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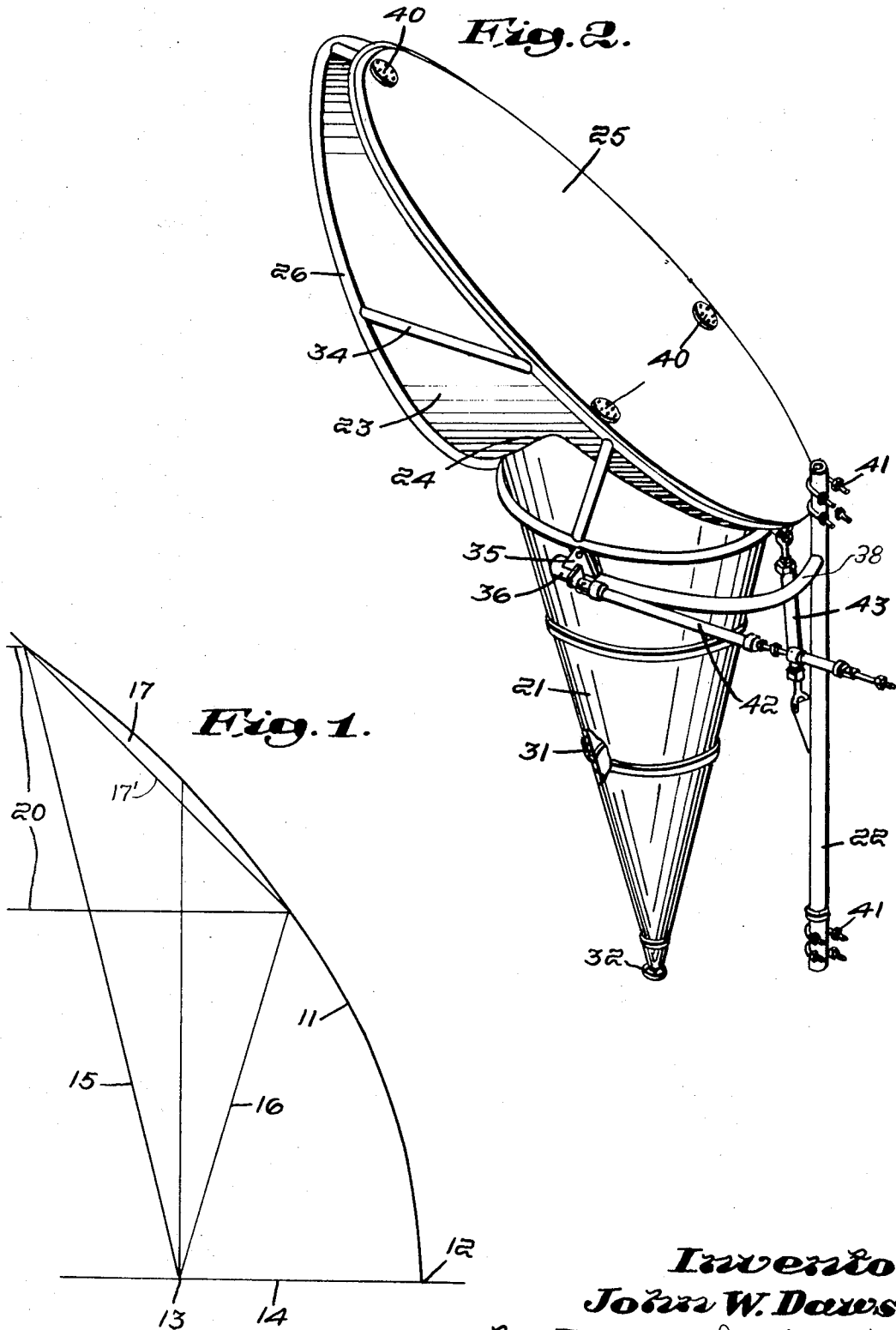
J. W. DAWSON

3,550,142

HORN REFLECTOR ANTENNA

Filed March 18, 1968

5 Sheets-Sheet 1



Inventor:
John W. Dawson,
 by Russell, Chittick & Pfund
Attorneys

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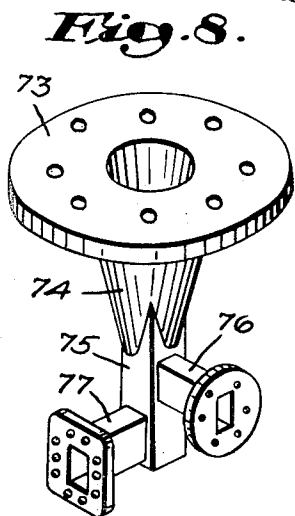
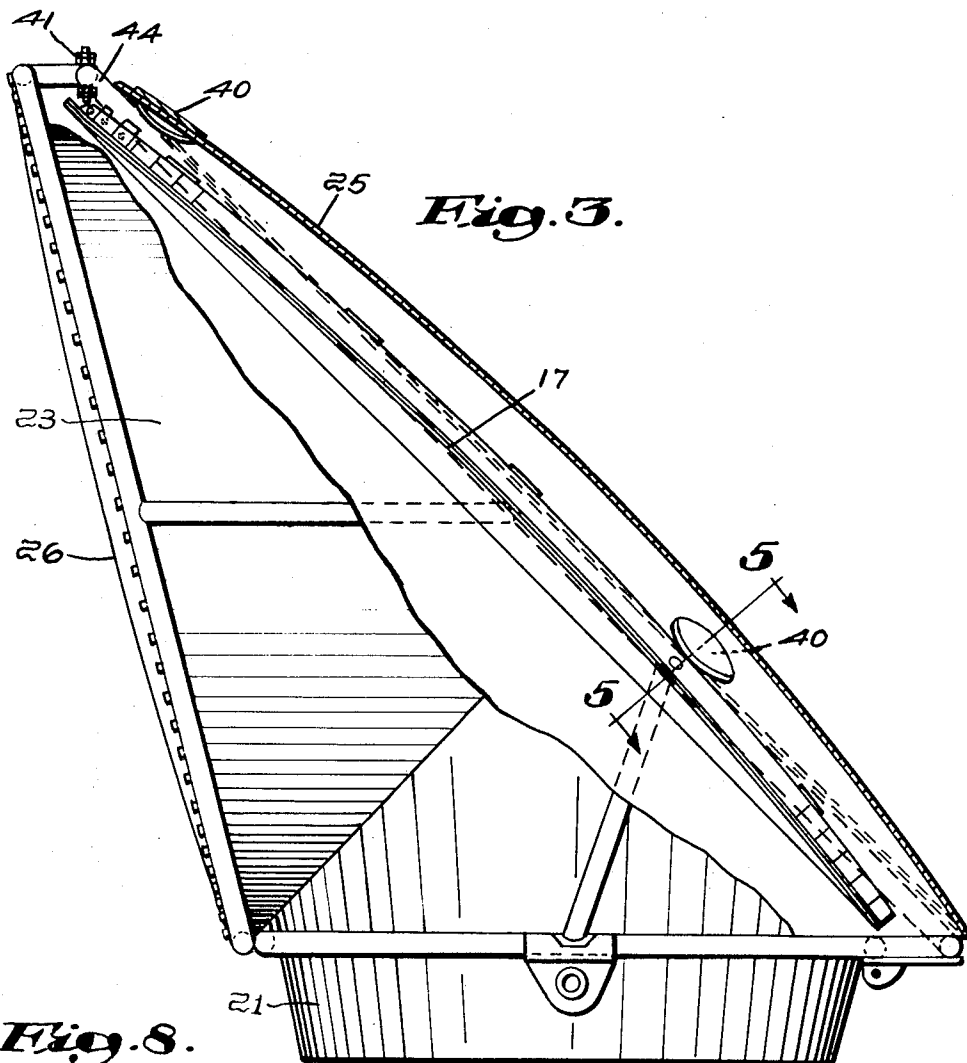
J. W. DAWSON

3,550,142

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5 Sheets-Sheet 2



Inventor:
John W. Dawson,
by Russell, Chittick & Pfund
Attorneys

Dec. 22, 1970

J. W. DAWSON

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Fig. 4.

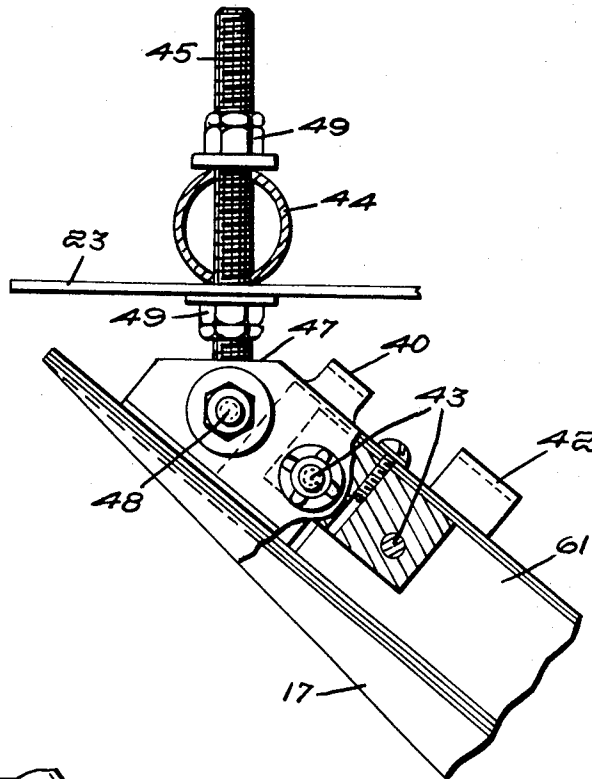
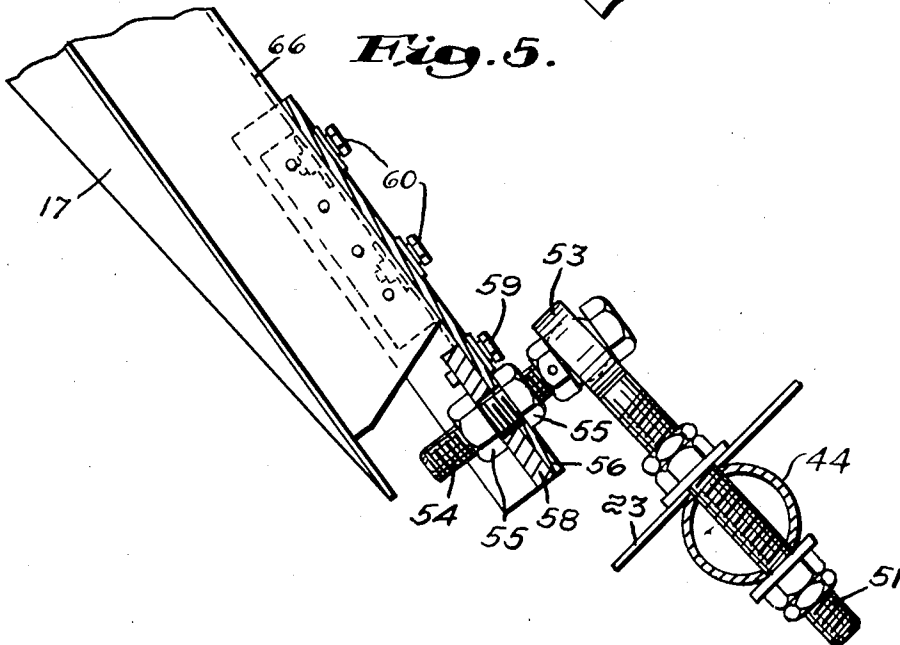


Fig. 5.



Inventor:
John W. Dawson,
by Russell, Chittick & Pfund
Attorneys

Dec. 22, 1970

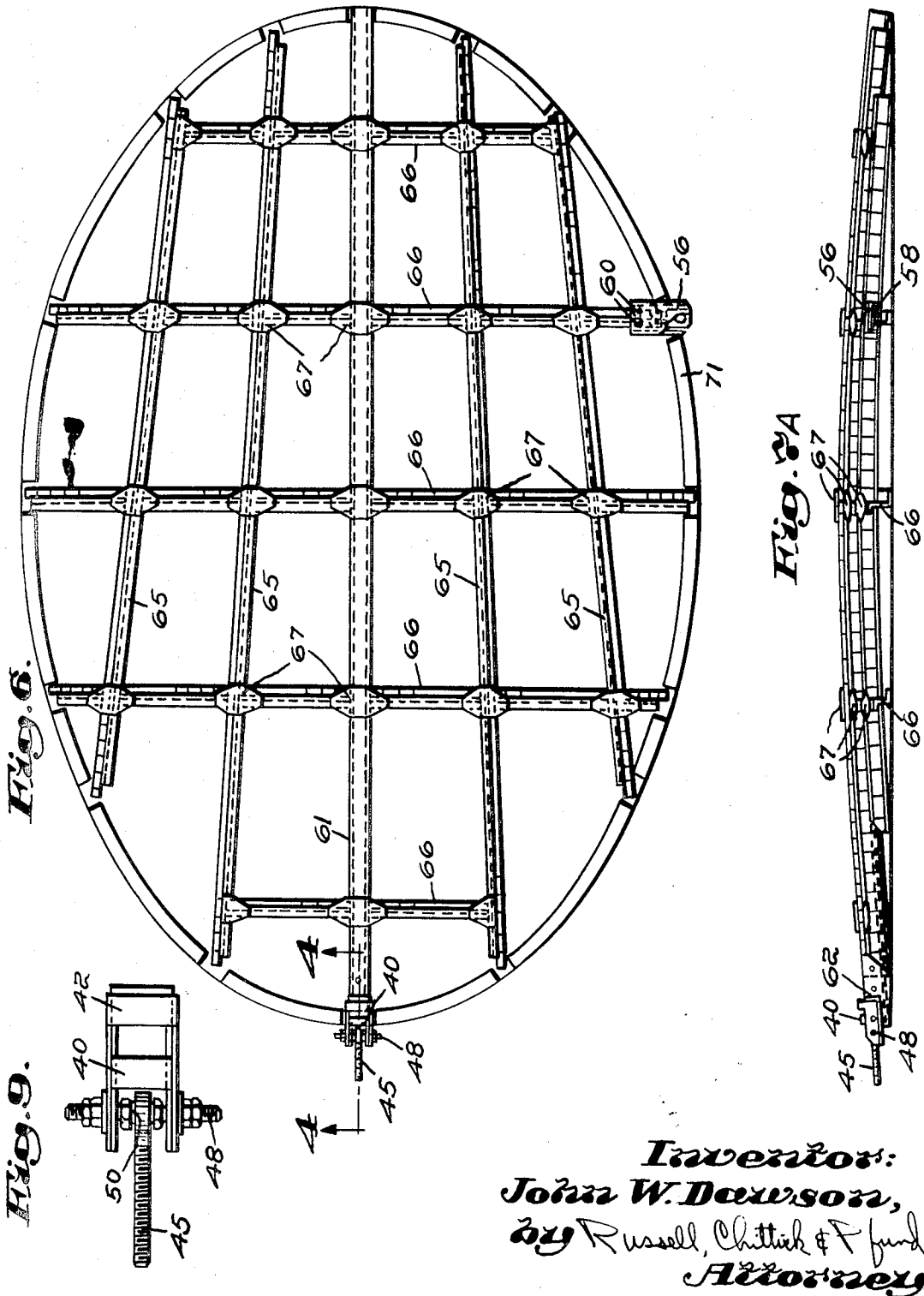
J. W. DAWSON

3,550,142

HORN REFLECTOR ANTENNA

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Inventor:
John W. Dawson,
by Russell, Chittick & Fund
Attorneys

Dec. 22, 1970

J. W. DAWSON

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HORN REFLECTOR ANTENNA

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Fig. 11.

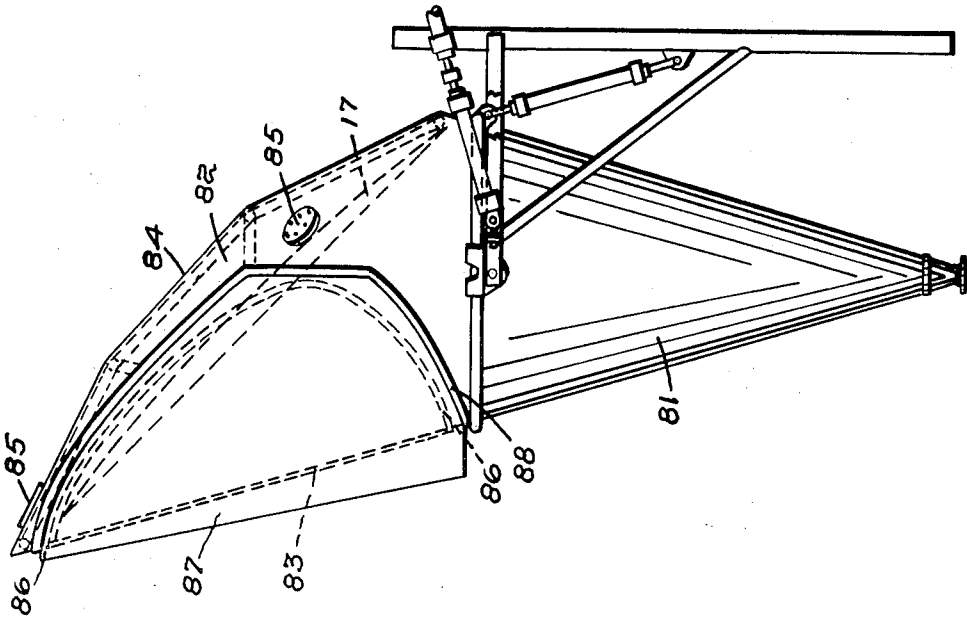
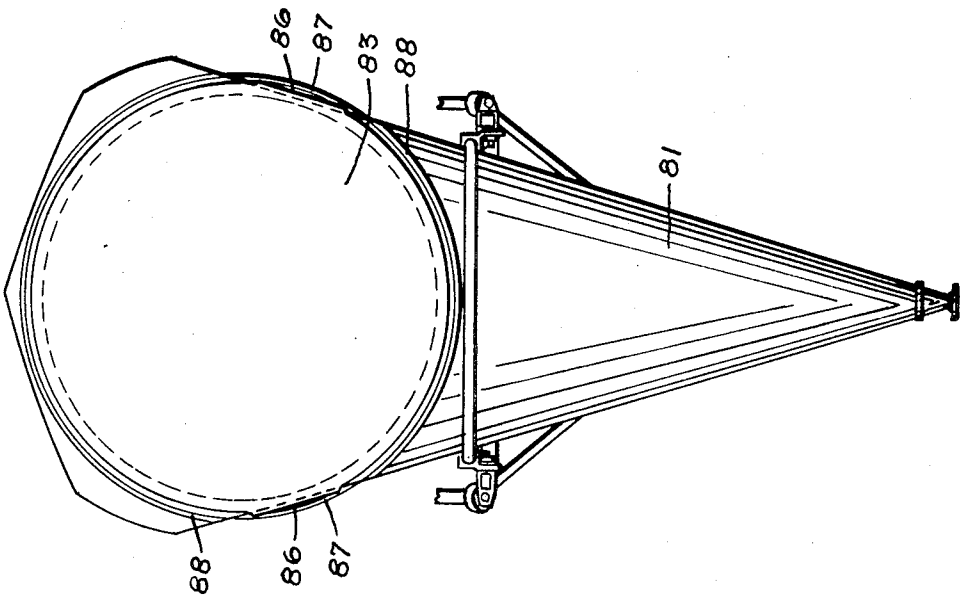


Fig. 10.



Inventor:
John W. Dawson,
by Russell, Chittick & Pfund
Attorneys

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HORN REFLECTOR ANTENNA

John W. Dawson, Norwell, Mass., assignor to Maremont Corporation, Saco, Maine, a corporation of Illinois
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Int. Cl. H01q 3/12, 19/14, 15/20
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20 Claims

ABSTRACT OF THE DISCLOSURE

A microwave horn antenna having a closed self-supporting thin wall housing in the form of a cone with a closure across the wide end has a precision paraboloidal deflector segment supported obliquely to the axis of the cone to reflect energy between the cone and free space through a window aperture in the housing. The reflector segment is supported within the housing only at a few points on its periphery as by attaching support rods having lateral flexibility to make the electrical dimensions of the reflector independent of strain such as due to solar heating and of external loading due to wind and ice or internal loading due to pressurizing the enclosure.

FIELD OF THE INVENTION

This invention relates to microwave horn antennas of the type having a conical feed which illuminates a sector of a paraboloid reflector which are used to provide a directive beam with high gain and low side lobes. The invention provides an improved structure for such antennas by separating the structural and electrical components to provide optimum characteristics respecting construction and operation.

In the prior art, U.S. Pat. No. 2,416,675 to Beck et al., a horn reflector antenna of integral construction is shown in which the reflecting parabolic sector is supported by a roof truss construction to form a pressurized enclosure. This prior art construction requires the electrical reflecting surface of the paraboloid to be manufactured and maintained to the required accuracy while subject to distortion due to solar heating, to external wind and ice loading and to internal loads if the enclosure is pressurized. Accurate surface parabolic sectors can be manufactured by a number of techniques, but to build and maintain the critical surface accuracy of a large size sector when it is subject to considerable variable loading forces presents a difficult problem. In the prior art the necessary rigidity has been achieved by strong, relatively massive structures conforming to the parabolic shape which have been strong and rigid enough to support the reflecting surface under load.

In the present invention the housing for a parabolic reflector sector is constructed of members whose cross-section provide inherent rigidity both to internal pressure loads and externally applied forces. This housing also provides the necessary electrical properties for the horn reflector antenna and supports the more critically contoured parabolic sector in a manner to isolate it from substantially all loads except those imposed by the weight of the reflector. Thus any suitable fabrication technique can be used to manufacture a light weight reflector and its accuracy can be maintained in service indefinitely.

By means of the support rods which suspend the reflector surface from the roof of the enclosure, the accurate adjustment of the reflecting surface can be achieved both with respect to the axis of the conical feed horn and the direction of propagation through the aperture in the housing. Since the reflector surface is a sector of a paraboloid which bears a definite relation to the geometry of the feed horn, it is imperative for optimum performance that the reflector surface be adjusted accurately for

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position on the three reference axes and rotationally relative to the same three axes. These precision adjustments can be achieved relatively simply by means of the few support elements used in the present invention after the assembly is completed thus making the manufacture and assembly of the housing and reflector relatively independent, since it is not necessary to manufacture the housing in finished positional relation to the reflecting surface.

Since the only function of the reflector surface is electrical, its mechanical construction can take extremely simple form and in the preferred embodiment of self-supporting surface is constructed by using an extremely thin metal sheet which is stretch-formed to the desired paraboloidal surface contour and on its back or convex surface a series of radial and transverse ribs are attached. These ribs are preferably very light weight Z-cross-section beams which have kerfs cut therein through the bottom flange and substantially upward through the web just short of the top flange to make the beams completely flexible. These flexible beams are applied to the contoured reflector plate and attached by spot welding or adhesive to render the beams mechanically rigid again by virtue of their connection to the reflector plate. In this condition the reflector surface backed by the beam network becomes a unit which is self-supporting and can be suspended within the housing from three support points and maintain its electrical dimensions within the desired tolerances.

The objects of the present invention, accordingly, are to achieve the foregoing advantages which flow from separating the mechanical and electrical functions of the horn antenna and reflector surface assembly. These objects and other advantages will become apparent from the following detailed description taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a diagram illustrating the geometry of the paraboloidal reflector;

FIG. 2 is a perspective view of a preferred embodiment of the present invention;

FIG. 3 is a side elevation view of the embodiment of FIG. 2 with portions broken away;

FIG. 4 is a sectional view taken through the line 4—4 of FIG. 6;

FIG. 5 is a sectional view taken on line 5—5 of FIG. 3;

FIG. 6 is a top plan view of the reflective surface reinforced on its back side by radial and transverse beams;

FIG. 7A is an edge elevation of the reflective surface shown in FIG. 4;

FIG. 7B is a view similar to FIG. 7A of an alternative form of reflective surface structure.

FIG. 8 is a perspective view of a representative waveguide transmission line adapter for connection to the horn antenna of FIG. 2;

FIG. 9 is an enlarged view of a portion of FIG. 6; and
FIGS. 10 and 11 are front and side elevation views of a modification.

Referring now to FIG. 1, the geometry of the paraboloid as an antenna will be described. A parabolic curve 11 has an apex at the origin 12 and a focus 13 on the focal axis 14. As is well known, the characteristic of the parabolic curve 11 is to reflect energy originating at the focus 13 and striking the parabolic surface 11 in parallel rays parallel to the focal axis 14. When used as an antenna the parabolic curve 11 is used to generate a surface of revolution by rotating the curve 11 about the axis 14 and the paraboloid so generated exhibits the same properties in three dimensions as indicated in the plane figure of FIG. 1. If a source were placed at 13, directing energy upward radially within the limits of the cone defined between the lines 15 and 16, the portion of the paraboloid 11 intersected by the cone 15, 16, would be effective to

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convert the energy into a parallel-ray beam 20 and likewise energy arriving parallel to the direction of the axis 14 would be concentrated by the paraboloidal surface within the boundaries 15 and 16 of the cone to be focused at the focus 13. The present invention utilizes a reflector confined within the boundaries of an extended cone and in the preferred embodiment will employ a sector of a paraboloid of revolution corresponding to the portion 17 shown in FIG. 1.

FIG. 2 shows the closed conductive housing employed in the preferred embodiment of the present invention. The construction shown in FIG. 2 contemplates the use of thin sheet metal which inherently provides the electrical conductivity required. It will be understood that a construction of dielectric material would be just as satisfactory provided that the inner surfaces were given a conductive coating.

The housing comprises a hollow cone 21 which for convenience will be described as mounted with a vertical axis on a suitable mast 22 and for such installation the cone 21 intersects a horizontal cylinder 23, the intersection of these two geometric figures forming the familiar saddle-shaped boundary curve 24.

The cylinder 23 is closed at one end by an oblique closure plate 25 which intersects the axis of cylinder 23 and cone 21 at approximately 45°. The plate 25 has three hand hole covers 40 for adjustment purposes hereinafter described. The actual boundary between the closure plate 25 and the cylinder 23 corresponds to the intersection of a plane and a cylinder but for structural reasons the plate 25 is preferably a slightly domed-shaped member outwardly convex and tightly joined to cylinder 23.

The saddle-shaped intersection seam 24 and a seam 26 formed between closure plate 25 and cylinder 23 are all likewise pressure-tight and may be formed by welding, for example, to permit the entire unit to be pressurized when the open face of the cylinder 23 is closed by a convex electromagnetic energy transparent window 26, which constitutes the aperture of the antenna. The aperture is the projection of the area of intersection of the cone 21 with an oblique transverse plane 17' across the wide end of the cone.

The cone 21 may be manufactured in sections and suitable techniques employed to provide a smooth conductive inner surface. Thus as indicated at 31 an enlarged rim on the lower section of the cone is adapted to receive the bottom edge of the upper section of the cone 21 to provide a smooth inner surface at the connection of the two sections. This boundary may be welded and ground flat or sealed with conductive plastic compositions or otherwise rendered free of discontinuity as respects the electromagnetic wave propagated by the horn. At the bottom of the cone 21 a flanged section 32 is provided for fitting any desired feed line or adapter that may be employed with the horn antenna. For example, a direct circular waveguide can be connected directly to the flange 32 for propagating the TE₁₁ mode into the cone 21. Other connections to the flange 32 may be made with suitable transitions or matching sections as required and as well understood by those skilled in the art. A representative example of one such section is described hereinafter with reference to FIG. 8.

Basically, the structure shown and thus far described with reference to FIG. 2 is self-supporting particularly when the window 26 is in place and the entire enclosure housing is pressure-tight and pressurized, since each surface is convex outward and the skins forming the surfaces of cone 21, cylinder 23, closure 25 and window 26 have shapes which tend to produce only tension loading within the skin itself as internal pressurization is applied. Such a structure could be supported and mounted by a relatively large mounting flange located at the maximum diameter section of the cone 21. As shown in FIG. 2, however, the housing is supported within a framework made up of tubular members 34 surrounding the periphery of the

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various sections. This framework 34 may be supported on a horizontal pivot axis at hinge 35 which mounts on a semicircular frame 38.

The mast 22 can be mounted to an installation tower or any suitable structure by connectors such as U-bolts 41 and when so mounted the directivity of the horn antenna may be adjusted in azimuth by the length of an adjusting strut 42 and in elevation by pivoting the horn housing about the horizontal axis 36 as determined by the length of a vertical strut 43.

Referring now to FIG. 3, the general arrangement of the suspension of the parabolic sector 17 is shown. The reflector 17 is supported preferably from only three points as by rod suspension members thus minimizing distortion of the segment by forces transmitted through its suspension points. These rod suspensions furthermore preferably have transverse flexibility thereby accurately supporting the reflector 17 in position but making this position relatively independent of thermal or force strains in the housing itself. The suspension consist of a top support 41 and two side supports under hand hole cover plates 40. These supports are anchored by means of bolts which pass through the tubular elliptical frame member 44 surrounding the top closure 25. The top closure 25 provides hand hole access when plates 40 are removed to reach each of the suspension linkages to permit factory adjustment of the position of the reflector 17 relative to the internal geometry of the enclosure so that optimum electrical performance is obtained.

FIG. 4 is a vertical section view through the fitting 41 showing a suspension bolt 45 secured to tubular frame member 44 after passing through the uppermost portion of cylinder 23. The rod 45 is connected to a trunnion housing 47 which attaches to a central reflector backing beam 61 by means of bolts 43. The rod 45 terminates in a spherical self-aligning bearing 50 (FIG. 9) to receive the shaft of a bolt 48 which passes through the trunnion 47 to support the weight of the reflector sector 17 without transmitting transverse forces thereto. The self-aligning bearing 50 for the bolt shaft 48 in combination with the variable length adjustment of the bolt 45 provided by the nuts 49 provides the necessary degrees of freedom.

The two side suspensions are similar. One side suspension is shown in the sectional view of FIG. 5 to comprise a bolt 51 passing through the frame member 44 and the cylindrical skin 23 to terminate in self-aligning bearing 53 through which a bolt 54 passes. The bolt 54 is secured by nuts 55 to a plate 56 which is fastened to one of the transverse beams 66 on the back of the reflector plate 17. The plate 56 has a transverse slotted hole to receive the bolt 54 and is backed by a reinforcing plate 58 which is attached to the plate 56 by fasteners 59 which pass through slotted holes in the plate 56. Thus the transverse position of the bolt 54 can be established relative to the plate 56 before the fasteners 59 are secured. In similar manner, fasteners 60 which fasten the plate 56 to the beam 66, pass through longitudinally slotted holes in the plate 56 to permit the longitudinal position of the bolt 54 relative to the beam 66 to be adjusted before the fasteners 60 are secured. To facilitate the adjustment of the bolt 54 the nut 55 may be secured as by welding to the plate 58.

As seen in FIGS. 4 and 6 the trunnion 47 comprises nesting inner and outer U-brackets 40 and 42, respectively, which trunnions have horizontal and vertical slotted holes through which pass bolts 43 which fasten the trunnion to the beam 61 thereby permitting the position of the trunnion mount relative to the fixed beam 61 on the back of the reflector sector 17 to be established. By means of the length adjustments of the bolts 45, 51 and 54 and the slotted connections between the bolt mounting assemblies and the beams 66 and 61 which are secured to the back of the reflector sector, the necessary three degrees of translation and rotational freedom for the reflector sector are achieved.

Referring now to FIGS. 6 and 7A, the structural features of the parabolic sector 17 will be described. The sheet metal surface 17 is first stretch-formed over a male mold to conform the undersurface thereof to the shape of a paraboloid of revolution of the parabola 11 shown in FIG. 1. While the surface sheet 17 is on the mold a series of radial and transverse beam sections are applied. The central beam 61 has a hollow square cross section and lies directly along the path of the parabola 11. This beam 61 terminates in a cutaway portion 62 which extends out to the edge of the paraboloid surface 17 and in the end of beam 61 an internal block is mounted. The block is bored to receive the transverse bolts 43 which mount the trunnion 47 and thus provides a compression member to support the side walls of the square cross section beam 61 as the bolts 43 are tightened.

A plurality of radial beams 65 are secured to the back surface of the paraboloid 17 in a position corresponding to the locations taken by the parabola 11 as it is rotated about its apex 12 to generate the paraboloid of revolution. Thus the beams 65 generally have a radial configuration relative to the apex 12. The cross section of beams 65 is preferably Z-shaped to facilitate attaching the lower flange by spot-welding or otherwise to the convex surface of the paraboloid 17. To conform the beams 61 and 65 to the convex shape of the paraboloid 17, regularly spaced kerfs are cut therein through the lower flange and the web of the beam to a position just short of the top flange thereof. This gives the unattached beam considerable bending ability to conform to the convex shape and once fitted to the back side of the paraboloid 17 and secured thereto the strength of the skin forming the paraboloid 17 restores the integrity of the lower flange across the saw kerf and the structure becomes rigid and self-supporting without distortion of the accurately formed paraboloid shape of the concave surface 17.

A plurality of transverse beams 66 is provided between the radial beams 65 and the central beam 61 substantially perpendicular thereto and lying actually along the circumferential path traced by a point on parabola 11 as it is rotated to generate the paraboloid 17. The beams 66 are attached to the central beam 61 and the radial beams 65 by gusset plates 67 and are otherwise attached to the convex surface of the paraboloid 17 as described for the radial beams. At the extremities of one of the transverse beams the mounting channels 56 are secured by means of fasteners 61.

The completed paraboloid sector 17 with reinforced bracing and mounting hardware may be completed by adding microwave absorbing strips 71 along the periphery on the convex side thereof. When so mounted the microwave absorbing material is between the paraboloid 17 and the roof closure 25 in the region of the periphery of the paraboloid 17 and this position is well suited to absorb any energy which leaks around into the space between these two members. The absorbing material could likewise be mounted on the inner surface of the roof closure member 25 in approximately the same position and other expedients for the absorption of stray microwave energy may also be employed if desired.

Referring now to FIG. 8, a dual frequency rectangular waveguide to circular transition section will now be described. As previously mentioned, circular waveguide propagating the TE₁₁ mode can be connected directly to the flange 32 of the cone as shown in FIG. 2 with an appropriate impedance matching section if desired. Other connections can be made using suitable transitions for either single or dual mode operation. If a rectangular waveguide feed is employed a rectangular to circular transition section will ordinarily be required. As shown in FIG. 8, a dual frequency adapter comprises a flange 73 constructed to mate with the flange 32 of FIG. 2. A tapered conical section 74 merges with a square cross section guide 75 which on two adjacent faces thereof is

coupled to a high frequency waveguide 76 and a low frequency waveguide 77. The waveguides 76 and 77 are fitted with suitable flanges for connection to standard waveguide sections and are coupled to the square waveguide section 75 with the usual mode converters to propagate through the transition section 74 to energize the cone feed of the horn antenna with the radial mode. Throughout the specification where propagation is described it will be understood that reciprocity applies and the description could be as well interpreted for reception as for transmission of energy.

Referring to FIGS. 10 and 11, a modified form of construction of the housing for the horn antenna will now be described. In this embodiment the housing is formed of only three elements, a hollow cone 81, which is closed by an oblique roof closure 82 and an electromagnetic energy transparent window skin 83 that generally conforms to the surface of the cone in the region of an aperture cut therein. Thus the housing construction is simplified at the expense of a somewhat more complex shape for the window 83. As in the previously described embodiment, the reinforced paraboloid 17 may be suspended by three points from the domed roof 82, which, if necessary, may be reinforced by an internal tubular rib truss 84. As previously described, access panel plates 85 are provided for making the final alignment adjustments of the paraboloid 17.

The upper portion of the cone 81 has an aperture corresponding to the horizontal projection of the area of the paraboloid 17. This area is closed by a window which wraps around the conical shape and conforms thereto with an external flange 86 secured to the skin of the cone 81. This radome may be attached by suitable rivet fasteners which are flush on the internal surface or by means of an adhesive. With this shape for the window, great structural strength is achieved since the arc shape required to conform to the surface of the cone 81 at the location of the aperture therein provides inherent strength without reinforcement except for the edge seal to the outer surface of the cone 81.

The cone 81, the roof closure 82 and the window 83 form a closed pressurized housing which can be maintained with any desired atmosphere and pressure for improved electrical characteristics. To further improve the electrical characteristics, particularly with reference to back scatter and side lobes for the antenna pattern, an external cylindrical shroud 87 surrounds the aperture of the antenna. The shroud 87 is attached to the outer skin of the cone 81 by means of a flange 88. With the addition of the shroud 87 a significant reduction in back scatter radiation is achieved without the necessity for complicating the construction of the pressurized enclosure.

While a paraboloid 17 has been described as the preferred surface for the horn antenna, it will be appreciated that other surfaces may be used for different purposes and in particular that the antenna can be operated with a plane reflector surface with some deterioration in performance. It will also be apparent that other portions of the geometry described with reference to FIG. 1 can be used, in particular, the right circular cone and right circular cylinder are not essentials since other angular configurations of the intersection between the cone feed and the cylindrical aperture can be obtained using other portions of the parabola 11. It is also apparent that circular cross-sections are not essential to the elements of the enclosure and the terms cone and cylinder should be used in their generic sense when mentioned herein.

Other frame members may be used particularly with respect to the back support for the paraboloidal sheet 17. For example, as shown in FIG. 7B, a tubular ring frame 18 rigid in torsion and flexure can surround the sector 17 and be attached, as in FIG. 7A, to the interior of the housing for support. Also a peripheral flange on the sector 17 can be formed to which a torsion-box structure generally conforming to the convex shape of the back of

sector 17 but spaced a small distance therefrom may be used.

These and other modifications can be made by those skilled in the art while availing themselves of the advantages of the present invention.

I claim:

1. A microwave horn antenna comprising:

a conductive surface cone with a waveguide coupling at the apex for propagating one or more confined radial modes having any predetermined polarizations along the axis within the cone;

a conductive surface closure for the wide end of said cone, the conductive surfaces of said cone and closure being formed to provide a conductive housing with a microwave transparent aperture that is the projection of an area of intersection of said cone with an oblique transverse plane across the wide end of said cone; and

a microwave mirror surface member generally coextensive with said area of intersection for translating microwave energy between said radial modes in said cone and corresponding plane parallel-ray modes in free space through said aperture, said mirror surface member supported within said housing so as to be isolated from mechanical loads on the surfaces of said cone and said closure.

2. The antenna according to claim 1 in which said mirror surface member is supported within said housing by a plurality of separate points of attachment to the interior of said housing, said attachments providing transverse freedom between said housing and said mirror surface member.

3. The antenna according to claim 1 in which said mirror surface member is supported within said housing by a plurality of rigid rods connected between said housing and said member through couplings having transverse freedom.

4. The antenna according to claim 1 in which said microwave mirror surface member has a mirror surface contour corresponding to that portion of a paraboloid which lies in said area of intersection, has its focus at said apex and a focal axis parallel to the direction of the propagation of energy through said aperture.

5. The antenna according to claim 4 in which said mirror surface member is supported within said housing by a plurality of rigid rods with connections between said housing and said mirror surface member through couplings having transverse freedom.

6. The antenna according to claim 5 in which said mirror surface member is suspended on three rigid rods connected between the back surface of said mirror surface member and the inner surface of said closure.

7. The antenna according to claim 6 in which said housing is a self-supporting structure having rigid thin walls forming said cone and said closure with pressure-tight seams at the intersections of said walls and including a pressure tight radome covering said aperture.

8. The antenna according to claim 7 in which the surfaces of said cone, closure and radome are outwardly convex to reduce stress concentrations in said walls and said radome resulting from internal pressurization of said housing.

9. The antenna according to claim 4 in which said portion of a paraboloid is formed of a thin sheet having a concave reflecting surface and a convex back surface reinforced by a plurality of longitudinal and transverse beams, each of said beams having an upper and lower flange and a plurality of spaced kerfs transversely separating said lower flange to permit said beams to conform to said convex back surface, and means for rigidly attaching the separate kerf-separated portions of said lower flange to said convex back surface.

10. The antenna according to claim 4 in which said closure includes a conductive cylinder around said aperture axially aligned with said direction of propagation and extending beyond the projected boundary of said cone.

11. An antenna according to claim 10 in which said cylinder extends in the opposite direction within the projected boundary of said cone such that said closure includes a portion of said cylinder joined to said cone along the line of intersection of said cylinder and said cone.

12. An antenna according to claim 11 in which said housing is a self-supporting structure comprising a domed top plate spaced above said portion of said paraboloid, rigid thin walls forming said cone and cylinder with pressure-tight seams connecting said walls and said top plate, and a pressure-tight radome closing said aperture.

13. An antenna according to claim 4 in which said portion of a paraboloid is suspended in spaced relation beneath a portion of said closure and including microwave absorbing material in the region between said portions around the periphery of said portion of a paraboloid.

14. The antenna according to claim 1 and including a radome closure secured across said microwave transparent aperture, said conductive housing and said radome completely enclosing said mirror surface member.

15. The antenna according to claim 14 in which said mirror surface member is supported within said housing by a plurality of rigid rods connected to said housing through couplings having transverse freedom.

16. The antenna according to claim 4 in which said portion of a paraboloid is formed of a thin sheet having a concave reflecting surface and a convex back surface reinforced by a frame in the form of a rigid tubular ring.

17. The antenna according to claim 16 in which said housing is a self-supporting structure having rigid thin walls forming said cone and said closure with pressure tight seams at the intersections of said walls and including a pressure tight radome covering said aperture.

18. The antenna according to claim 3 in which said plurality of rigid rods comprises three rigid rods which are adjustable in length to position said mirror surface member adjustably relative to said housing.

19. The antenna according to claim 18 in which one of said three rigid rods is attached at one end of said mirror surface member on the center line of said member and the other two rods are attached symmetrically on opposite sides of said center line near the other end of said member.

20. The antenna according to claim 19 in which the attachment of said rods to said mirror surface member includes means for adjusting the transverse position of said member relative to the axial direction of said rods to provide three degrees of translational and rotational freedom relative to said housing.

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HERMAN K. SAALBACH, Primary Examiner

T. VEZEAU, Assistant Examiner

U.S. Cl. X.R.

343—761, 784, 786, 839, 840, 872, 915