

Feb. 9, 1965

J. S. COOK ETAL

3,169,246

ANTENNA ARRAY OF SAME DIRECTED HORN REFLECTOR UNITS  
SUPPORTED IN A SIDE-BY-SIDE MANNER

Filed March 15, 1963

4 Sheets-Sheet 1

FIG. 1

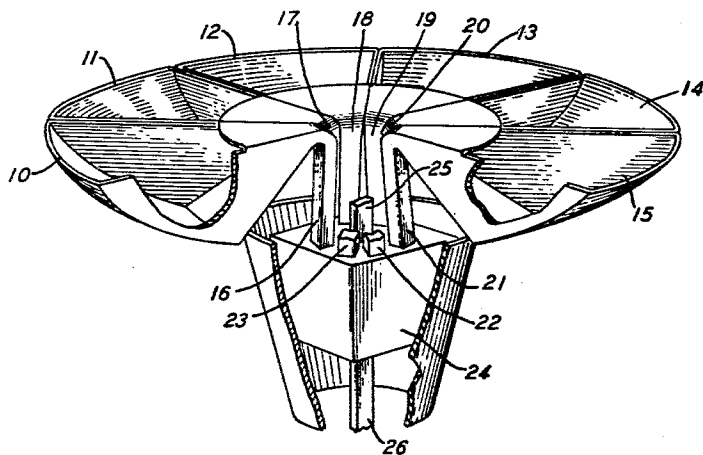
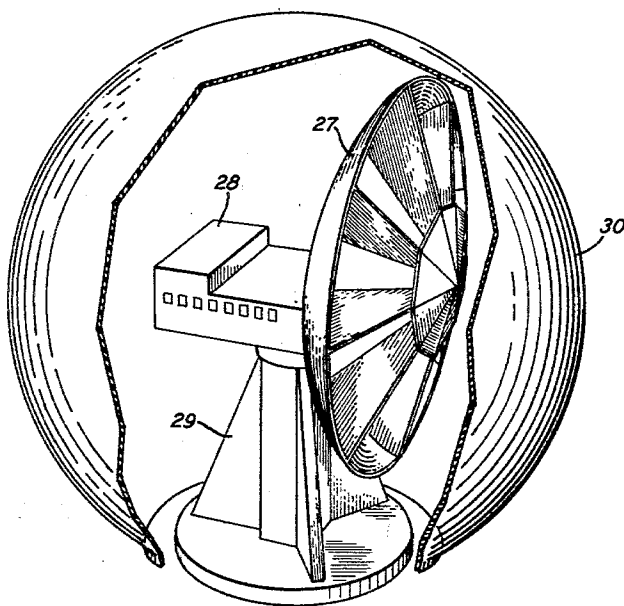


FIG. 2



INVENTORS J. S. COOK  
J. N. HINES  
BY

*W. H. Hines*  
ATTORNEY

Feb. 9, 1965

J. S. COOK ET AL

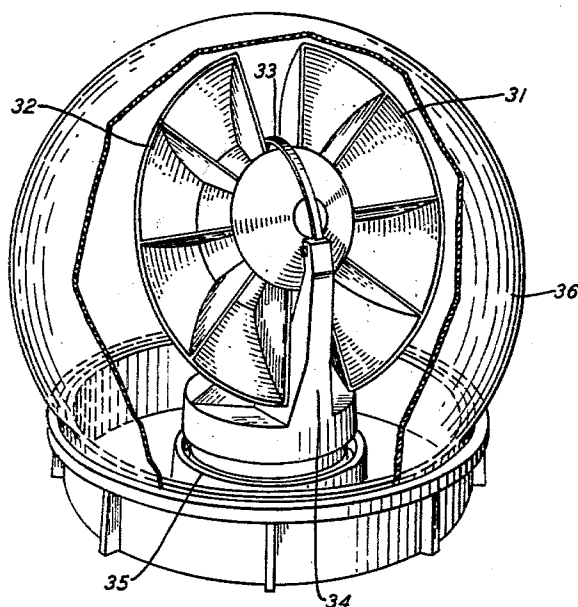
3,169,246

ANTENNA ARRAY OF SAME DIRECTED HORN REFLECTOR UNITS  
SUPPORTED IN A SIDE-BY-SIDE MANNER

Filed March 15, 1963

4 Sheets-Sheet 2

FIG. 3



**Feb. 9, 1965** **J. S. COOK ETAL** **3,169,246**  
 ANTENNA ARRAY OF SAME DIRECTED HORN REFLECTOR UNITS  
 SUPPORTED IN A SIDE-BY-SIDE MANNER  
 Filed March 15, 1963 4 Sheets-Sheet 3

J. S. COOK ETAL 3  
RAY OF SAME DIRECTED HORN REFLECTOR UNITS  
SUPPORTED IN A SIDE-BY-SIDE MANNER

**3,169,246**

4 Sheets-Sheet 3

## TRANSMITTER WAVEGUIDE CIRCUITRY

TO  
TRANSMITTER

Feb. 9, 1965

J. S. COOK ETAL

3,169,246

ANTENNA ARRAY OF SAME DIRECTED HORN REFLECTOR UNITS  
SUPPORTED IN A SIDE-BY-SIDE MANNER

Filed March 15, 1963

4 Sheets-Sheet 4

FIG. 6

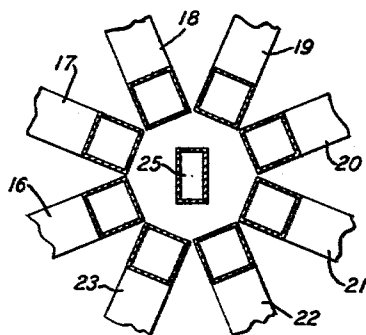
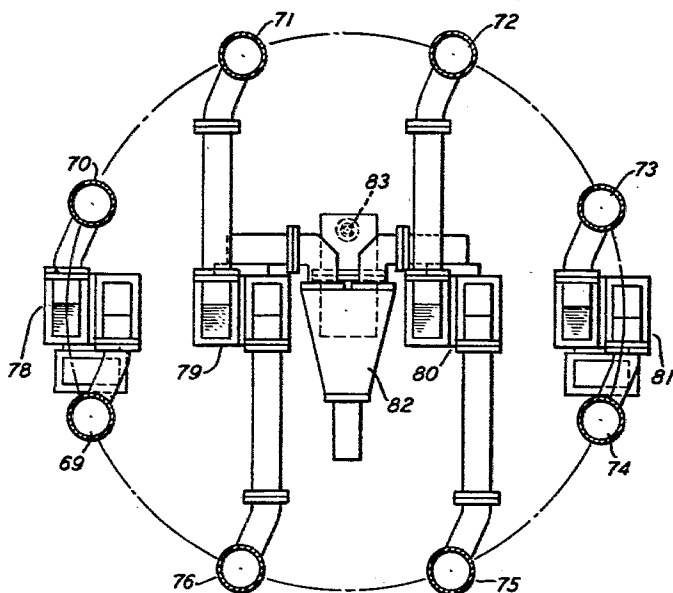


FIG. 5



1

3,169,246

## ANTENNA ARRAY OF SAME DIRECTED HORN REFLECTOR UNITS SUPPORTED IN A SIDE-BY-SIDE MANNER

John S. Cook, New Providence, and John N. Hines, Morristown, N.J., assignors to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Filed Mar. 15, 1963, Ser. No. 265,386

10 Claims. (Cl. 343-776)

This invention relates to antenna systems and in particular to arrays of directional antennas.

Parabolic-reflector antennas have been widely used because they possess certain desirable electrical and mechanical features. They have, for example, relatively high gain characteristics and physical symmetries that are desirable from manufacturing and operating viewpoints. Unfortunately, however, they have far side lobe to main lobe sensitivity ratios which sometimes cause extraneous signals appearing within the far side lobes to produce undesirable effects. (The expression "far side lobes" as used in this specification is an expression of art identifying minor lobes of the radiation pattern directed at angles substantially different from the antenna pointing direction.) The signals appearing in these side lobes are particularly objectionable when using recently developed low-noise high-gain receivers to receive weak signals.

Antennas which have lower far side lobe to main lobe sensitivity ratios than those of parabolic-reflector antennas are horn-reflector antennas. Horn-reflector antennas also have low-loss feedlines and substantially uniform and highly efficient transmission characteristics over relatively wide frequency and ambient temperature ranges. They have, therefore, been used to advantage with low-noise high-gain receivers to receive relatively weak signals. (Several types of horn-reflector antennas are disclosed in the literature. See, for example, U.S. Patent 2,416,675, issued to Beck and Friis on March 4, 1947; U.S. Patent 2,817,837, issued to Dale and Friis on December 24, 1957; and "A Horn-Reflector Antenna for Space Communications," by Crawford, Hogg and Hunt, beginning on page 1095 in the July 1961 issue of the Bell System Technical Journal.)

Although horn-reflector antennas have electrical characteristics which are superior in some applications to those of parabolic-reflector antennas, they have mechanical characteristics which result in more severe construction and operating requirements. They, for example, are larger than and lack the symmetry of comparable parabolic-reflector antennas. These two characteristics produce a number of undesirable results. Firstly, horn-reflector antennas require the use of stronger, which generally means heavier, structural elements. Secondly, the heavier structures in turn require larger and stronger mounting foundations. Thirdly, the heavier and larger structures have greater moments of inertia which require higher powered mechanical steering mechanisms. Fourthly, when radomes are required, the larger structures require larger radomes. Although these more severe construction and operating requirements have been successfully met in present day large horn-reflector antenna installations, they have resulted in large expenditures of time and money. It would therefore be advantageous to have antenna arrangements having mechanical characteristics similar to or better than those of parabolic-reflector antennas and electrical characteristics similar to those of horn-reflector antennas.

An object of the present invention is to provide in an antenna arrangement size and weight characteristics similar to or better than those of comparable parabolic-reflector antennas and electrical characteristics similar to those of comparable horn-reflector antennas.

2

In accordance with the invention in one of its broader aspects a plurality of horn-reflector antennas are arranged to form at least a portion of a substantially circular array with the apexes of the antennas at substantially the center of the array and the apertures of the antennas directed in substantially the same direction. The apexes of the antennas are connected to an electrical coupler unit located at substantially the center of the array. As discussed subsequently, this coupler may take any one of a number of forms.

In some embodiments of the invention, the plurality of horn-reflector antennas is a composite structure formed by joining together individual antennas. In other embodiments, the plurality of horn-reflector antennas is a unitary structure with the antennas formed within the structure.

The coupler may comprise any one of a number of known combinations of elements. The particular combination selected for an embodiment will depend upon various factors such as technical requirements and availability. A typical coupler may include, for example, polarizers-depolarizers, diplexers, amplifiers and sum and difference signal adders.

The electrical characteristics of embodiments of the invention are similar to those of a single horn-reflector antenna. The mechanical characteristics, on the other hand, are similar to those of a parabolic-reflector antenna. The latter is achieved in accordance with the invention because, firstly, the horn-reflector antennas are clustered in a compact circular array which has the basic configuration of a parabolic-reflector antenna. Secondly, the sides of the antennas provide what in effect comprise septums. These septums provide rigidity which in turn permits the strength and consequently the weight of some of the other structural elements to be reduced.

A feature of the invention is that when an embodiment is a composite structure of individual antennas and the individual antennas are small enough to be moved as units, the embodiment may be easily transported from one location to another. The antennas may, for example, be manufactured in a factory, transported to a site and assembled. Similarly a relatively large structure may be relatively easily moved from one site to another.

Another feature of the invention is that the outputs of the antennas may be combined to allow slight electrical scanning. This is particularly advantageous to counteract slight pointing errors caused by wind buffeting when embodiments are used without radomes.

Still another feature of the invention is that embodiments may be easily arranged to provide monopulse tracking signals.

Other objects and features of the invention will become apparent from a study of the following detailed description of several specific embodiments.

In the drawings:

FIG. 1 is a fragmentary view of an embodiment of the invention;

FIG. 2 is a view of an embodiment of the invention in a typical installation;

FIG. 3 shows an embodiment of the invention in an installation forming the principal subject matter of patent application Serial No. 265,418 filed on even date herewith by A. R. Smith and A. H. Williamson, Jr.;

FIG. 4 is a partial view of one combination of elements that may be used as a coupling unit when practicing the invention; and

FIGS. 5 and 6 are sectional views of the combination shown in FIG. 4.

FIG. 1 is a fragmentary view of one embodiment of the invention. The embodiment in its complete form comprises eight individual horn antennas arranged in a side-by-side manner to form a circular array. Only six of

3

the antennas, identified as 10 through 15 are shown in the fragmentary view. Associated with antennas 10 through 15 are feedlines 16 through 21, respectively. Each of these feedlines has a substantially right angle bend so that the ends of the lines opposite to those connected to the antennas terminate toward the rear of the antennas. Portions of the feedlines associated with the two unillustrated antennas are identified as 22 and 23, respectively. Feedlines 16 through 23 are connected to a coupler unit 24. Two additional feedlines 25 and 26 are connected to coupler unit 24. Feedline 25 is for connection to a receiver while feedline 26 is for connection to a transmitter.

The antennas of the embodiment of FIG. 1 may be of either the sectoral or conical horn-reflector type. Both of these types are described in the previously referred to prior art. Furthermore, the apertures may lie in a plane as shown or they may lie in a convex or concave conical surface. An arrangement in which the apertures lie in a convex conical surface is shown in FIG. 2.

Coupling unit 24 of FIG. 1 may comprise any one of a number of arrangements. It may, for example, comprise polarizers-depolarizers, diplexers, sum and difference beam adders and amplifiers. A particular arrangement which is discussed subsequently is disclosed in FIGS. 4, 5 and 6.

The invention lends itself to combining the individual antenna outputs to permit a limited amount of electrical scanning. (The scanning range is naturally limited by the beam-widths of the individual horns.) Such scanning could be used to counteract slight pointing errors produced by wind buffeting when operating without a radome.

With respect to electrical characteristics, the embodiment of FIG. 1 and other embodiments of the invention have desirable low far side lobe to main lobe sensitivity ratios and are intrinsically capable of the broadband and low loss feedline characteristics found in individual horn-reflector antennas.

With respect to mechanical characteristics, it will be noted that the general shapes of the structure of FIG. 1 and other structures built in accordance with the invention are substantially identical to that of a parabolic-reflector antenna. The structures may, however, be formed of lighter weight elements than those of comparable parabolic-reflector antennas because of the added rigidity provided by the septums formed by the sides of the horn-reflector antennas. Still another mechanical advantage is that when the arrangement is of a composite nature as shown in FIG. 1 and the individual antennas are of a size whereby they may be transported as separate units, the structure may be relatively easily dismantled, moved to another site and reassembled.

FIG. 2 illustrates a relatively large antenna installation utilizing an embodiment of the invention. The circular array of horn-reflector antennas identified as 27 is a unitary structure; that is, unlike the embodiment of FIG. 1 wherein a group of individual antennas are assembled to form an array, the antennas in the present structure are formed by building the entire assembly. The circular array 27 is mechanically connected to a control cab 28 so that the array may be moved to cause its radiation pattern to vary in elevation. Control cab 28 is in turn rotatably mounted to a pedestal 29 so that the radiation pattern of array 27 may be varied in azimuth. The entire structure is enclosed in a radome 30.

FIG. 3 illustrates an embodiment of the invention which embodiment comprises a part of an installation forming the principal subject matter of patent application Serial No. 265,418 filed on even date herewith by A. R. Smith and A. H. Williamson, Jr. This installation takes advantage of the individual nature of the antennas. In particular, the array is formed in two unitary sections 31 and 32 with four antennas in each section. Sections 31 and 32 are affixed to a ring member 33 which in turn is rotatably mounted on a pedestal 34 so that the radiation

4

pattern of the array comprising sections 31 and 32 may be moved in elevation. Pedestal 34 is rotatably mounted on a base 35 so that the radiation pattern of the array may be moved in azimuth. The entire structure is mounted in a radome 36. As fully described in the Smith et al. application, this installation utilizing an embodiment of the invention permits further weight reduction, a better balanced structure and a more compact structure. As a result of these improved characteristics, the drive mechanisms may be made more economical because of a lower moment of inertia, the base structure may be reduced because of supporting less weight and the radome may be made smaller because of the more compact nature of the installation.

In the above-described illustrative embodiments of the invention, complete or substantially complete circular arrays of antennas are disclosed. In accordance with the invention, there need not be a complete circular array as the invention may be practiced with only a portion of such array. However, fuller advantage of the invention is obtained when the array is in a complete circular form. Furthermore, the array need not be exactly circular but instead only substantially circular. It may be desirable from a beam shaping standpoint, for example, to make the array slightly elliptical in disposition.

FIGS. 4, 5 and 6 are partial views of one combination of elements that may be used as coupling unit 24. FIG. 5 is a sectional view of FIG. 4 taken at 5—5 while FIG. 6 is a sectional view of FIG. 4 taken at 6—6.

Before discussing the combination of FIGS. 4, 5 and 6 in detail, a few general comments are first presented. Firstly, because of the symmetrical nature of the combination some of the elements are not seen in these views because they are identical with and lie directly behind the illustrated elements. Secondly, some of the elements which are duplicates of the illustrated ones are not shown because to show them would tend to overly complicate the drawings. The unillustrated elements are, however, considered in the following discussion. Thirdly, the combination is for use with an eight antenna arrangement as shown in FIG. 1. In view of this, reference numerals used in FIG. 1 are used in the presently considered drawings where applicable. Finally, each element in the combination is both well known to those skilled in the art and functions in a conventional manner. These elements, therefore, are not discussed in detail.

In FIG. 4, a ring of eight parallel polarizer-depolarizer assemblies, each with its associated waveguide transition units, forms a "bird cage" assembly. The upper end of this "bird cage" assembly is connected to the antennas of FIG. 1 via their respective feedlines 16 through 23. Only feedlines 16 and 21 through 23 appear in FIG. 4 because the remaining feedlines lie behind the illustrated ones. This may be better appreciated by referring to FIG. 6. The lower end of the "bird cage" assembly is connected to a plurality of diplexers which, in turn, are connected to transmitter and receiver waveguide circuitry. In particular: feedlines 16 through 23 are connected to waveguide transition units 37 through 43, respectively, which provide transitions from square waveguides to circular waveguides (units 38 through 41 are directly behind units 37, 44, 43 and 42, respectively); transition units 37 through 44 are connected to waveguide transition units 45 through 52, respectively, which provide transitions from circular waveguides to square waveguides turned 45 degrees in cross section with respect to feedlines 16 through 23 (units 46 through 49 are directly behind units 45, 52, 51 and 50, respectively); transition units 45 through 52 are connected to polarizer-depolarizer units 53 through 60, respectively (polarizer-depolarizer units 54 through 57 are directly behind polarizer-depolarizer units 53, 60, 59 and 58, respectively); polarizer-depolarizer units 53 through 60 are connected to transition units 61 through 68, respectively, which provide transitions from square waveguides to circular waveguides (units 62

5

through 65 are directly behind units 61, 68, 67, 66, respectively); and units 61 through 68 are connected to diplexers 69 through 76, respectively.

Diplexers 69 through 76 connect the circuitry thus far described to the combining waveguide circuitry for the receiver and the distributing waveguide circuitry for the transmitter. The transmitter distributing waveguide circuitry lies below diplexers 69 through 76 as shown in FIG. 4 while the receiver combining waveguide circuitry lies within the "bird cage" assembly. Because the transmitter distributing waveguide circuitry is substantially identical to the receiver combining waveguide circuitry, the former is not shown in detail but instead is indicated in block form by block 77. The transmitter waveguide circuitry is connected to an unillustrated transmitter by feedline 26.

The receiver combining waveguide circuitry comprises eight hybrid junctions. Seven of these junctions combine in three stages the receiver outputs from diplexers 69 through 76 to produce both a summation signal output and a pointing error signal output. The eighth hybrid junction is used in co-operation with two of the other junctions to produce a second pointing error signal output. In particular and as shown in both FIGS. 4 and 5, the receiver outputs of diplexers 69 and 70, diplexers 76 and 71, diplexers 75 and 72 and diplexers 73 and 74 are combined in hybrid junctions 78 through 81, respectively. The E plane arm outputs of junctions 78 and 81 are terminated while the E plane arm outputs of junctions 79 and 80 are coupled into a hybrid junction 82. The H plane arm output of junction 82 is terminated while the E plane arm provides a pointing error signal output at a connector 83. The H plane arm outputs of junctions 78 and 79 are coupled to a hybrid junction 84 while the H plane arm outputs of junctions 80 and 81 are coupled to a hybrid junction 85. The E plane arm outputs of junctions 84 and 85 are terminated while the H plane arm outputs are coupled to a hybrid junction 86. The H plane arm of junction 86 provides a summation signal output on feedline 25 while the E plane arm provides a pointing error signal at a connector 87 which is shown in phantom view in FIG. 4. One of the signals available at connectors 83 and 87 may be used for measuring pointing errors in an azimuthal sense while the other signal may be used for measuring pointing errors in an elevational sense.

Although several embodiments of the invention have been illustrated and described in detail it is understood that other embodiments may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A structure comprising a plurality of horn-reflector antennas forming at least a portion of a generally circular configuration with the apexes of said antennas directed towards the center of said circular configuration and the directivity pattern of each of said antennas directed in substantially the same direction, and electrical coupling means connected between said antennas and at least one transmission line.

6

2. A combination in accordance with claim 1 in which said structure is a composite structure comprising a plurality of individual horn-reflector antennas.

3. A combination in accordance with claim 1 in which said structure is a unitary structure in that said antennas exist only as a result of said structure.

4. In combination

a structure comprising a plurality of horn-reflector antennas arranged in a substantially side-by-side manner to form at least a portion of a circular array with the apexes of said antennas at substantially the center of said circular array and the apertures of said antennas directed in substantially the same direction, and

electrical coupling means connected between said apexes and at least one transmission line.

5. A combination in accordance with claim 4 in which said structure is a composite structure comprising a plurality of individual horn-reflector antennas.

6. A combination in accordance with claim 4 in which said structure is a unitary structure in that said antennas exist only as a result of said structure.

7. In combination

a plurality of horn-reflector antennas,

means supporting said antennas in a substantially side-by-side manner in the form of at least a portion of a circular array with the apexes of said antennas at substantially the center of said circular array and the apertures of said antennas directed in substantially the same direction, and

electrical coupling means connected between said apexes and at least one transmission line.

8. In combination

a plurality of horn-reflector antennas,

means supporting said antennas in a generally circular configuration with the apexes of said antennas directed towards the center of said circular configuration and the directivity pattern of each of said antennas directed in substantially the same direction, and

electrical coupling means connected between said apexes and at least one transmission line.

9. A combination comprising

a plurality of horn-reflector antennas, and

means supporting said antennas in a substantially side-by-side manner to form at least a portion of a circular array with the apexes of said antennas directed toward the center of said array and the apertures of said antennas directed in substantially the same direction.

10. In combination

a plurality of horn-reflector antennas forming at least a portion of a generally circular array with the apexes of said antennas directed toward the center of said array and the apertures of said antennas directed in substantially the same direction, and electrical coupling means connected to the apertures of said antennas.

No references cited.