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R. S. REINHOLD

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MICROWAVE ANTENNA WITH ADJUSTABLE REFLECTOR SHAPE AND
AUTOMATICALLY REGULATED FOCAL DISTANCE
SPACING OF RADIATION ELEMENT

Filed March 7, 1960

4 Sheets-Sheet 1

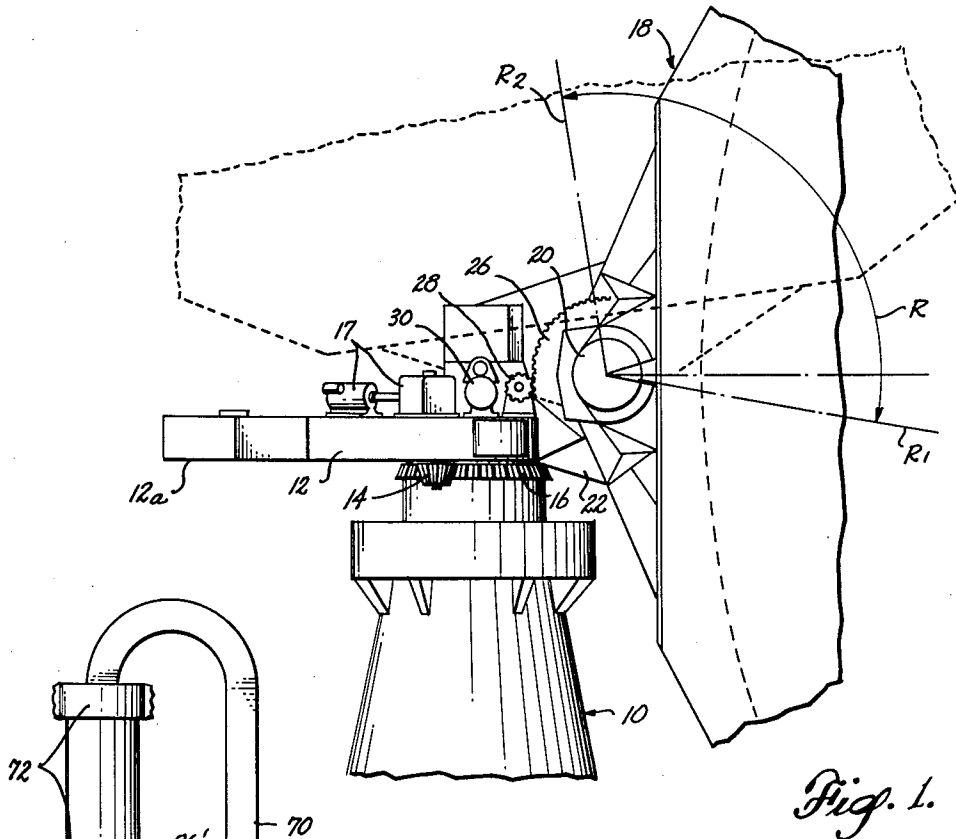


Fig. 1.

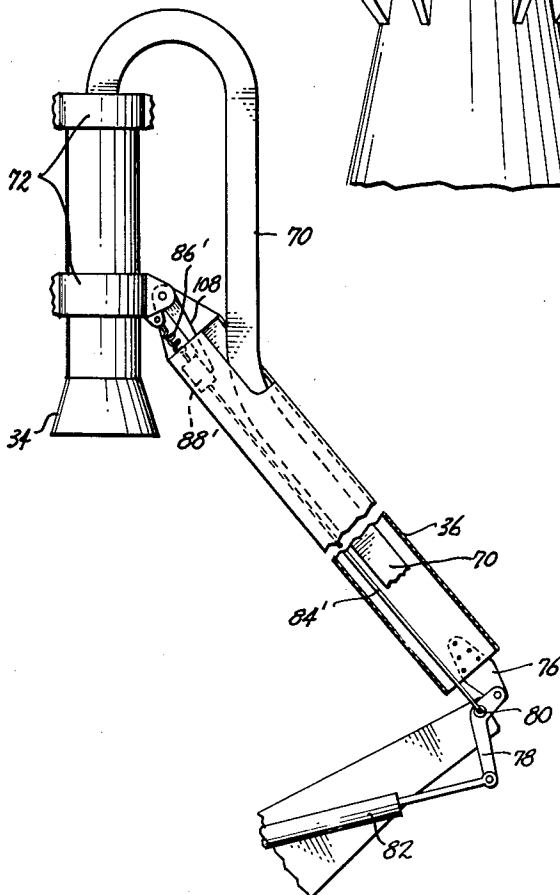


Fig. 9.

INVENTOR.
RICHARD S. REINHOLD

BY
Reynolds, Black & Christensen

ATTORNEYS

Feb. 5, 1963

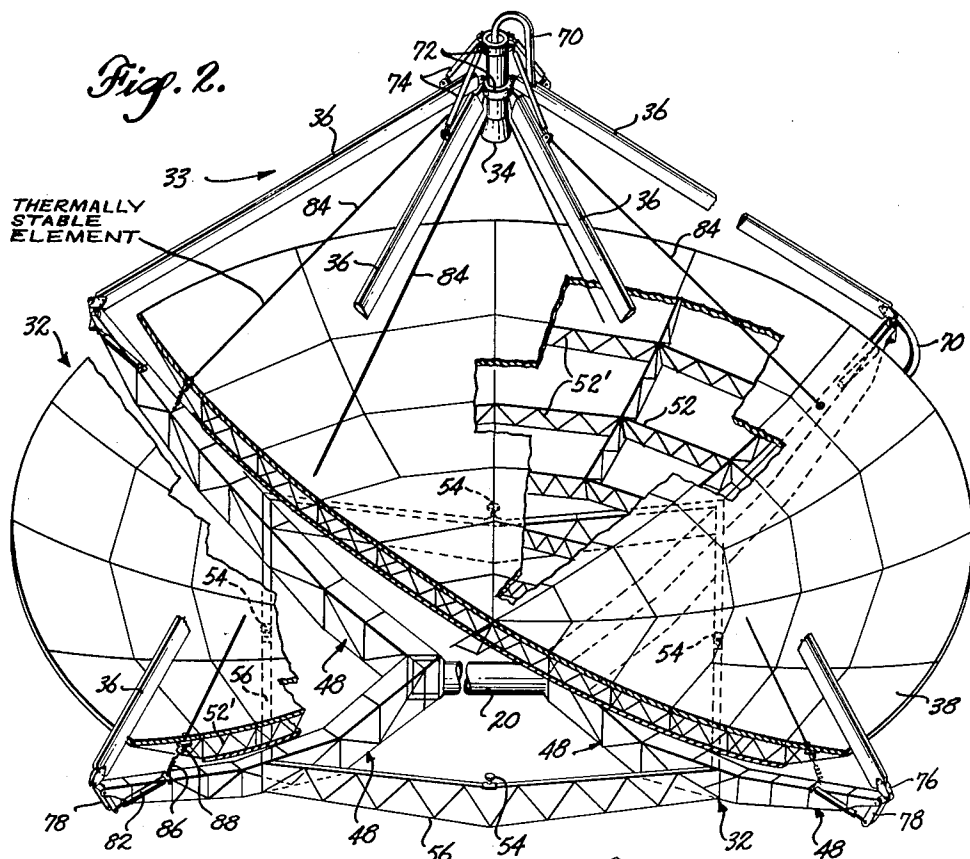
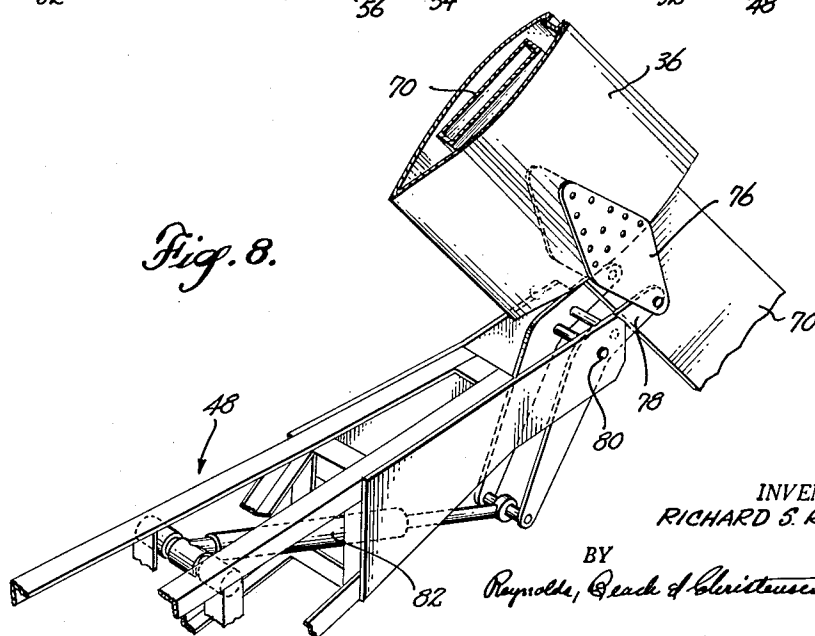
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4 Sheets-Sheet 2



INVENTOR.
RICHARD S. REINHOLD

BY
Reynolds, Grack & Blittman

ATTORNEYS

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R. S. REINHOLD

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4 Sheets-Sheet 3

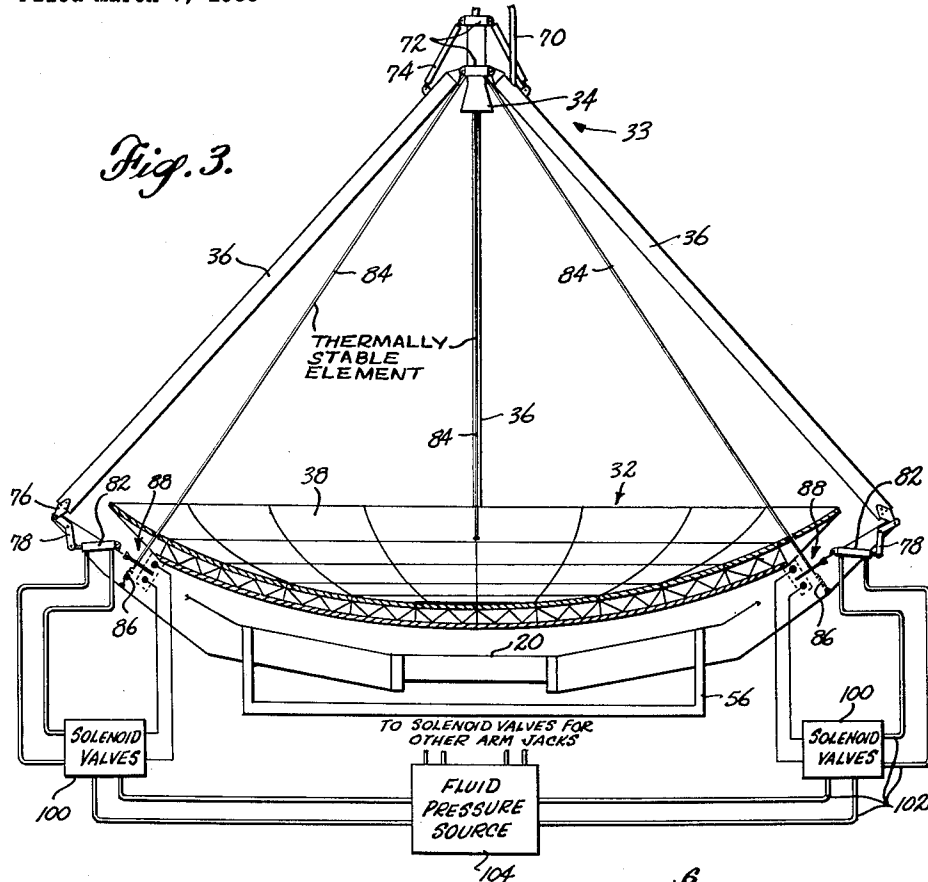


Fig. 5.

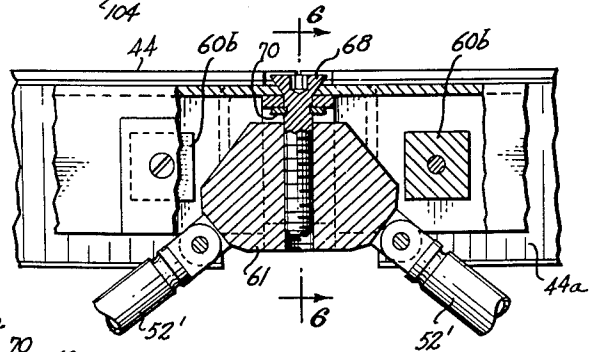
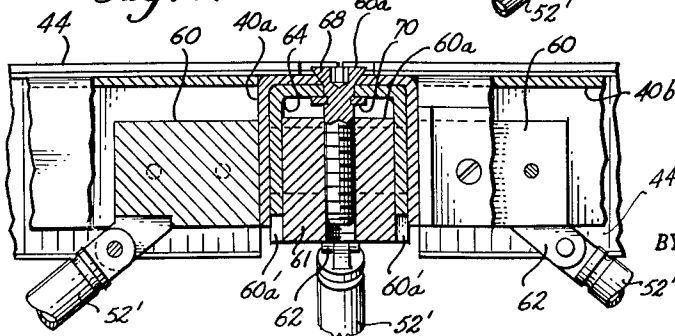


Fig. 6.



INVENTOR.
RICHARD S. REINHOLD

BY *Reynolds, Beach & Christensen*

ATTORNEYS

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R. S. REINHOLD

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4 Sheets-Sheet 4

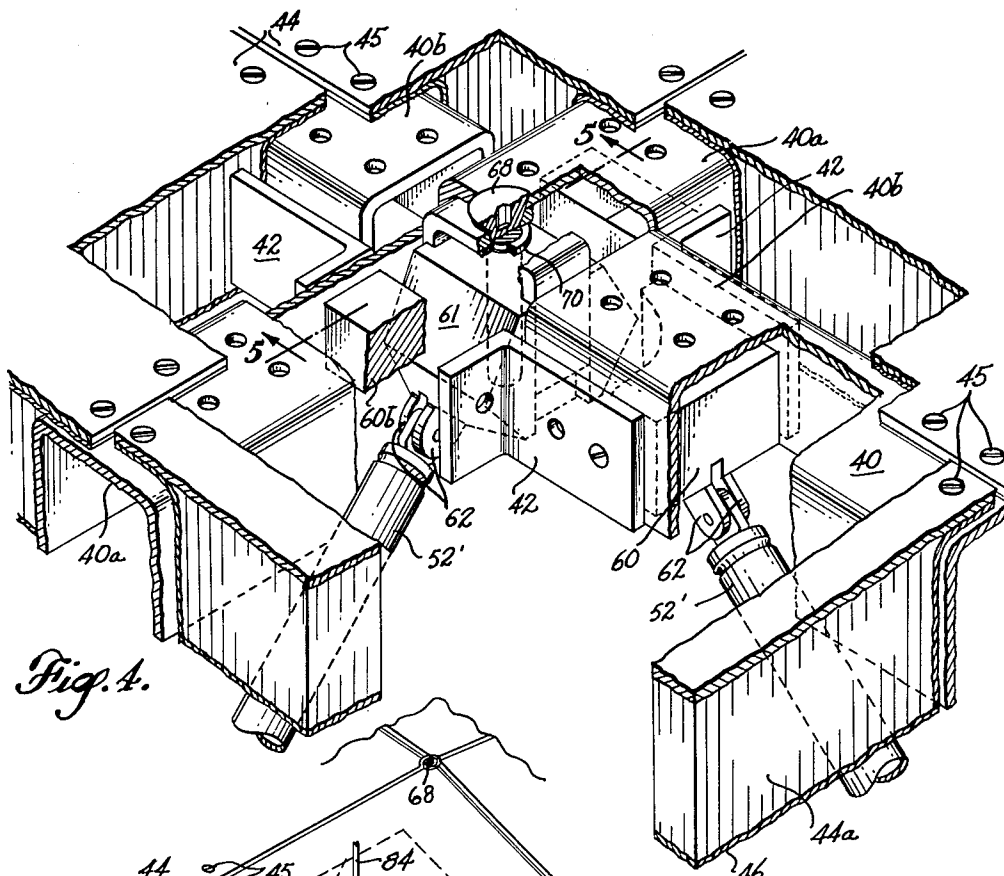


Fig. 4.

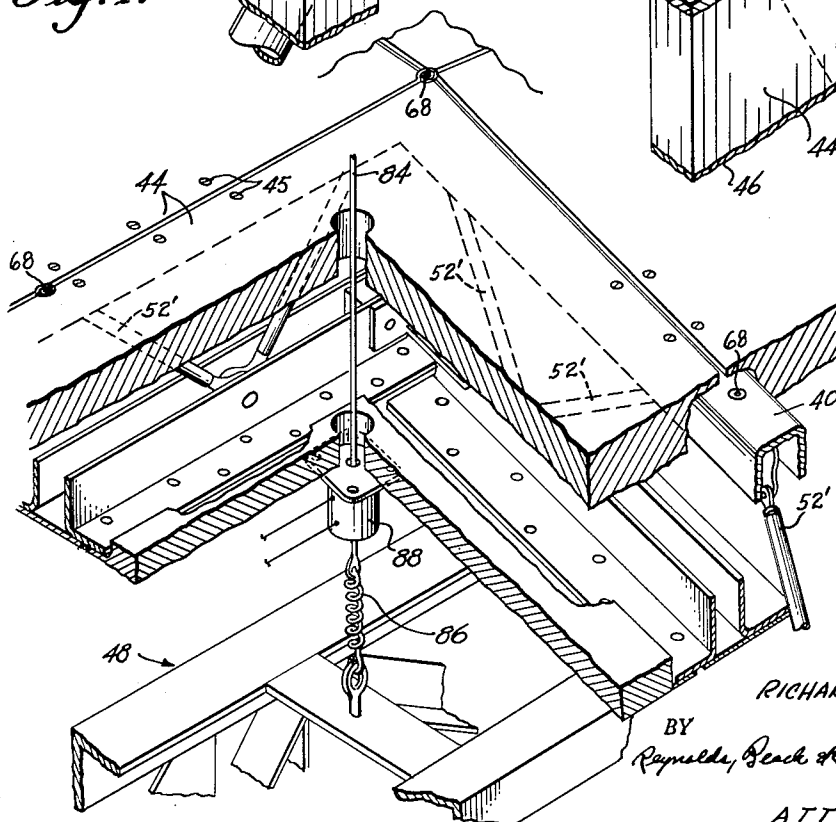


Fig. 7.

INVENTOR.
RICHARD S. REINHOLD

BY
Reynolds, Beach & Christensen

ATTORNEYS

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3,076,964

MICROWAVE ANTENNA WITH ADJUSTABLE REFLECTOR SHAPE AND AUTOMATICALLY REGULATED FOCAL DISTANCE SPACING OF RADIATION ELEMENT

Richard S. Reinhold, Seattle, Wash., assignor to Boeing Airplane Company, Seattle, Wash., a corporation of Delaware

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13 Claims. (Cl. 343—761)

This invention relates to improvements in electromagnetic microwave high-gain antennae of the type employing a concave reflector and a cooperating radiation element. More specifically the invention is directed to a knock-down antenna suitable for construction in very large sizes, and including means for precisely adjusting its reflector contour, and means for continuously sensing and correcting anti-focal displacements of its radiation element.

The invention is herein illustratively described by reference to its presently preferred form as applied to a microwave radar type antenna of the paraboloid reflector and cooperating horn type, such as has been used in microwave early warning systems, in astronomic studies, etc.; however, it will be recognized that certain modifications and changes therein with respect to details may be made without departing from the underlying essentials involved.

In order to achieve higher and higher antenna gains, parabolic reflector diameters have been progressively increased and operating wavelengths have been progressively decreased. Reflectors of the order of 100 feet in diameter operated at microwave frequencies of the order of a few centimeters or less are now considered necessary in order to meet certain radar and other detection system requirements. In many cases these antennae are operated in polar regions or under other extremely adverse climatic conditions, and in remote areas. The necessity of transporting and erecting antenna structures of this order of size at isolated outposts virtually requires a knock-down type of construction with parts which are readily assembled and adjusted in the field. Because of the great size of the structure and the shortness of the wavelengths used, reflector contour and radiation element positioning are extremely critical. Deviations from design specifications even of the order of a fraction of an inch in the contoured shape of a 100 foot reflector, or in the 60 odd feet of spacing between the horn and the reflector, for example, can seriously reduce gain, increase side lobes, and cause mismatch antenna impedance in relation to that of the connected electronic R-F system. These deviations, whether present during assembly or arising due to strains during operation, must be adequately corrected. Moreover, the means used for adjusting the reflector, and that used for correctively repositioning the horn, must not create objectionable shadows or blind spots in the radiation pattern nor otherwise interfere with antenna efficiency. Such a means must not impair the structural integrity of the system nor be complicated to maintain or operate.

The present invention is concerned generally with providing a solution to these and related problems. Further it provides a means by which reflector shape of a sectionalized antenna may be readily adjusted both during and after installation. It also provides an automatically operating and instantly responsive means by which any displacement of the radiation horn from the intended focal point of the adjusted reflector is instantly sensed and corrected during operation of the system.

A further object is to achieve these purposes in a relatively simple and inexpensive manner such that the

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different zones or local areas of the reflector surface may be adjusted independently of each other without disturbing the adjustment of other zones nor interrupting any of the structural interconnections between antenna components.

In accordance with this invention as herein disclosed, the reflector structure comprises two main parts, a reflectively covered paraboloidal skeletal structure and a supporting truss structure. The skeletal structure comprises intersecting stiffener members joined in a contoured form-retentive open framework having a limited degree of flexibility and covered by a reflective skin or surfacing means. This skeletal structure is backed by the relatively rigid truss structure presenting a plurality of mounting elements distributed at intervals over the breadth and width of the skeletal structure on the back side thereof, and connected to corresponding points on the skeletal structure. The connecting means used at each of these locations preferably comprise screw-threaded connecting elements which are adjustable in order to vary the local spacing between the rigid truss structure and the flexible skeletal structure and thereby vary the reflector contour independently in each of the many contiguous zones making up the total reflector area. Using optical tooling methods or other suitable gauging techniques, total reflector contour may be readily and quickly conformed in the field to design specifications by a simple process of turning the different connecting screws by the proper amounts and in the proper directions to appropriately bend the covered reflector skeletal into the required shape.

In accordance with another important feature of the invention the primary radiation element is supported at or near the focal point of the adjusted reflector by means of a plurality of elongated arms or struts which diverge rearwardly therefrom to points of connection on the reflector structure. These elongated arms, or parts thereof, are mounted for adjustable movement relative to the reflector structure in directions lengthwise of the arms. Such movement is produced by arm actuators in response to the control action of means for sensing displacement of the radiation element from its on-focus position. Such sensing means preferably comprises, in association with each of said arms, reversible switch means, by which the arm actuator is controlled, and a switch actuator comprising a length of Invar wire or other thermally stable means, and a variable or yieldable element (e.g. a spring), by which the wire is stretched approximately parallel to its associated arm. The wire and spring extend serially between the two positional references, namely, the reflector structure and the horn. The reversible switch means, which may be of an electrical, mechanical or fluid type, depending upon the actuator system used, have relatively movable elements respectively connected one to one of the positional references and another effectively to the juncture between the wire and spring. Preferably the arm actuators comprise bell cranks pivoted intermediate their ends on the reflector truss structure and having one end coupled to the rearward ends of the trusses and their opposite ends connected to switch-controlled reversible fluid operated jacks.

These and other features, objects and advantages of the invention will become more fully evident from the following description thereof by reference to the accompanying drawings.

FIGURE 1 is a simplified fragmentary side elevation view of a typically supported paraboloid type reflector antenna and the upper portion of its supporting base.

FIGURE 2 is a frontal perspective view of the antenna, with parts broken away to show certain details of construction.

FIGURE 3 is a semi-schematic sectional side view of

the antenna, illustrating the means for regulating focal-point spacing of the primary radiation element in relation to the reflector structure.

FIGURE 4 is a fragmentary perspective view, with parts broken away, illustrating details of the skeletal structure in the reflector and of the means for adjusting the spacing between the skeletal structure and the associated rigid trusswork to which it is connected for support.

FIGURE 5 is a sectional detail taken on line 5—5 in FIGURE 4.

FIGURE 6 is a sectional detail taken on line 6—6 in FIGURE 5.

FIGURE 7 is a fragmentary perspective view, with parts broken away, illustrating mechanism for sensing displacement of the primary radiation element from its intended location.

FIGURE 8 is a perspective view at enlarged scale showing a suitable means for actuating the supporting struts in order to maintain correct positioning of the primary radiation element.

FIGURE 9 is a simplified side view of a modified strut and sensing means combination wherein the sensing wire is housed internally of the strut for protection purposes.

While the details of the supporting base and its connections to the antenna proper form no part of this invention, a typical arrangement is diagrammatically illustrated in FIGURE 1 for purposes of background. The upright supporting base 10 supports the rotary turret 12 which turns on a vertical axis and carries a pinion gear 14 engaging a stationary ring gear 16 encircling the top of the base. The pinion gear 14 is driven by the motor and gear reduction unit 17 in order to rotate the turret in azimuth. The antenna structure 18 has a suitable framework to be described which includes a horizontal trunnion or shaft 20 journaled in bearing supports 22 mounted on the turret 12, the turret 12 having a counterweight 12a on the side thereof opposite the antenna. A sector gear 26 mounted in a vertical plane on the back side of the antenna structure is engaged by a turret-mounted pinion 28 driven by power means 30 in order to vary the elevation angle of the antenna. In the illustration the elevation angle range R extends from the lowermost position R1 slightly below the horizontal to an opposition position R2 slightly beyond the vertical. In some cases it may be desirable to provide for complete traversal of the antenna through more than 180 degrees of swing in a vertical plane. Usually the antenna is housed within a dielectric radome, although this sometimes may not be necessary or possible.

Referring now to FIGURES 2 et seq. it will be seen that the antenna itself comprises essentially two main parts, namely, the paraboloidal reflector structure 32 and the primary radiation element and its supporting means 33. The radiation element in this case comprises a short length of circular wave guide terminating in a flared portion or horn 34, directed toward the paraboloid. The horn is supported at the reflector focus in this case by four diversely directed struts or arms 36 grouped in quadrature about the antenna beam axis. Thus, radiation normally incident on the paraboloid from a remote source is directed into the entrance of the horn 34, whereas radiation issuing from the horn 34 is directed against the paraboloid surface in order to produce a reflected planar wave front which propagates in a direction normal to the paraboloid "aperture." With such an antenna of relatively large diameter in terms of the operating wavelength, extremely high gain is attainable, i.e., a beam width of the order of one degree or less measured at the half-power points.

As previously indicated, the large size of the structure and the short wavelengths used have presented serious difficulties in the attainment and adjustment of accurate shapes and spacings of parts. Temperature induced strains and other causes of distortion of reflector shape and focal-point spacing of the horn further complicate the problem.

In solving these problems the invention employs a re-

flector structure 32 which comprises an open framework of mutually intersecting stiffener members 40 joined together into a composite skeletal structure substantially of the paraboloidal contour desired for the reflector.

These stiffeners preferably comprise channel-shaped members arranged much in the form of a spider web, one group of members, 40a, extending radially from the paraboloid center at regular angular spacings, and the other group of members, 40b, extending in concentric circular patterns. Preferably the radially extending members 40a are each of one piece, extending continuously from the center to the outer edge, whereas the circularly arranged members 40b form straight chords of the circles defined by them, and individually terminate at their points of intersection with the radially extending members 40a. The members 40a and 40b are interconnected at each intersection by four structural angle brackets 42 bolted to them (FIGURE 4). Between the rearwardly directed flanges of the ends of channels 40b reinforcing blocks 60 are placed to be bolted to the channels and the angles 42. Similarly blocks 60b are placed between flanges of the channels 40a to be bolted together with the angles 42.

To the concave or front side of the skeletal open framework formed by the thus interconnected stiffeners 40a and 40b are fastened a plurality of covering reflector sheet sections 44, each shaped to the individual frame openings in the framework. These reflector sections are fastened at their edges as by screws to the webs of channels 40a and 40b in contiguous edge-to-edge relationship so as to present a substantially continuous reflective surface over the entire area of the framework. The maximum gap width permissible between edges of these reflector sections (e.g. 1/4" in a typical case, depending upon direction of the plane of polarization relative to the extent of the gap and upon operating wavelength) presents no serious difficulties of attainment.

The reflective sections 44 may be formed of thin layers of sheet metal on their front sides backed by reinforcing honeycomb structure 44a in order to stiffen them in the areas between stiffeners. The honeycomb core 44a is closed on its back side by a cover sheet 46 of any suitable material. The resulting composite reflector skin is capable of withstanding the strains incident to distortions due to temperature changes or loading, or due to corrective adjustments of reflector shape. By proper "stressed skin" design, as used in aircraft structures, added strength and stiffness are derivable from the reflector sections without precluding the degree of flexibility necessary to permit bending the assembled reflector in situ to its correct shape.

Behind the covered semi-flexible skeletal structure is a rigid truss structure which in this case is formed in two main parts. The first part comprises the two pairs of trusswork cantilever girder arms 48 connected together by the shaft 20 and braced by the trusswork beams 56 arranged as the sides of a square. The second part is supported by the first part and comprises the trusswork 52 providing a backing for the reflector skeletal structure previously described and of the same essential spider web configuration as the latter. The intersection points of the trusswork 52 preferably correspond to those of the skeletal structure comprising members 40a and 40b. The rigid structure 52 is preferably mounted on the four supporting members 54 carried by the respective brace beams 56 midway between the ends of the latter. The details of this connection are of secondary importance and are not shown herein.

At each intersection the trusswork 52 comprises a mounting block 61 juxtaposed to the back side of the skeletal structure. The mounting block 61 has suitable supporting ears 62 by which truss structure web members 52' are rigidly connected to it as an integral part thereof. A U-shaped guide member 64 has legs which slide in parallel guide ways 61a formed in the block 61 and which are directed perpendicular to the adjacent

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plane of tangency to the paraboloidal surface. At its web or crown the member 64 is centrally apertured to pass the shank of an Allen head screw 68 which is in threaded engagement with the mounting block 61. The outer face of the Allen head 68a is preferably set slightly behind the front surface of the reflector skin 44. The screw head bears against the apertured web of the radial channel 40a and holds it against the guide 64 whereas a fixed collar 70 seated in an annular groove around the screw shank beneath the web of the guide member 64 completes a thrust connection which causes the guide member 64 and its associated stiffener 40a to remain together throughout adjustments effected by rotation of the screw. Inasmuch as the truss structure comprising the members 52' is relatively rigid, whereas the skeletal structure comprising members 40a and 40b is relatively flexible, turning of the screw in one direction causes the latter structure, and with it the reflector surface 44, to move in a forward direction (i.e., toward the horn), whereas turning of the screw in the opposite direction causes a reverse movement of the reflector. A similar adjustable screw connection is provided preferably at each point of intersection of the skeletal structure, also at intervening points, as shown in FIGURE 7, so that the entire surface contour of the reflector shape may be correctly modified with all of the reflector parts securely and rigidly interconnected.

While in the example a single horn 34 is shown, it is possible, and indeed desirable in some situations, to employ a horn cluster. While in the example only one of the struts 36 houses a wave guide 70 which extends lengthwise of the strut to the horn 34 from the associated electronic apparatus (not shown), any of the other struts 36 may also house wave guides.

At their outer or forward ends, the struts 36 are connected, as by means of the coupling collars 72 and the braces 74 to the horn 34. The horn is thus maintained rigidly in alignment with the reflector axis.

At their opposite or rearward ends, each of the struts carries mounting tabs 76 by which it is connected to one end of a bell crank 78 which is pivoted intermediate its ends, on a shaft 80, on the outer end of one of the girders 48. The opposite end of each bell crank is pivotally connected to a fluid-actuated reversible jack 82 operable to swing the bell crank in either direction. The bell crank arms are so oriented that swinging of the bell crank either way from its normal position shown in FIGURE 8 effects endwise movement of the associated strut 36 either forwardly or rearwardly in order to correct horn positioning.

In order to detect slight shifts in position of the horn 34 in relation to the reflector focal point, there is associated with each of the struts 36 an elongated "Invar" wire 84 stretched from an anchor point on the horn 34, or otherwise in the vicinity of the reflector focal point, to a point of connection, through a wire-tensioning spring 86, with a rigid part of the reflector structure, such as the cantilever arm 48 near the bell crank. The wires extend approximately parallel to their associated struts 36. Of "Invar" alloy or other temperature-stable material, the wire does not change materially in length with change in temperature, and thereby represents a reliable means for gauging changes in horn position relative to the strut base due to changes in length of the arms 36 or other causes. Thus, an increase or decrease in the amount of deflection in the spring 86 occurs as a function of changes in position of the horn 34 measured lengthwise of the adjacent strut 36. A switch 88 has an element interposed in the connection between the spring and the wire and has co-operating contacts mounted on its housing which is connected to the reflector structure as a positional reference. Thus, as the horn moves forwardly out of its normal position with an increase in length of an arm 36, one switch contact is engaged. Conversely, when the arm

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contracts and shifts the horn inwardly from its normal position, the opposite switch contact is engaged.

As shown in FIGURE 3, these switches are connected to solenoid valves 100 which are interposed in reversible actuating fluid connections 102 between the fluid operated jacks 82 and a pressure fluid source 104. The valves are so arranged that engagement of a switch contact resulting from anti-focal displacement of the horn results in the immediate shifting of the associated arm 36 in order to restore the horn's position.

In FIGURE 9 the "Invar" wire 84' is shown protectively housed inside the hollow arm 36 along with the wave guide 70. In this case, spring 86' is connected between the horn 34 and the forward end of the wire, and the housing of switch 88' is connected to a fitting 108 rigid with the horn.

These and other variations and different aspects of the invention will be recognized by those skilled in the art on the basis of the foregoing disclosure of its preferred embodiment.

I claim as my invention:

1. Microwave antenna apparatus comprising a supporting base, a contoured antenna reflector structure of predetermined height and width mounted on said base, and a primary antenna means including a radiation element directed electrically against said reflector, said reflector structure comprising a skeletal structure including elongated stiffener members joined together in intersecting relationship into a composite grid-like contoured structure having a front presented by said stiffener members generally defining a predetermined antenna reflector contour, reflective sheet means of such flexibility as to require support to maintain a contour, said sheet means being secured as a covering on said skeletal structure's front and presenting substantially continuous reflector surfacing thereon, the interconnected skeletal structure and reflector surfacing comprising a semirigid form-retaining reflector structure, a supporting truss structure mounted on said base and spanning, immediately behind said skeletal structure, over at least a substantial portion of the height and width of the skeletal structure, the truss structure being rigid in relation to the reflector structure, and a plurality of independently-adjustable spacing devices interposed between and interconnecting the skeletal structure and truss structure at respective locations distributed at spaced intervals across at least a substantial portion of both height and width of the reflector, said spacing devices being operable to vary the front-to-rear spacing between the skeletal structure and truss structure, whereby to support the reflector structure in predetermined contour-maintaining rigid relation to the truss structure and to permit changing the contour of said reflector structure by independent adjustment of selected spacing devices.

2. The antenna apparatus defined in claim 1, wherein the adjustable spacing devices each comprise cooperable screw and nut elements, one connected to the skeletal structure and the other to the truss structure, the connection of one such element to its structure permitting relative rotation of the element therein while restraining the same against shifting endwise of itself relative to the structure.

3. The antenna apparatus defined in claim 2, wherein the spacing devices individually comprise a nut element fixedly connected to the truss structure and engaged by a screw element rotationally connected to the skeletal structure, and guided means comprising part of the skeletal structure slidably engaging the nut element to be guided thereby for adjustive movement of said guided means, and thereby of the adjoining portion of skeletal structure, accompanying adjustive rotation of the screw element.

4. The apparatus defined in claim 3, wherein the spacing devices are connected to the skeletal structure substantially at intersections between the elongated stiffener members therein.

5. The apparatus defined in claim 1, wherein the spacing devices are connected to the skeletal structure substantially at intersections between the elongated stiffener members therein.

6. The microwave antenna defined in claim 1, wherein the primary antenna means further comprises a plurality of elongated supports having forward ends supportingly connected to the radiation element to position the latter at a predetermined point in front of the reflector structure, said supports extending rearwardly in diverse directions from said radiation element and having rearward ends connected to the reflector structure, said elongated supports each comprising a portion movable lengthwise of the support to vary the position of the radiation element relative to said point, reversible actuating means operable to effect such movement of each support portion independently of the others, and independent positional control means for each such support comprising an elongated substantially constant-length element and a variable element connected to one end thereof, with said elements extending serially between positional references respectively comprising the reflector structure and the radiation element, and with said constant-length element stretching at least approximately parallel to its associated support, each such control means further including switch means having cooperating relatively movable switching elements respectively connected to one of said references and to said one end of the constant-length element, said switch means being controllingly connected to the actuating means and being operable thereby, in response to displacements of the radiation element, to apply restorative positional corrections to the radiation element.

7. The microwave antenna defined in claim 6, wherein the constant-length element comprises a long and relatively thin length of material having thermally stable dimensional properties, and the variable element comprises a relatively short resilient means connected to the reflector structure, one of the switching elements being connected to the reflector structure.

8. The microwave antenna defined in claim 7, wherein the elongated supports individually comprise a rigid elongated member and a movable supporting means connecting the rearward end of such member to the reflector structure and being operable to move the elongated member lengthwise of itself, in either direction, relative to the reflector structure.

9. The microwave antenna defined in claim 8, wherein the movable supporting means comprises a bell crank having one end connected to the rearward end of the rigid elongated member, a fluid-operated jack reactively connected between the opposite ends of the bell crank and the reflector structure, said bell crank having an immediately located pivotal connection to the reflector structure.

10. The microwave antenna defined in claim 1, wherein the primary antenna means further comprises elongated support means supportingly connected at one end to the radiation element to position the latter at a predetermined point in front of the reflector structure, said support means extending rearwardly from said radiation element and being connected to the reflector structure, said elongated support means comprising a portion movable fore and aft of the antenna to vary the position of the radiation element relative to said point, reversible actuating means operable to effect such movement, and positional control means comprising an elongated substantially constant-length element and a variable element connected to one end thereof, with said elements extending serially between positional references respectively comprising the reflector structure and the radiation element, such control means further including reversible switch means having cooperating relatively movable switching elements respectively connected to one of said references and to said one end of the constant-length element, said switch means being

controllingly connected to the actuating means and being operable thereby, in response to displacements of the radiation element, to apply restorative positional corrections to such element.

11. A microwave antenna comprising a reflector structure having front and rear and having a primary antenna means including a radiation element directed electrically toward the front of said reflector structure, and support means supportingly connected at one end to the radiation element to position the latter at a predetermined point in front of the reflector structure, said support means extending rearwardly from said radiation element and being connected to the reflector structure, said elongated support means comprising a portion movable fore and aft of the antenna to vary the position of the radiation element relative to said point, reversible actuating means operable to effect such movement, and positional control means comprising an elongated substantially constant-length element and a variable element connected to one end thereof, with said elements extending serially between positional references respectively comprising the reflector structure and the radiation element, such control means further including reversible switch means having cooperating relatively movable switching elements respectively connected to one of said references and to said one end of the constant-length element, said switch means being controllingly connected to the actuating means and being operable thereby, in response to displacements of the radiation element, to apply restorative positional corrections thereto.

12. A microwave antenna comprising a reflector structure having front and rear and having a primary antenna means including a radiation element directed electrically toward said reflector structure, and a plurality of elongated supports having forward ends supportingly connected to the radiation element to position the latter at a predetermined point in front of the reflector structure, said supports extending rearwardly in diverse directions from said radiation element and having rearward ends connected to the reflector structure, said elongated supports each comprising a portion movable lengthwise of the support to vary the position of the radiation element relative to said point, reversible actuating means operable to effect such movement of each support independently of the others, and independent positional control means for each such support comprising an elongated substantially constant-length element and a variable element connected to one end thereof, with said elements extending serially between positional references respectively comprising the reflector structure and the radiation element, and with said constant-length element stretching at least approximately parallel to its associated support, each such control means further including reversible switch means having cooperating relatively movable switching elements respectively including a first switching element connected to one of said references and a second switching element connected to said one end of the constant-length element, said switch means being controllingly connected to the actuating means and being operable thereby, in response to displacements of the radiation element, to apply restorative positional corrections to such radiation element.

13. The microwave antenna defined in claim 12, wherein the constant-length element comprises a long length of wire having thermally stable dimensional properties, and the variable element comprises a relatively short resilient means connected to the reflector structure, the first-mentioned switching element of said switch means being connected to the reflector structure.

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