United States Patent [19]

Gustincic

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[54] **WIDE ANGLE ANTENNA SYSTEM**

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[73] Assignee: **Cubic Corporation**, San Diego, Calif.

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[21] Appl. No.: **427,797**

[52] **U.S. Cl.** **343/783**; 343/786; 343/854

[51] **Int. Cl.**[2] **H01Q 3/26**

[58] **Field of Search** 343/754, 755, 786, 787, 343/837, 914, 783, 854

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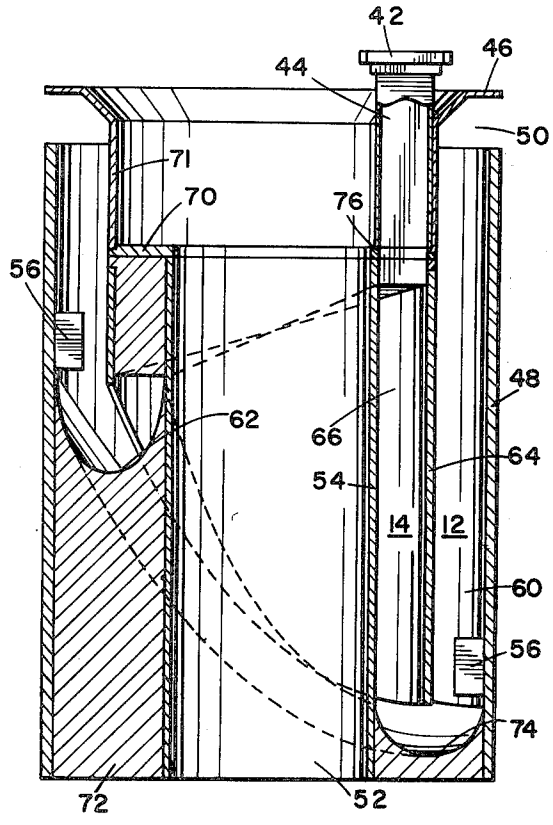
Primary Examiner—Eli Lieberman

Attorney, Agent, or Firm—Brown & Martin

[57] **ABSTRACT**

An antenna employing electronically controlled radiating elements that produce a primary illumination of a circular ring source aperture. The aperture is fed by a parallel plate waveguide that contains radiating elements curved around to conform to a cylindrical surface, and that is fed by a similarly curved widely flared feed horn forming a power divider to the radiating elements.

17 Claims, 21 Drawing Figures



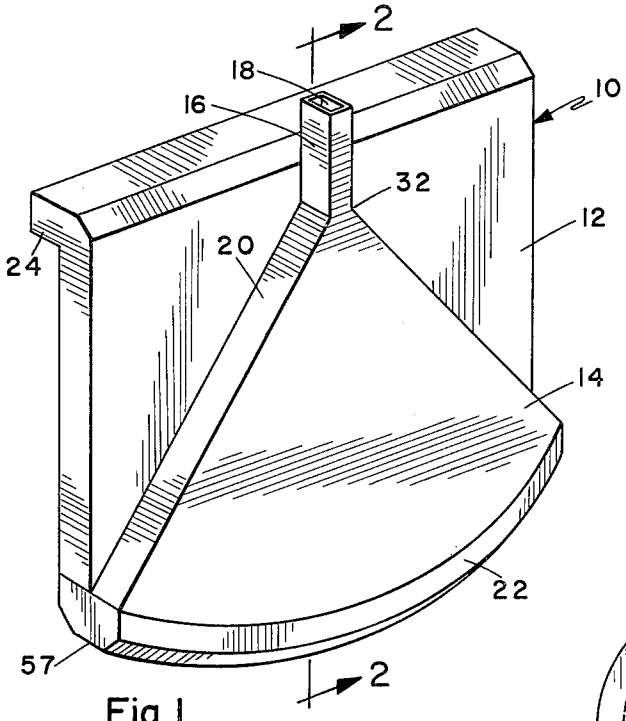


Fig. 1

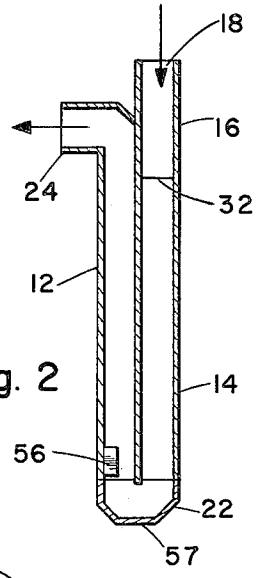


Fig. 2

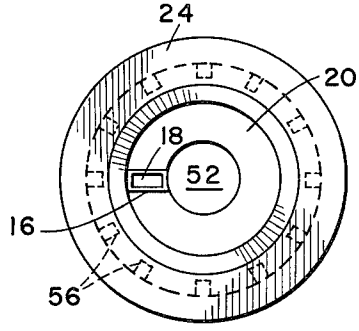


Fig. 3

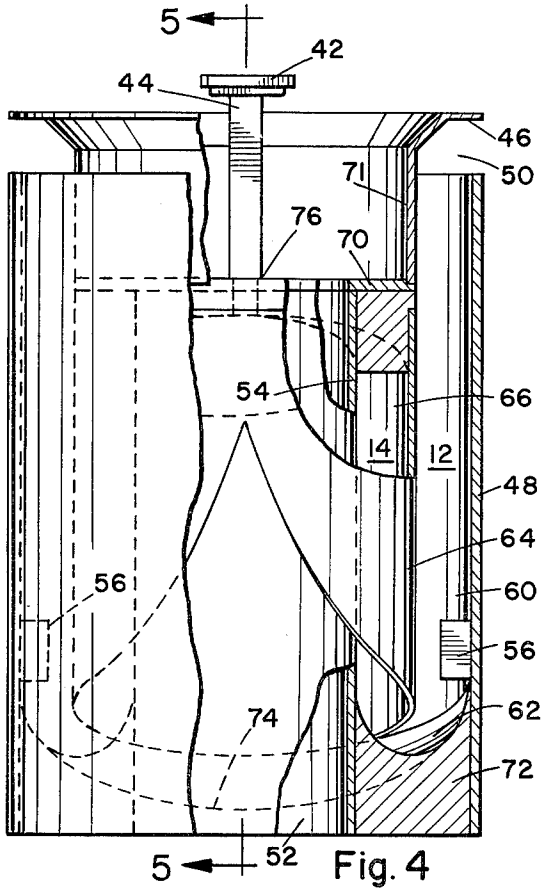


Fig. 4

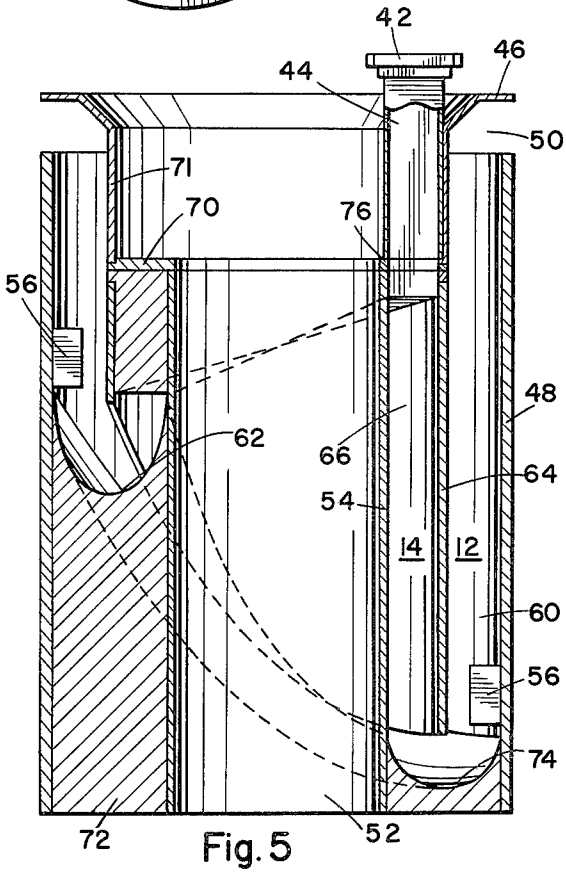


Fig. 5

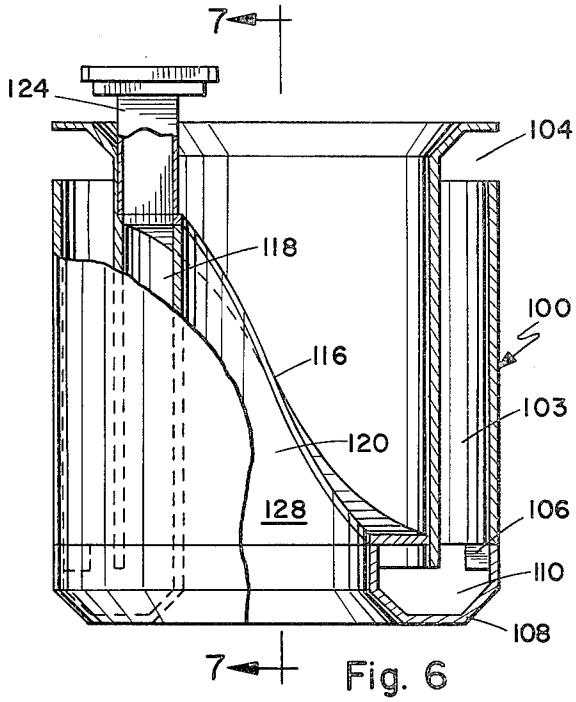


Fig. 6

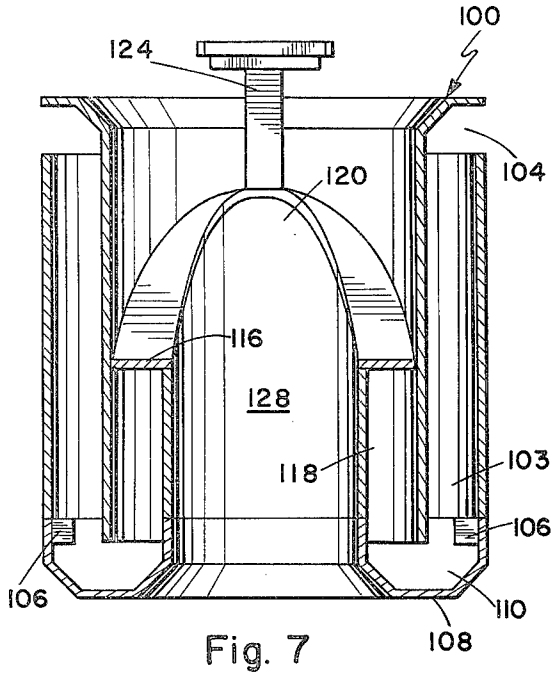


Fig. 7

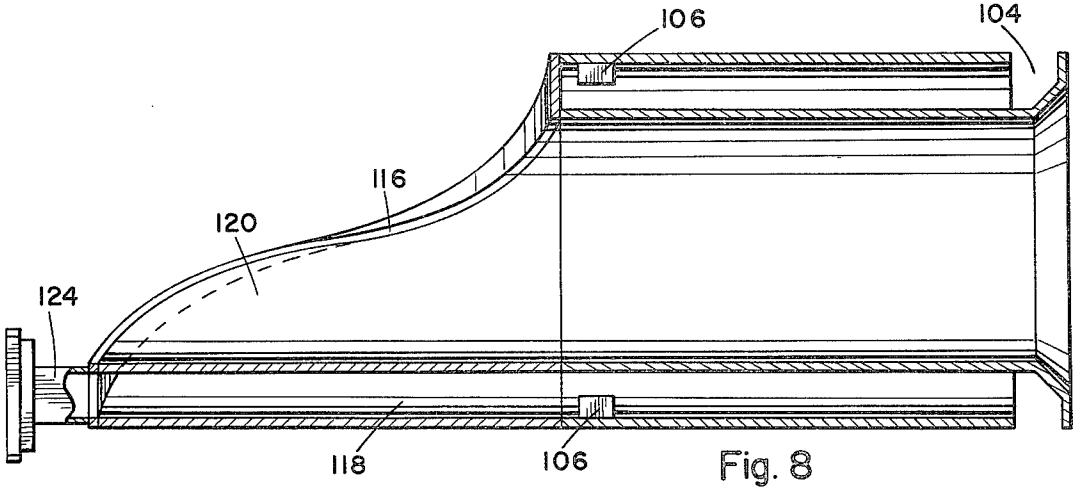


Fig. 8

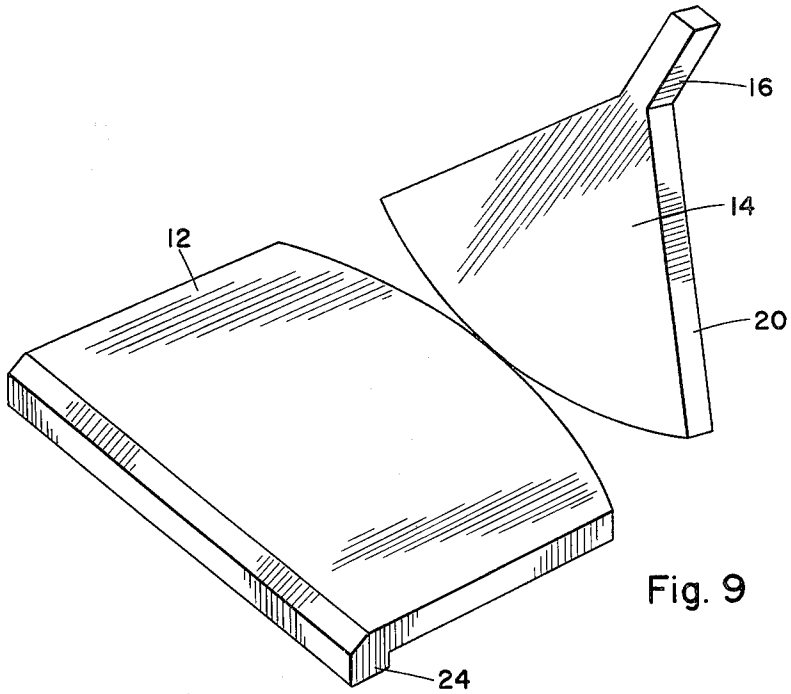


Fig. 9

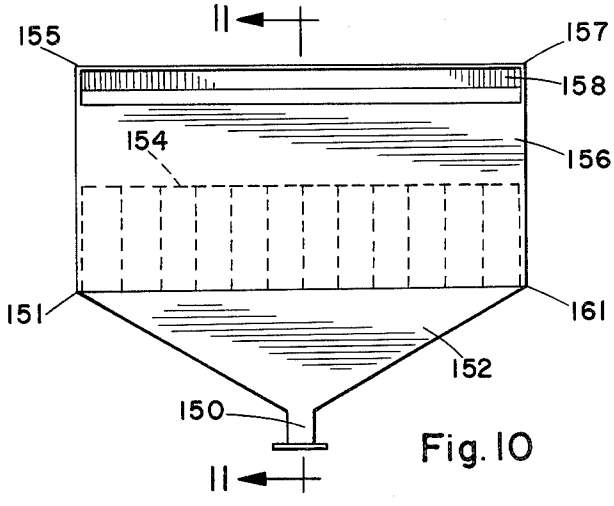


Fig. 10

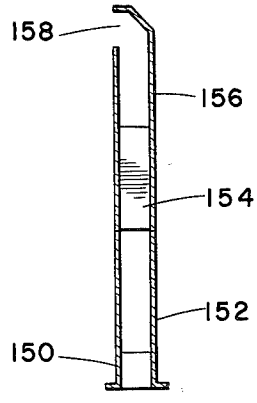


Fig. 11

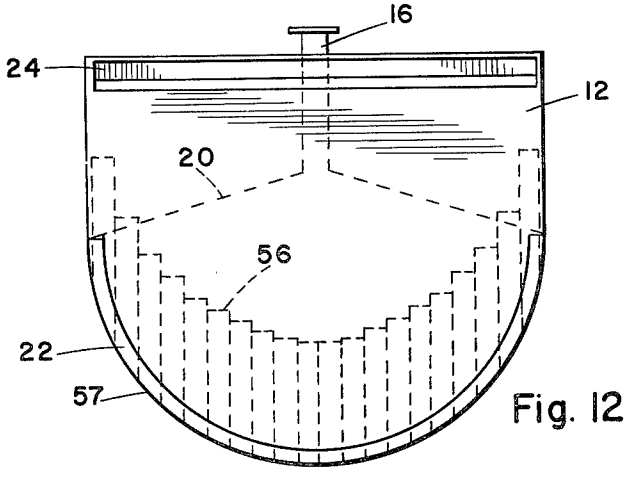


Fig. 12

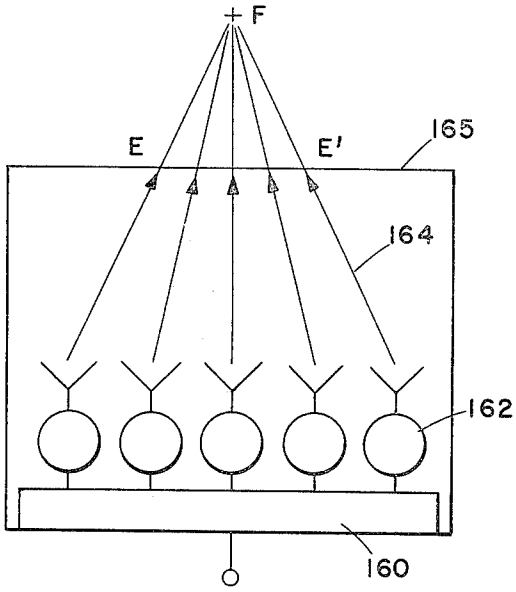


Fig. 13

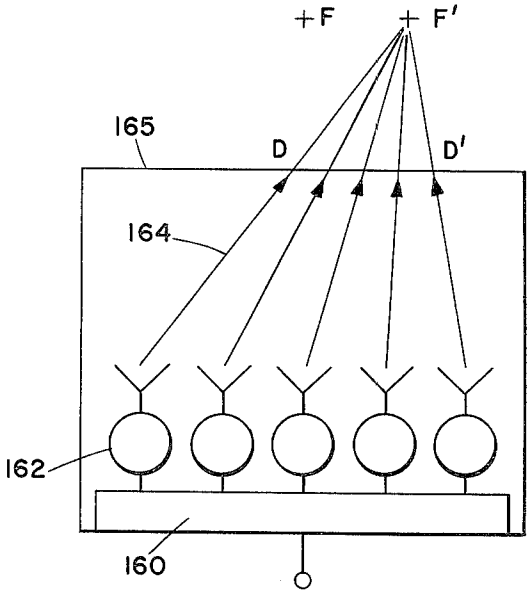


Fig. 14

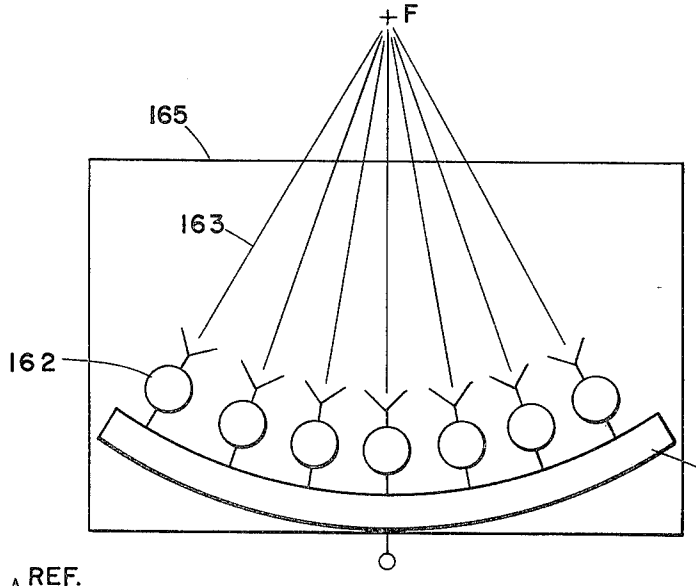


Fig. 15

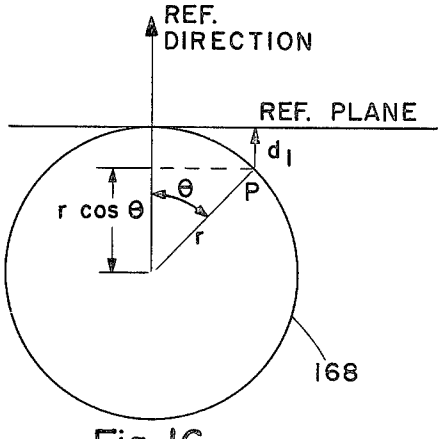


Fig. 16

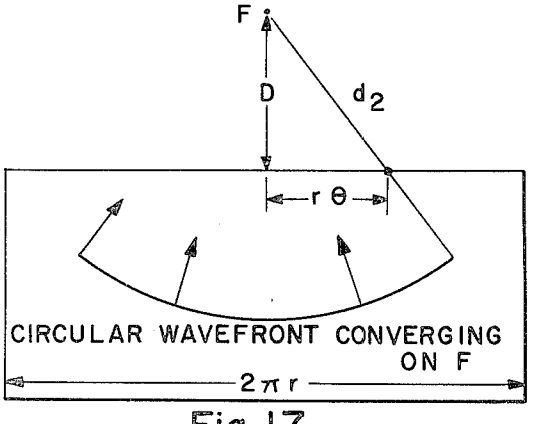


Fig. 17

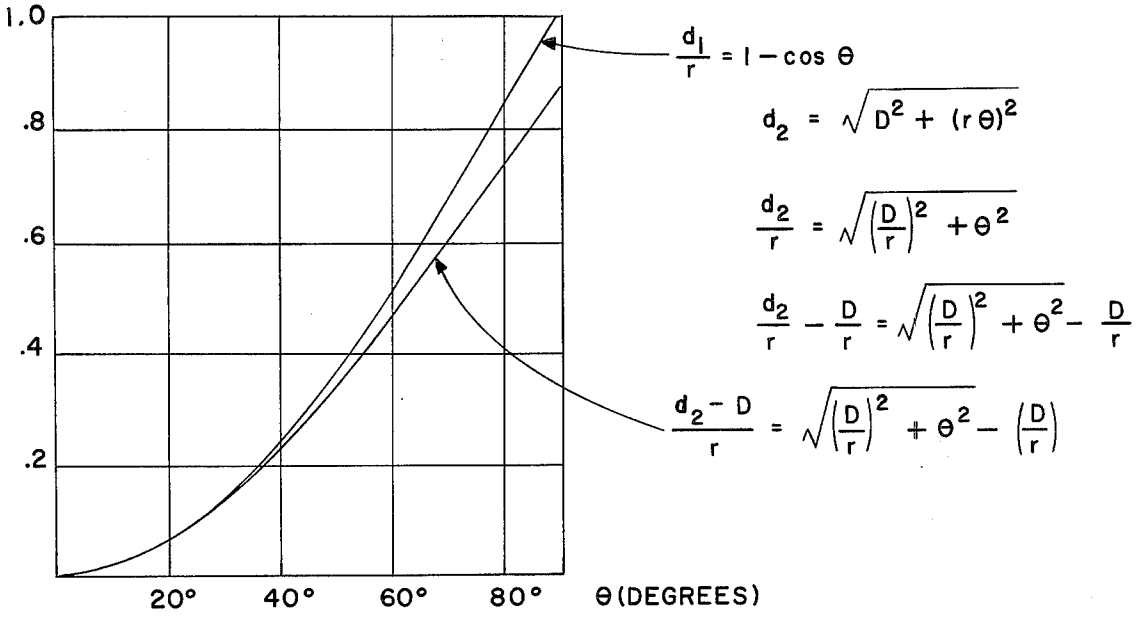


Fig. 18

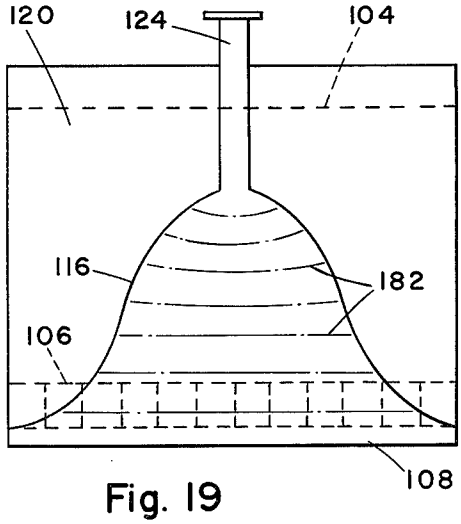


Fig. 19

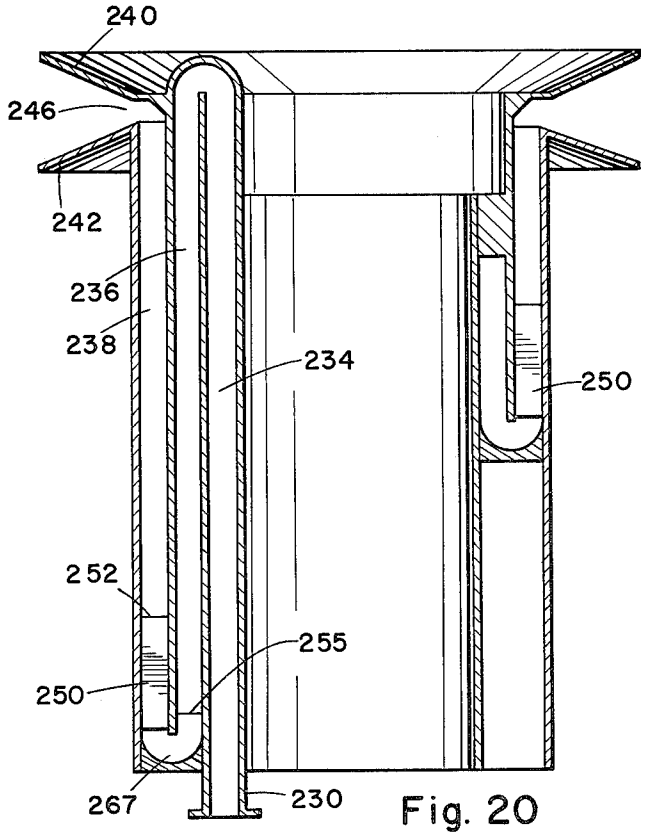


Fig. 20

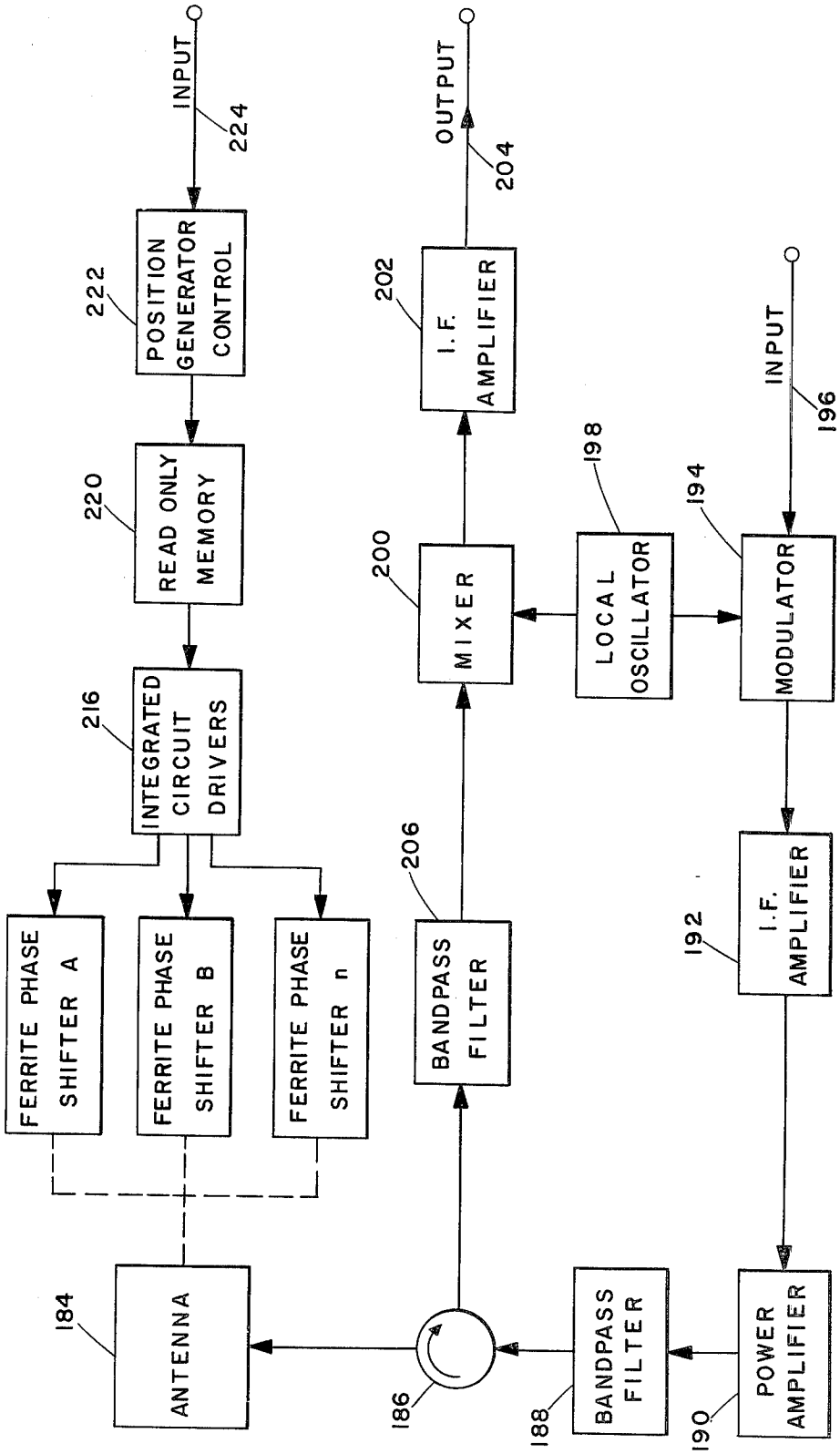

INPUT
224
POSITION GENERATOR CONTROL
222
READ ONLY MEMORY
220
INTEGRATED CIRCUIT DRIVERS
216
FERRITE PHASE SHIFTER A
FERRITE PHASE SHIFTER B
FERRITE PHASE SHIFTER n
ANTENNA
184
OUTPUT
204
I.F. AMPLIFIER
202
MIXER
200
LOCAL OSCILLATOR
198
INPUT
196
MODULATOR
194
I.F. AMPLIFIER
192
BANDPASS FILTER
206
BANDPASS FILTER
188
POWER AMPLIFIER
190
186

Fig. 21

WIDE ANGLE ANTENNA SYSTEM

BACKGROUND OF THE INVENTION

It is well known that a microwave antenna beam can be scanned by means of electronic phase shifters. There are, however, severe limitations associated with the size of the angular range over which such existing antennas can be scanned. In a typical conventional scanning antenna, a power divider network distributes the microwave energy among a number of radiating elements, each of which has an electronic phase shifter. By adjusting the phase shifter to produce a phase gradient across the antenna aperture, the antenna beam can be scanned through a given angle. Because the antenna is scanned, the projected aperture in the direction of the antenna beam is less than the actual aperture at broadside. Thus the effective antenna size is reduced with scan and consequently the beam becomes broader and the antenna loses gain. So such planar arrays are generally restricted to scan ranges of about ± 45° in which the gain loss is held to about 30 percent at the limits of scan. Additional mutual coupling losses due to reflections at the radiating elements at large scan angles also limit the useful scan range of this type of antenna.

Existing schemes designed to overcome the scan limitations of the planar arrays can involve a switching procedure, wherein two planar arrays are arranged so that their combined ± 45° scan ranges covers the forward 180° sector. By means of an additional microwave electronic switch, the microwave energy can be commutated to the appropriate antenna and this antenna scanned to the desired angle in its half of the 180° sector. By increasing the number of arrays and switches, it is possible to achieve any angular coverage and reduce the range of scan over which the individual arrays must operate. A variation of this approach, which does not require quite the multiplicity of array elements, is the circular conformal array. In this array, the elements are arranged in a circle and multiple switches are used to commutate the energy to a certain number of adjacent elements.

There are two major disadvantages in these switched wide angle scanning techniques that are overcome by the invention herein. The first limitation of the existing wide angle systems is that they require electronic microwave switches. The power handling capability of the antenna is thus entirely determined by the power limitations of the switch. This is a severe limitation in the many applications that require high peak and average power handling. Also, the switches are in series with the total antenna input and thus their loss represents a direct loss in antenna gain. At high frequencies or in applications where multiple switching is used, the switch loss can become prohibitive.

The second disadvantage in the switched antenna scheme lies in the inefficient use that is made of the antenna aperture and radiating components. In any given scan position, the antenna contains "dead elements". These are unexcited elements and phase shifters that are switched off and do not contribute to the radiating beam. These unused elements represent a substantial inefficiency in antenna size, weight, cost and complexity.

Thus it is advantageous to have an antenna that will provide continuous wide angle electronic scanning of a microwave antenna beam over an azimuthal angular region of at least 180° without an appreciable reduction in gain due to scanning, and to provide the scanning solely by means of electronic phase shifters feeding a singular circular aperture in a geometrical configuration, without the use of additional microwave electronic switches to commutate energy to various parts of a curved aperture.

SUMMARY OF THE INVENTION

In preferred embodiments of this invention, a parallel plate wave guide is fed by a flared feed horn that functions as a power divider horn. The waveguide and feed horn are curved to a cylindrical shape with the waveguide being open at one end and having a 90° aperture forming a curved ring source aperture. A plurality of separate radiating elements, such as phase shifters, are positioned in the waveguide adjacent the feed horn and arranged around the cylindrical volume for feeding the circular ring source aperture.

The radiating elements are in effect arranged on a cylindrical surface within the parallel plate waveguide and radiate into the wave guide. The parallel plate waveguide is curved so as to conform to the surface of the cylinder. So the radiation from the radiating elements or phase shifters illuminates the portion of the aperture as defined by an arc on a curve, which is the cylindrical portion of the ring aperture. Because of the cylindrical geometry, the radiation from the arc collimates to form an antenna beam in the plane of the arc. By introducing a phase gradient along the radiating elements, the illuminated arc portion can be made to move around the periphery of the cylinder or end ring aperture with little change in the amplitude and relative phase of the illumination. As the arc beam moves around the periphery, a wide angle scan is achieved without projected aperture loss. Since no switches are used, the antenna has a power handling capability of a planar array and the antenna eliminates the inefficiencies associated with the unexcited elements.

In applications, the radiating elements need only be scanned through relatively small angles, for example ± 25°, in order to move the arc beam half way around the periphery and generate a 180° scan. Thus the antenna acts as a scan transformer, multiplying the angle of scan at a slight cost of aperture reduction, since the total radiating aperture formed by all of the elements in parallel plate waveguide is less than the arc projection. This reduction in aperture is actually an advantage in high power applications where it is desired to spread the power out over as many phase shifters as possible so as to minimize the maximum power each phase shifter is required to handle.

In operating the antenna as an antenna system, the antenna functions as a scan transmit and receive antenna. The antenna rapidly switches a highly directive beam through a 360° angular sector with a minimum of gain loss. The rapid beam switching capability is made possible through the use of electronic scanning elements, which cannot be performed by mechanical beam positioning. Yet the antenna has the capability to control a beam over a complete 360° angular sector. The antenna provides a single RF output which can be connected to any receiver or transmitter system and the antenna can accept DF steering commands or can generate or provide a complete antenna system with a minimum of interfacing electronics. Besides having the ability to scan a directive antenna beam through a 360° sector, the antenna system has the ability to adjust the

shape of the beam according to system requirements. Thus the beam may be widened to provide instantaneous wide angle coverage for, for example, coverage of multiple targets. In general the electronics system for operating the antenna employs any suitable means for driving the radiating units or the phase shifters in a transmit or receive mode, and providing individual control to the phase shifters for controlling the scan in the desired azimuth. An example of one way of driving the system is to employ a position memory via a position generator to track particular targets in sequence.

It is therefore an object of this invention to provide a new and improved method and apparatus for providing a wide angle antenna and a wide angle antenna system for scanning and transmitting microwave beams.

Other objects and many advantages of this invention will become more apparent upon a reading of the following detailed description and an examination of the drawings, wherein like reference numerals designate like parts throughout and in which:

FIG. 1 is a perspective view of a basic form of the antenna.

FIG. 2 is a sectional view taken along line 2—2 of FIG. 1.

FIG. 3 is a top plan view of the structure of FIG. 1 rolled into a cylindrical configuration.

FIG. 4 is a side elevation view, partially cut away, of a particular form of the antenna.

FIG. 5 is a sectional view taken on line 5—5 of FIG. 4.

FIG. 6 is a side elevation view, partially cut away, of an alternate form of the antenna structure.

FIG. 7 is a sectional view taken on line 7—7 of FIG. 6.

FIG. 8 is a longitudinal sectional view of a further, non-folded form of the antenna structure.

FIG. 9 is a perspective view, illustrating the combining of a power divider horn with a parallel plate wave guide for the configuration illustrated in FIGS. 1 through 5.

FIG. 10 is a plan view of an embodiment of the invention, with the power divider horn and wave guide being in a flat configuration and with the phase shifters arranged horizontally.

FIG. 11 is a sectional view taken on line 11—11 of FIG. 10.

FIG. 12 is a plan view of the embodiment of FIG. 1, illustrating the position of the phase shifters.

FIG. 13 is a diagrammatic illustration of the beam radiated by the phase shifters through the wave guide in the flat configuration of FIG. 10.

FIG. 14 is a diagrammatic illustration similar to FIG. 13, but with the beam being directed at an angle.

FIG. 15 is a diagrammatic illustration of the beam with the phase shifters being arranged in a curved configuration.

FIG. 16 is a diagrammatic illustration of the distance relationships of the beam radiated from a circular antenna aperture.

FIG. 17 illustrates the distances the beam travels from a circular wave front converging on a single point.

FIG. 18 is a graph illustrative the curve divergence for different value of O in the antenna beam configurations of this invention.

FIG. 19 is a diagrammatic illustration of the RF wave fronts of the antenna configuration illustrated in FIGS. 6 and 7.

FIG. 20 is still another embodiment of the invention.

FIG. 21 is a block diagram of a representative circuit for driving the antenna in a transmit mode and receive mode, with electronic scanning through electronic control of the phase shifters.

Referring now to the drawings, the initial approach and concept of the antenna of this invention is the utilization of a space feed to excite multiple radiators or phase shifters arranged in parallel to control RF energy from a single power divider horn. With reference to FIGS. 10 and 11, a widely flared horn 152 receives RF energy from input 150. The horn 152 spreads the energy over a wide region and guides it to N phase shifters 154, all arrayed in parallel. These phase shifters 154 are positioned in a parallel plate wave guide 156 having a 90° aperture 158. This arrangement makes it possible to divide the relatively high power levels of the transmit mode into reasonable power increments that can be handled conveniently with high speed electronic devices. This power division occurs in an open region between two parallel metal surfaces of the wave guide 156 and does not require loss of power-dividing networks or electronic components. Once the power division has occurred, the phase of the electromagnetic waves through each phase shifter can be controlled in such fashion as to produce a shaped-beam pointing in any spacial direction. In this embodiment, the antenna illustrated is planar, rather than circular, and it serves also to explain the concept of the invention. Each phase shifter intercepts approximately 1/N of the input power. The phase shifters are adjusted to produce any type of phase distribution across the aperture 158.

While this antenna has many applications and can be steered to any direction in a plane on a line normal to the antenna, the structure and operation suffers from a loss of aperture with increasing angle of scan. This results in a decreased gain and an increased beam width as the antenna beam is scanned from the broadside direction. However, these problems can be alleviated by folding the planar antenna illustrated in FIG. 11 into a cylinder. In this structure, the antenna is folded so that the side 151 and 155 is coincident with the other side 157 and 161 of the antenna at the rear of the array. The antenna is thus folded into a cylindrical configuration with the input 150 at one side of the cylinder. This structure has the general configuration of that illustrated in FIG. 8, and can have the folded over feed input such as is illustrated in FIG. 2.

In this cylindrical embodiment, the phase shifter or radiating elements 154 must be recomputed for each desired angle of scan. However, the antenna will then scan over plus or minus 90° with no loss in aperture for any angle of scan. The difficulty with this embodiment is the frequency sensitiveness of the antenna. Additional phase shifter settings must be programmed even for slight frequency changes.

In the non-folded configuration 9, more improved version of the invention for most uses is that generally illustrated in FIGS. 1, 2 and 12. With specific reference to FIGS. 1 and 2, a widely flared feed horn 14 receives RF energy through opening 18 in the guide 16. The horn 14 is connected to a parallel plate, wave guide 12 that is connected by a 180° mitered bend connection 22. The wave guide aperture 24 is curved to a 90° angle providing an output in the azimuth normal to the wave guide. It will be noted, that the bottom configuration of the connection 22 is curved. Referring to FIG. 12, the bottom edge surface 57 from A to C and from C to A' is circular. This circular outer wall surface extends

from the upper edge surfaces 20 of the horn 14. Since the phase shifters are positioned inside the wave guide immediately adjacent the aperture of the horn 14, the phase shifters 56 are positioned with a circular orientation relative to the input connection 32 to the horn 14. Thus the input radiated RF energy contacts all of the phase shifters simultaneously. This provides a major advantage of relative insensitivity to frequency changes. In this configuration, the contour of the curve of surface 57 is such that for all phase shifters set at 0°, a perfectly formed pencil beam is produced in a direction broadside to the antenna. The antenna beam can thus be steered in a collimated beam over a ±180° sector when the antenna is folded into a cylindrical form, as will be described hereinafter, with relatively minor variations in the individual phase shifter settings as a function of frequency.

To achieve the preferred embodiment of this invention, the antenna structure, as illustrated in FIGS. 1 and 2, is curved into a cylindrical shape after being connected together as generally illustrated in FIG. 9. This cylindrical shaped embodiment is that illustrated in FIGS. 3, 4, and 5. Referring to FIGS. 4 and 5, the horn 12 is folded into a cylinder having an outer cylindrical surface 48 and an inner cylindrical surface 64. The inner cylindrical surface 64 also functions as the outer wall of horn 14, which has an inner surface 54. In this curved configuration, the 180° mitered bend 22 forms a trough 62 having a low point 74. The input wave guide 44 has a connector 42 and feeds energy through connection 76 to the horn channel 66, where the RF energy spreads to the mitered bend 62 and then passes through phase shifters 56 in the cylindrical wave guide 60 and then through the 90° aperture 50 forming a wave guide rim aperture that is circular in configuration. The ring shaped aperture has an upper lip 46 that aids in directing the beam radially outward in an azimuth normal to the wave guide surface 48. The upper end of the antenna structure is filled by a cylindrical member having a ring wall portion 70 and a wall 71. The center 52 of the antenna structure is open and the open portions between walls 48 and 54 below the 180° mitered bend 62 are filled with a powdered aluminium material 72. Thus the bottom end of the mitered bend 62 has the shape of the mitered bend 22 in FIGS. 2 and 12, with the phase shifters 56 positioned in a circular configuration relative to the inputs of the RF energy and relative to the outputs through the wave guide.

In operation, the horn 14 functions as a power divider for feeding RF energy to the parallel plate wave guide. The power divider may take, for example, the form of an E-plane sectorial horn in which the energy distributes itself with uniform phase and amplitude over the horn aperture, which has the lower end curved at 57. The 90° mitered bend that provides the ring shaped aperture of the wave guide, gives an improved aperture match for the beam, which beam radiates at right angles to the parallel plate wave guide 12. A mathematical analysis that will be described in more detail hereinafter, illustrates that if the radiating elements or phase shifters are phased to focus their energy at a point F, see FIGS. 13 and 14, then the region E–E′ included between the rays emanating from the outer elements to point F, approximately 90 percent of the cylinder radius beyond the end of the parallel plates, will be illuminated with the proper phase to form the azimuth beam when the cylinder is rolled up. Thus for illustrative purposes, when RF energy is supplied from RF energy source 160 to antenna phase shifters 162, and directed by electronic scanning control the phase shifters 162, then the beam 164 in passing through aperture E–E′ is focused on point F and will have the proper phase when focused on point F′ as illustrated in FIG. 14. The amplitude of the illumination on E–E′ is controlled by the amplitudes of the radiating elements, that illuminate the various portions of E–E′. Introducing an amplitude taper over the radiating elements produces a corresponding amplitude taper over E–E′ allowing control over the antenna side lobes.

In order to scan the antenna, it is only necessary to refocus the radiating elements toward a point F′ translated to the right or left of F, but the same distance from the end of the parallel plates as represented by 165. The new illumination D–D′ illustrated in FIG. 14 will almost be the same as the old illumination E–E′ as shown in FIG. 13, since both are caused by similar converging wave fronts. The illustration D–D′ of FIG. 14 will be translated on the periphery, since the wave front from the radiators is converging to F′ instead of F. As previously mentioned, this translation of the illumination is the equivalent of a scanning of the antenna.

It may be understood that by so orientating the beam as illustrated in FIGS. 13 and 14, with a curved wave guide as illustrated in FIGS. 3, 4 and 5, the beam 164 becomes collimated. This can correspond to a configuration of FIG. 10 where the phase shifters or radiators are arranged parallel. Since it is desired to produce a wave front that converges to the point F, it is advantageous to arrange the radiating elements or phase shifters at equal distances from the point F as shown in FIG. 15. With the radiating elements 162 arranged on a circle and being fed from microwave source 160, no phase shift is required to generate the broadside beam 163 and the phase shifters are only used to scan the beam to either side of broadside. Since electronic phase shifters are not true time delay devices, this arrangement of radiators produces an antenna with the greatest microwave band width. When the antenna of this configuration is rolled into cylindrical form, the antenna is provided as illustrated in FIGS. 3, 4 and 5.

When the radiating elements are not arranged on a circle but in a line as illustrated in FIGS. 13 and 14, and the power divider is designed to produce uniform illumination, the antenna is symmetrical and invariant to a rotation about the axis of the cylinder. Under these conditions, the antenna pattern will have high side lobe levels and a high gain associated with an antenna beam generated by a uniformly illuminated aperture. In addition, the antenna will be capable of a full 360° scan. To demonstrate the ability of the antenna to maintain phase coherence while the beam is scanned through large angles, and to provide a qualitative explanation for the operation of the antenna in electronic-scanned transmit and receive modes, reference is made to the diagrammatic illustrations in FIGS. 16 and 17 that complement the illustrations previously described in FIGS. 13, 14 and 15.

Referring to the antenna configuration, which is essentially illustrated in FIGS. 3, 4, and 5, there is illustrated the top view of a cylinder 168 having a radius r. Radiation leaves a point P on the periphery of the cylinder that is located at an angle θ with respect to a reference direction. The distance d_1 which the radiation travels in going from P to a reference plan tangent to the cylinder, as illustrated, is given by:

$$d_1 = r(1-\cos\theta)$$

Let the cylinder **168** now be underdeveloped into a rectangular sheet, as illustrated in FIG. **16,** and let the radiation impinging on point P be that of a circular wave converging on point F, a distance D in front of the undeveloped periphery. Then the distance d_2, which the radiation must travel to go from P to the point of constant phase, F, is given by:

$$d_2 = \sqrt{D^2 + (r\theta)^2}$$

Now if $d_2 = d_1$ plus a constant for all values of θ, then the radiation of the developed cylinder will emerge from point P and reach all parts of the reference plane in phase. In general, this is only approximately true, because the values of d_1/r and $(d_2 - D)/r$ for different values of θ will vary slightly when D/r is chosen to be 1. However, these amounts of variance are not significant enough to affect the operation of the device. As can be seen in FIG. **18** the respective curves for the values are identical for small amounts of θ so that d_1 and d_2 differ only by the constant value D. As θ increases, the difference between the curves increases. It has been found that for a value of $D/r = 0.9$, the two curves most closely approximate each other over the range of θ from 0° to 60°.

In another embodiment, see FIGS. **6** and **7,** the antenna structure **100** comprises a widely flared horn **120** that received RF energy through input **124.** The input horn has a volume **118,** that extends on the input side to the 180° mitered bend **110** formed by bottom member **108.** In this embodiment, the phase shifters **106** are positioned in a parallel alignment in the wave guide **103.** The edge wall **116** of the horn **120** has a configuration that provides substantially uniform contact of the wave fronts of the RF energy with the radiating elements of phase shifters **106,** providing an output beam to the circular aperture **104** of the wave guide **103** to provide phase coherence while the beam is scanned through changes of angles. As illustrated in FIG. **19,** the wave fronts **182,** because of the configuration of side walls **116,** achieve a general lateral configuration at the contacting of the phase shifters **106** to maintain the correct orientation of the RF energy to reduce frequency sensitivity.

As illustrated in FIG. **8,** the configuration of the embodiment of FIGS. **6** and **7** is illustrated in an end line configuration wherein the horn **120** is not doubled back to provide a horn aperture connection of 180°. Thus the feed **124** feeds directly through the antenna to the lip portion **114** and the circular ring shaped aperture **104.**

In another embodiment, see FIG. **20,** an antenna similar to that previously disclosed in FIGS. **3** through **5** has a completely reversed input **230** that feeds RF energy through guide **234** to the horn **236** and into the inner phase shifter aperture **255** and passes through the 180° bend **267** of the wave guide aperture into the phase shifters **250** and through the outer phase shifter aperture **252** and through the outer wave guide **238** to the ring shaped apertue **246** formed by upper and lower lips **240** and **242.** This configuration allows the feed to be supplied to the lower side of the antenna rather than to the upper end of the antenna and still provides a compact configuration.

Referring to FIG. **21,** there is illustrated in a block diagram, a form representative circuit of a driving circuit that may be used to drive the antennas of this invention. In this circuit, an input energy signal is supplied through line **196,** to a modulator **194** that is modulated by the output of a local oscillator **198.** The RF frequency of the modulator **194** is fed through an IF amplifier **192,** a power amplifier **190,** a band pass filter **188** and through a circulator **186** to supply the RF energy of the desired frequency and information to the antenna **184** in the transmit mode. In the receive mode, the antenna **184** is scanned and the information signal is passed through circulator **186,** through band pass filter **206** and into mixer **200** where the input signal is mixed with the output of the local oscillator **198** and the output is fed through IF amplifier **202** to an output **204** that is processed in the known manner. In driving the phase shifters, the ferrite phase shifters, such as ferrite phase shifters A, B and N that are positioned in the antenna **184,** are drived by integrated circuit drivers **216.** The integrated circuit drivers may be programmed to provide any desired array in the manner previously described. One system is through use of a read only memory **220** that is controlled by a position generator control **222** that is responsive to an input **224** that functions in the known manner. Other known circuit arrangements can be used to drive the phase shifters and to provide RF energy to the antenna horn in the antenna **180.**

Having described, my invention I now claim:

1. A microwave antenna comprising,
a parallel plate waveguide with a parallel plate flared feed horn,
said feed horn having outwardly diverging edge walls to said parallel plate waveguide,
said waveguide and feed horn having a curved shape with said waveguide being open at one end forming a curved ring source aperture,
and a plurality of separate phase shifters positioned in said waveguide adjacent said feed horn and arranged around the curved volume for dividing the power of the received electromagnetic waves and controlling the phase of the electromagnetic waves through each phase shifter.

2. A microwave antenna as claimed in claim **1** wherein,
said waveguide and said feed horn being curved to cylindrical shape.

3. A microwave antenna as claimed in claim **2** wherein,
said phase shifters being positioned in equal spaced locations across the entire aperture.

4. A microwave antenna as claimed in claim **3,** wherein,
said phase shifters are positioned in parallel.

5. A microwave antenna as claimd in claim **2** wherein,
each of said phase shifters being positioned with equal distant spacing across the aperture of said waveguide,
and said phase shifters are positioned in a curved arrangement relative to said aperture for providing a substantially uniform radiating beam distribution that is not substantially affected by changes in frequency.

6. A microwave antenna as claimed in claim **5** wherein,
said flared feed horn has a neck portion,
said neck portion being connected to said flared feed horn at a first location,

and said phase shifters being arranged in a circular orientation relative to said first position.

7. A microwave antenna as claimed in claim 5 wherein,

said waveguide and said feed horn are positioned in side by side parallel relationship with the horn aperture being connected to the waveguide by a 180° waveguide bend,

and said phase shifters being positioned adjacent said bend.

8. A microwave antenna as claimed in claim 7 wherein,

said interconnecting bend having a substantially circular lower end configuration across the width of said waveguide and horn aperture, whereby said phase shifters are thereby positioned in a circular configuration relative to the waveguide aperture.

9. A microwave antenna as claimed in claim 2 wherein,

said waveguide and said feed horn have a cylindrical configuration with said feed horn being concentric inside of said waveguide.

10. A microwave antenna as claimed in claim 9 wherein,

said waveguide aperture having a 90° bend for radiating the beam at right angles to the parallel plate waveguide.

11. A microwave antenna as claimed in claim 2 wherein,

said aperture of said waveguide having a 90° bend to radiate a beam at right angles to said parallel plate waveguide.

12. A microwave antenna as claimed in claim 2 including,

means for spreading and guiding the energy in said horn to the phase shifters for providing a collimated beam in a direction broadside to the antenna when the radiating elements are set at 0°.

13. A microwave antenna as claimed in claim 12 wherein,

the edge walls of said parallel plate flared feed horn being curved inwardly to provide a uniform distribution for frequency shifts of the energy to said radiating elements.

14. A microwave antenna as claimed in claim 10 wherein,

said flared feed horn being an E-plane sectoral horn in which the energy is distributed with uniform phase and amplitude over the horn aperture and guided to the phase shifters,

and said phase shifters being arranged in a circular configuration relative to the energy input to said horn.

15. A microwave antenna system comprising,

a parallel plate waveguide with a flared feed horn,

said feed horn having outwardly diverging edge walls to said parallel plate waveguide,

said waveguide and feed horn having a cylindrical curved shape with said waveguide being open at one end forming a circular ring source aperture,

a plurality of separate phase shifters positioned in said waveguide adjacent said feed horn and arranged around the cylindrical volume for feeding said circular aperture,

means for supplying energy to said feed horn that distributes over a wide region and is guided to the phase shifters,

circuit means for electronically controlling the phase shifters to provide a collimated beam to emanate from the ring aperture,

and said circuit means including means for introducing a phase gradient along the radiating elements to move the beam around the periphery of the ring aperture.

16. A microwave antenna as claimed in claim 15 wherein,

said flared feed horn having means forming a power divider horn that provides energy to said phase shifters causing said beam to be steered over a 180° sector with relatively minor variations in individual phase shifter settings as a function of frequency.

17. The method of radiating a beam from or scanning a microwave antenna comprising,

directing RF energy through a parallel-plate, flared feed horn forming a power divider horn to a plurality of phase shifters positioned across a parallel plate waveguide,

said waveguide and power divider horn having a cylindrical shape,

directing the energy controlled by the phase shifters through a 90° radiating aperture forming a circular ring aperture directed normal to the waveguide,

shifting the phase gradient along the phase shifters providing a collimated radiated beam,

directing the energy through the power divider horn to the phase shifters in the manner to provide a collimated beam set at 0° broad side to the antenna,

and steering the beam over a ± 180° sector with relatively minor variations in individual phase shifter settings as a function of frequency.

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