May 31, 1966 S. E. MILLER 3,254,342

ANTENNA SYSTEM WHEREIN BEAMWIDTH VARIATION IS ACHIEVED BY CHANGING SHAPE OF INTERMEDIATE REFLECTOR

Filed July 9, 1963 4 Sheets-Sheet 1

FIG. 1

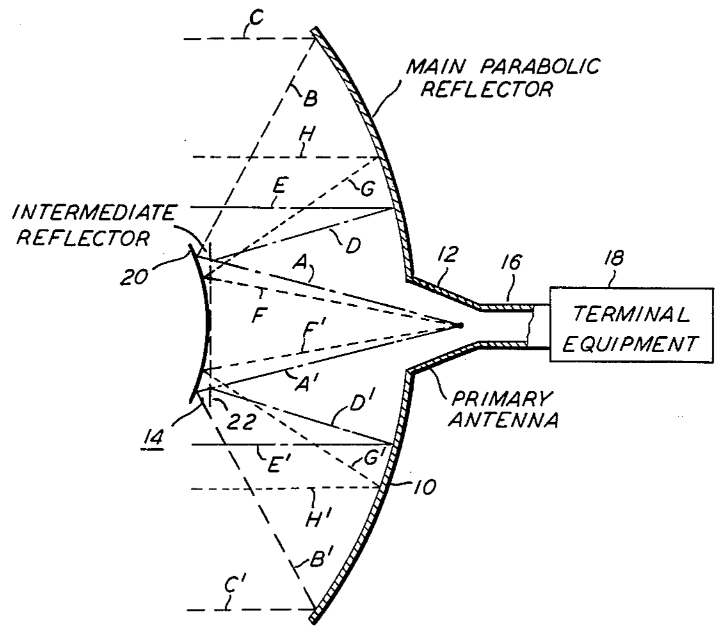

FIG. 2A

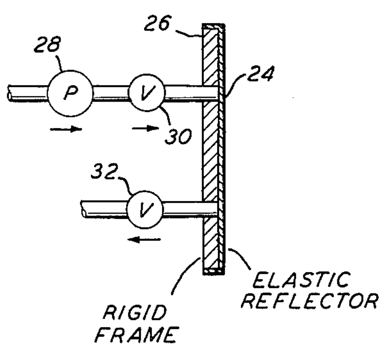

FIG. 2B

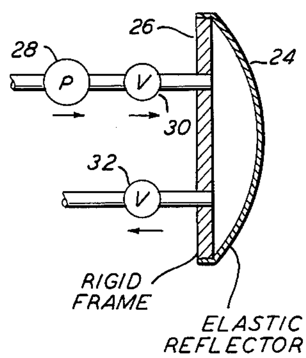

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FIG. 3A

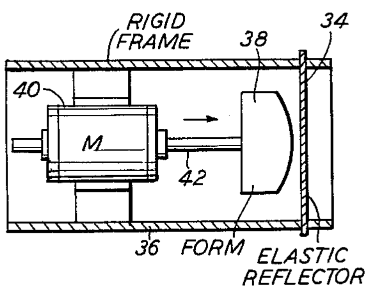


FIG. 3B

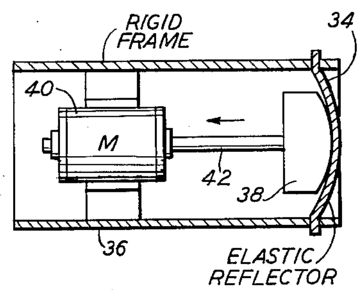


FIG. 4A

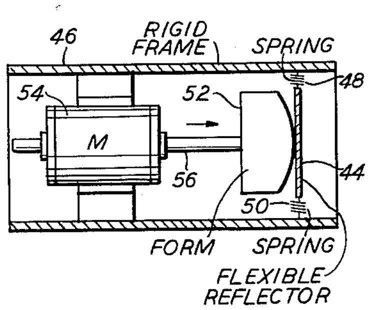


FIG. 4B

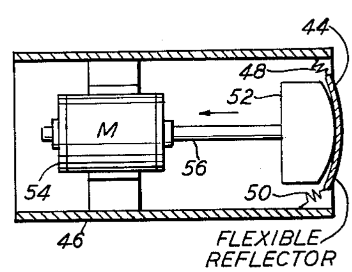


FIG. 5A

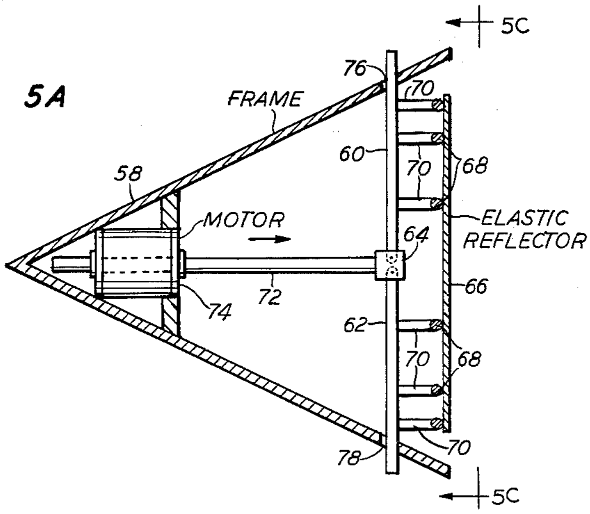


FIG. 5B

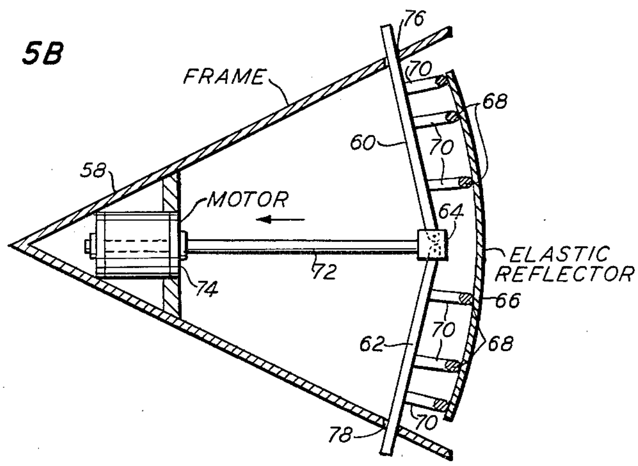


FIG. 5C

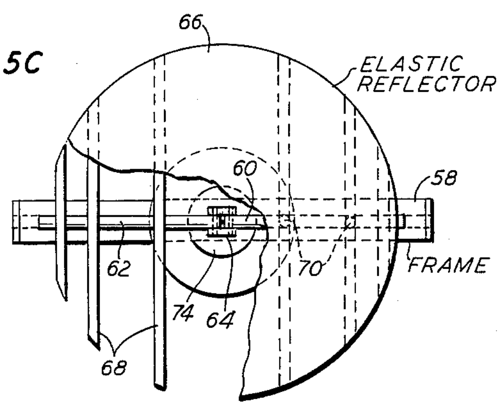


FIG. 6A

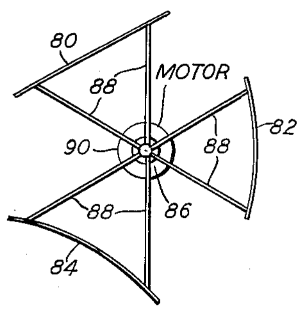


FIG. 6B

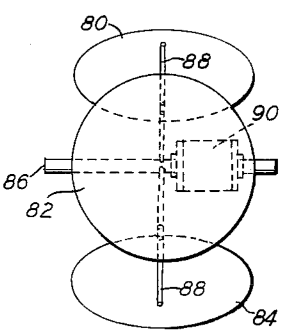


FIG. 7A

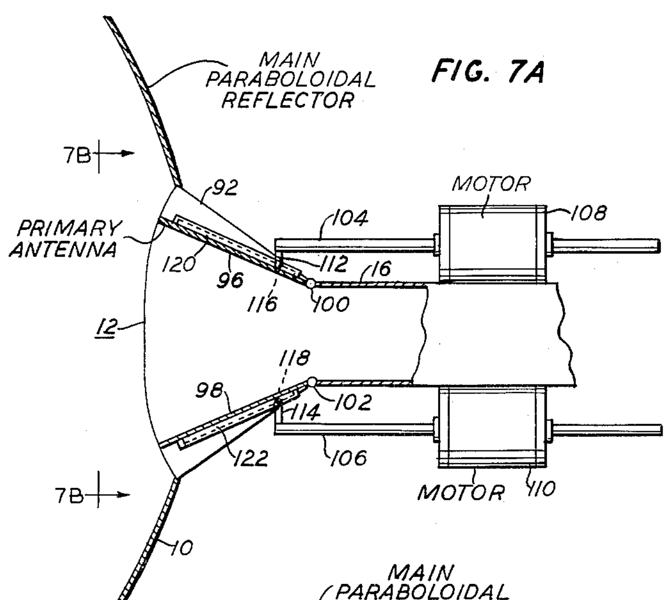
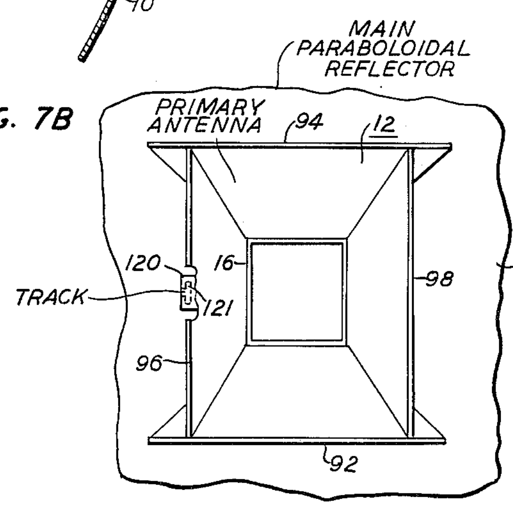


FIG. 7B



United States Patent Office

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ANTENNA SYSTEM WHEREIN BEAMWIDTH VARIATION IS ACHIEVED BY CHANGING SHAPE OF INTERMEDIATE REFLECTOR

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6 Claims. (Cl. 343—781)

This invention relates to antenna systems, and more particularly, to a variable-beamwidth antenna system of the type having a passive reflector and an active feed therefor.

In some applications for an antenna system of the type having a passive dish reflector and an active feed therefor it is desirable to have the capacity to vary the beamwidth of the principal lobe of the radiation pattern of the antenna system, so that a single antenna structure can be employed alternatively to perform two functions. As an example of such an application, a single antenna system capable of producing both a broad beam and a narrow beam, alternatively, can be employed in a radar system respectively for acquisition of and tracking a target. Dual use of a single antenna system under appropriate circumstances can result in conservation of space and equipment.

Dish antenna systems have been designed that cause variations in beamwidth by changing the contour of the reflector surface. Although not too difficult in small dish reflectors, this technique when employed to vary the beamwidth of huge dish reflectors, such as are becoming commonplace in modern long-range communication systems, creates structural problems of a high order due to the extensive area of the reflector surface that must be moved to change the contour of the reflector.

It is also a practice to vary the beamwidth of a dish antenna system by moving the feed away from the focus of the dish reflector, i.e., by defocusing the system. The beamwidth of an antenna system is fairly insensitive to defocusing, however, and large displacement of the feed from the focus is necessary to vary the beamwidth appreciably. Providing for such large displacement can involve structural problems equal in severity to those encountered in distorting the contour of the reflector.

In addition to the structural complications introduced by designs that permit variation of beamwidth of an antenna system, the radiation pattern of the antenna system is often adversely affected. For example, the wide-angle sidelobes of the radiation pattern may increase, detracting from the effectiveness of the principal lobe.

It is, therefore, the object of this invention to vary the beamwidth of an antenna system of the type having a passive reflector and an active feed therefor over a broad range of values without large displacement of the feed, movement of an extensive area of the reflector surface, or introduction of adverse effects in the radiation pattern of the antenna system.

In accordance with this object, in an antenna system of the type having a passive reflector and an active feed therefor, variation of beamwidth is accomplished by changing the extent of coupling between the reflector and the feed, i.e., the area of illumination of the reflector when the antenna system is considered in a transmitting mode. The beamwidth of a dish antenna system is inversely related to the area of illumination of the dish reflector.

In one embodiment of the invention a so-called Cassegrainian feed is employed, comprising a primary antenna situated at or near the dish reflector and directed toward the focus of the dish reflector, and an intermediate reflector, of smaller surface area than the dish reflector, placed in the path of the primary antenna to direct electromagnetic waves between the dish reflector and the primary antenna. The contour of the intermediate reflector is controllable, permitting change in the area of illumination of the dish reflector. By distorting the intermediate reflector surface rather than the dish reflector surface, the same extent of variation in beamwidth can be achieved while moving a smaller area of reflector surface.

The intermediate reflector contour can be controlled, for example, by employing a reflector structure comprising an elastic, reflective material stretched over a rigid frame. The walls of the frame and the reflector define an air-tight chamber. Introduction of fluid into this chamber causes the reflector to distend, thus changing shape.

A Cassegrainian feed is also employed in a second embodiment of the invention, in which the primary antenna radiation pattern is changed. This can be accomplished by varying the aperture area of the primary antenna, which changes the area of illumination of the intermediate reflector and, in turn, the dish reflector. The primary antenna comprises a pyramidal horn opposite walls of which are hinged to pivot at the throat of the horn. Movement of the unhinged ends of these walls varies the aperture area of the primary antenna.

The above and other features of the invention will be more fully understood from the following detailed description considered in conjunction with the drawings in which:

FIG. 1 is a plan view partially in section of an antenna illustrating the principles of the invention;

FIGS. 2A and 2B are views partially in section of one embodiment of the intermediate reflector, shown respectively in relaxed and distended conditions;

FIGS. 3A and 3B are views partially in section of another embodiment of the intermediate reflector, shown respectively in relaxed and distended conditions;

FIGS. 4A and 4B are views partially in section of another embodiment of the intermediate reflector shown respectively in relaxed and distended conditions;

FIGS. 5A and 5B are plan views partially in section of another embodiment of the intermediate reflector shown respectively in relaxed and distended conditions;

FIG. 5C is a front elevation in partial section of the embodiment of the intermediate reflector shown in FIGS. 5A and 5B;

FIGS. 6A and 6B are side and front elevations, respectively, of another embodiment of the intermediate reflector; and

FIGS. 7A and 7B are plan and front elevations, respectively, partially in section of a primary antenna structure whose aperture area is controllable.

In FIG. 1 an antenna system is shown comprising a main reflector **10**, shown as of parabolic shape, and a Cassegrainian feed having a primary antenna **12** and an intermediate reflector **14**. Intermediate reflector **14** is attached to main parabolic reflector **10** by spars, not shown, in conventional fashion. Main parabolic reflector **10** can take, for example, the shape of a concave paraboloid or a parabolic cylinder. If a paraboloidal main reflector is employed, beamwidth variation in either one or two planes might be desired, depending upon the application at hand. If a concave parabolic cylinder is defined by the surface of main parabolic reflector **10**, beamwidth variation generally would be confined to a single plane, viz., to the plane passing through main reflector **10** upon which a parabola is projected. The arrangements described hereinafter are applicable either to vary beamwidth in a single plane or in two planes.

The antenna system of FIG. 1 will be described operating in the mode of transmission. It will be understood, as in antenna operations generally, that reciprocity applies and that the antenna system receives electromagnetic waves in a fashion reciprocal to that of the described mode of operation. The extent of coupling between feed and reflector is described in the parlance of the antenna art as the area of illumination of the reflector by the feed, connoting operation as a transmitter. When this terminology, i.e., area of illumination, is used in the course of the detailed description of the following arrangements and in the claims it shall not be taken as limiting the antenna system to operation as a transmitter.

Wave guide 16 in FIG. 1 connects terminal equipment 18 to primary antenna 12. Rays A and A′ represent the limits of the electromagnetic wave radiated from primary antenna 12 toward intermediate reflector 14. Intermediate reflector 14 is shown as alternatively having either of two contours labeled 20 and 22. First, it will be assumed that contour 20, shown as a solid line, represents the shape of intermediate reflector 14. In this case, rays A and A′ impinge upon contour 20 and are reflected therefrom within the limits indicated by rays B and B′. Rays B and B′, in turn, impinge upon and are reflected from main parabolic reflector 10 to form the ultimate antenna beam. The distance between rays C and C′ represents the area of illumination of main parabolic reflector 10 which is inversely related to the beamwidth of the principal lobe of the far field radiation pattern of the antenna system. Next, it will be assumed that contour 22, shown as a dashed line, represents the shape of intermediate reflector 14. In this case, rays A and A′ impinge upon and are reflected from contour 22 within the limits represented by rays D and D′ which are, in turn, reflected from main parabolic reflector 10. The area of illumination of main parabolic reflector 10 is, in this case, represented by the distance between rays E and E′. From consideration of this ray description, it can be seen that different contours for intermediate reflector 14 produce different wavefronts for waves reflected therefrom, resulting in different areas of illumination of main parabolic reflector 10. This, in turn, is manifested in the far field of the antenna system by a change in beamwidth. For example, a narrower beamwidth is produced when contour 20 is operative than when contour 22 is operative.

It will now be assumed that the characteristics of primary antenna 12 are changed so that its radiation pattern is represented by rays F and F′ and contour 20 is the shape of intermediate reflector 14. Rays F and F′ impinge upon contour 20 and reflect therefrom within the limit represented by rays G and G′. Rays G and G′ reflect from main parabolic reflector 10, forming the ultimate antenna beam. It is apparent from comparison of the distance between rays H and H′ with the distance between rays C and C′ that a change in the area of illumination of main parabolic reflector 10 can also be accomplished by controlling the beamwidth of the radiation pattern of primary antenna 12.

FIGS. 2A and 2B show one embodiment of intermediate reflector 14. An elastic reflector 24 is fastened to the edges of a rigid frame 26, so that an air-tight chamber is formed between the opposite surfaces of elastic reflector 24 and rigid frame 26. Air from the atmosphere is forced into the chamber between elastic reflector 24 and rigid frame 26 by a pump 28 when an inlet valve 30 is opened. As air enters the chamber, elastic reflector 24 distends, with the result that it changes shape. This is illustrated in FIG. 2B. When it is desired to return elastic reflector 24 to a relaxed condition, shown in FIG. 2A as presenting a planar surface, an outlet valve 32 is actuated and air is dispelled from the chamber into the atmosphere. Elastic reflector 24 in its distended condition is analogous to contour 20 of intermediate reflector 14 shown in FIG. 1 and in its relaxed condition is analogous to contour 22 of intermediate reflector 14 shown in FIG. 1. The intermediate reflector arrangement of

FIGS. 2A and 2B would most advantageously be employed in situations in which beam variation is desired in two planes.

In FIGS. 3A and 3B an alternative embodiment of intermediate reflector 14 is disclosed. Here, an elastic reflector 34 is fastened to a rigid frame 36, which could be cylindrical or rectangular in the cross section normal to the plane of the drawing. A form 38, whose contour is to be transferred to elastic reflector 34, is coupled to a motor 40 by a shaft 42. In FIG. 3A form 38 is shown in its disengaged condition and elastic reflector 34 assumes its normal contour. When motor 40 operates, shaft 42 undergoes translational motion from left to right, driving form 38 against elastic reflector 34 and imposing the contour of form 38 upon elastic reflector 34.

A modification of the arrangement of FIGS. 3A and 3B is illustrated in FIGS. 4A and 4B. In this case, a flexible reflector 44 is suspended between a rigid frame 46, which also could be cylindrical or rectangular in cross section, and is held in tension by springs of which 48 and 50 are representative. A form 52, driven by a motor 54 coupled thereto by a shaft 56, imposes its shape upon flexible reflector 44, as shown in FIG. 4B, when moved against flexible reflector 44. Springs 48 and 50 restore flexible reflector 44 to its normal shape upon retreat of form 52 from flexible reflector 44.

Another structure for varying the contour of intermediate reflector 14 is shown in FIGS. 5A, 5B and 5C. An A-frame 58 supports movable members 60 and 62 that are hinged together at a block 64 and are supported at their other ends in openings 76 and 78, respectively, in A-frame 58. An elastic reflector 66 is situated at the base of A-frame 58 and vertical ribs 68 are attached thereto. Horizontal cross members 70 connect ribs 68 to movable members 60 and 62. One end of a a shaft 72, driven by a motor 74, is attached to block 64. When motor 74 translates shaft 72 from left to right, members 60 and 62 pivot at their points of contact with A-frame 58 at openings 76 and 78 and the ends of members 60 and 62 connected to block 64 move with shaft 72. This operation introduces a convex contour to elastic reflector 66 in a plane perpendicular to ribs 68.

FIGS. 6A and 6B show an arrangement of three different intermediate reflector contours respectively on surfaces, 80, 82, and 84 distributed radially about a shaft 86. Spoke supports 88 connect surfaces 80, 82, and 84 to shaft 86. Shaft 86 is appropriately supported for rotation by a motor 90 to position the desired surface as the intermediate reflector in the line of primary antenna 12 when it is desired to change the contour of intermediate reflector 14.

FIGS. 7A and 7B disclose a structure for primary antenna 12 that permits regulation of its radiation pattern. Primary antenna 12 takes the form of a pyramidal horn having stationary walls 92 and 94 and movable walls 96 and 98, pivoted about hinges 100 and 102. Shafts 104 and 106 are translated by motors 108 and 110, respectively. The translational motion of shafts 104 and 106 is transferred to walls 96 and 98 by means of interconnecting members 112 and 114, respectively, and arms 116 and 118, respectively, which are constrained to motion within tracks 120 and 122, respectively. As a result, movement of shafts 104 and 106 from right to left pushes the unhinged ends of walls 96 and 98 inwardly, thus contracting the aperture area of primary antenna 12. Conversely, movement of shafts 104 and 106 from left to right causes arms 116 and 118 to exert force against flanges 121 of tracks 120 and 122, which is transferred to walls 96 and 98 causing them to move outwardly and dilate the aperture of primary antenna 12. The effect of change in the aperture area of primary antenna 12 upon the beamwidth of the antenna system far field depends upon the location of intermediate reflector 14 with respect to primary antenna

12. If intermediate reflector **14** is placed in the near field of the radiation pattern of primary antenna **12**, as taught in Patent 3,231,893, issued on January 25, 1966, to D. C. Hogg and assigned to the assignee of this invention, dilation of the primary antenna aperture increases the beamwidth of the wave impinging upon intermediate reflector **14** and, as discussed in connection with FIG. 1, decreases the far field beamwidth. On the other hand, if intermediate reflector **14** is situated in the far field of primary antenna **12**, as in normally the case, dilation of the aperture of primary antenna **12** decreases the beamwidth of the wave impinging upon intermediate reflector **14** and, as discussed in connection with FIG. 1, increases the far field beamwidth.

If it is desired to vary both aperture dimensions of primary antenna **12**, walls **92** and **94** would be hinged and provided with apparatus, similar to that shown for walls **96** and **98**, for moving them. In this case, gaps would exist at the corners of the horn in some conditions, but these gaps would not adversely affect performance if not too large.

Practice of this invention is not limited to a Cassegrainian feed arrangement. A Cassegrainian feed arrangement, however, has many characteristics that enhance the radiation pattern of an antenna system and permits control of the area of illumination of the main parabolic reflector by means of relatively simple mechanical apparatus. Beamwidth control can be accomplished by providing a conventional feed located at the focus of the main parabolic reflector and varying the radiation pattern thereof. This can be done, for example, by providing a horn like that shown in FIGS. 7A and 7B at the focus, directed toward main parabolic reflector **10**.

What is claimed is:

1. An antenna system with means for changing the beamwidth of the radiation pattern of electromagnetic waves radiating from said antenna system which comprises a concave reflector having a focus and a vertex, said electromagnetic waves emanating from said concave reflector and having a plane wavefront, a primary antenna located near said vertex, said primary antenna being symmetrically oriented on and directed along the axis of said concave reflector toward said focus, an intermediate reflector having its axis coincident with the axis of said concave reflector, said intermediate reflector being situated to intercept the radiation pattern of said primary antenna, thereby coupling waves between said concave reflector and said primary antenna, and means for changing the shape of said intermediate reflector, thereby controlling the extent of coupling between said primary antenna and said concave reflector to introduce variation in the beamwidth of the radiation pattern of said antenna system without changing the plane wavefront characteristics of the electromagnetic waves emanating from said concave reflector.

2. The antenna system of claim **1** in which said intermediate reflector is constructed of elastic material and said means for changing the shape of said intermediate reflector comprises a rigid frame to which said elastic reflector is fastened to form an air-tight chamber defined by the surfaces of said rigid frame and said elastic reflector facing each other, means for introducing fluid into said chamber, and means for removing said fluid from said chamber.

3. The antenna system of claim **1** in which said intermediate reflector is constructed of elastic material and said means for changing the shape of said intermediate reflector comprises a rigid frame attached to the extremities of said elastic reflector and a form movable against the center portion of said elastic reflector to impose upon said elastic reflector its shape.

4. The antenna system of claim **1** in which said intermediate reflector is constructed of flexible material and said means for changing the shape of said intermediate reflector comprises a rigid frame that at least partially surrounds said flexible reflector, spring means holding said flexible reflector in tension and connecting said flexible reflector to said walls of said rigid frame, and a form movable against said flexible reflector to impart to said flexible reflector its contour.

5. The antenna system of claim **1** in which said intermediate reflector has a plurality of surfaces having respectively different contours and in which said means for changing the shape of said intermediate reflector comprises means for selectively arranging one of said surfaces to couple waves between said primary antenna and said concave reflector, the extent of the coupling between said primary antenna and said concave reflector depending upon the surface selected.

6. The antenna system of claim **1** in which said intermediate reflector is constructed of elastic material and said means for changing the shape of said intermediate reflector comprises a rigid frame attached to said elastic reflector and a form movable against said elastic reflector to change the shape of said elastic reflector.

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