revendications précédentes, dans lequel les fibres comprennent une fibre en graphite de module élevé.
13. Réflecteur (10) selon l'une quelconque des revendications précédentes, dans lequel les fibres sont entrelacées.
14. Réflecteur (10) selon l'une quelconque des revendications précédentes, comprenant en outre une isolation multiépaisseur appliquée pour protéger tout ou partie du réflecteur (10) des environnements thermiques subis en orbite.

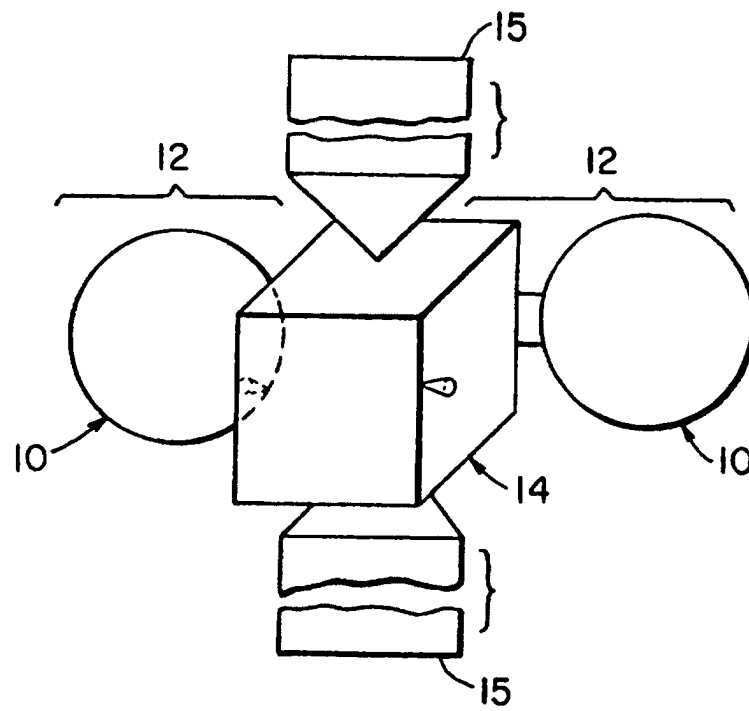


FIG. 1

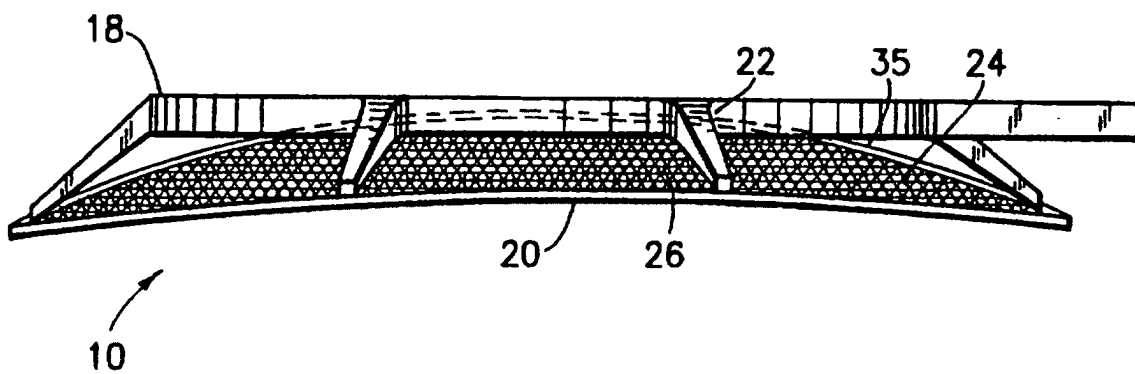


FIG. 2

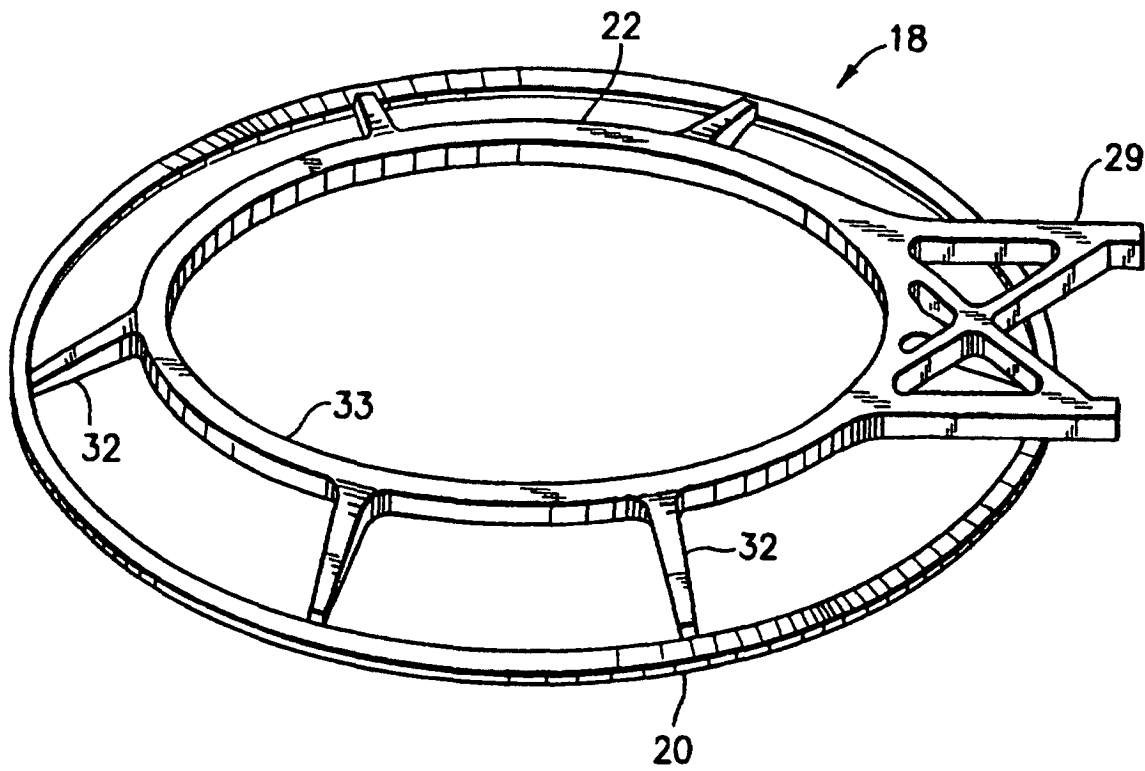


FIG. 3

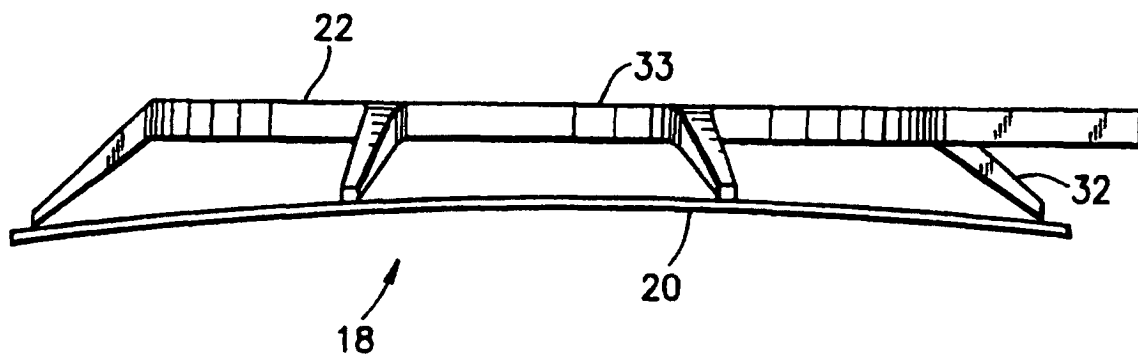


FIG. 4

FIG. 5

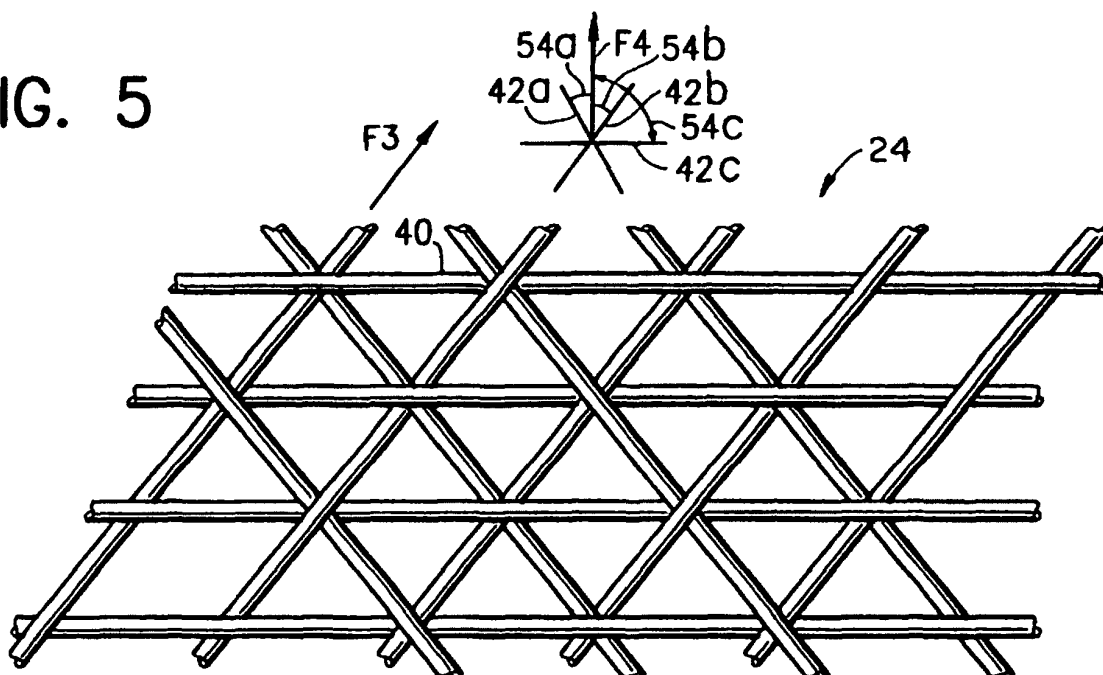


FIG. 6  
PRIOR ART

