343-726 OR

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Henf et al.

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[45] **Dec. 3, 1974**

[54] **SCANNING LENS ANTENNA**

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[73] Assignee: **The Singer Company**, Little Falls, N.J.

[22] Filed: **Nov. 14, 1973**

[21] Appl. No.: **415,634**

[52] **U.S. Cl.** **343/756,** 343/761, 343/779, 343/780, 343/783, 343/876

[51] **Int. Cl.** **H01q 19/12,** H01q 19/08

[58] **Field of Search** 343/757, 761, 839, 854, 343/756, 779, 780, 783, 876

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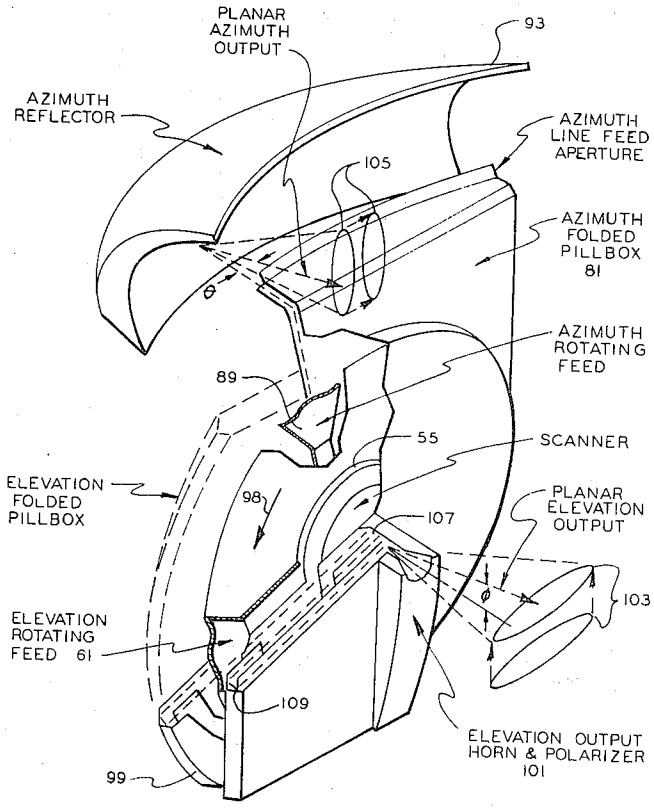
Primary Examiner—Eli Lieberman

Attorney, Agent, or Firm—T. W. Kennedy

[57] **ABSTRACT**

An improved microwave antenna for use in aircraft guidance in which respective azimuth and elevation antenna are fed through dielectric lenses by respective rotating scanners to result in scanned planar beams without physical antenna rotation. The respective scanners are mechanically coupled to thereby insure synchronization so that radiation is fed to only one antenna at a time.

13 Claims, 23 Drawing Figures



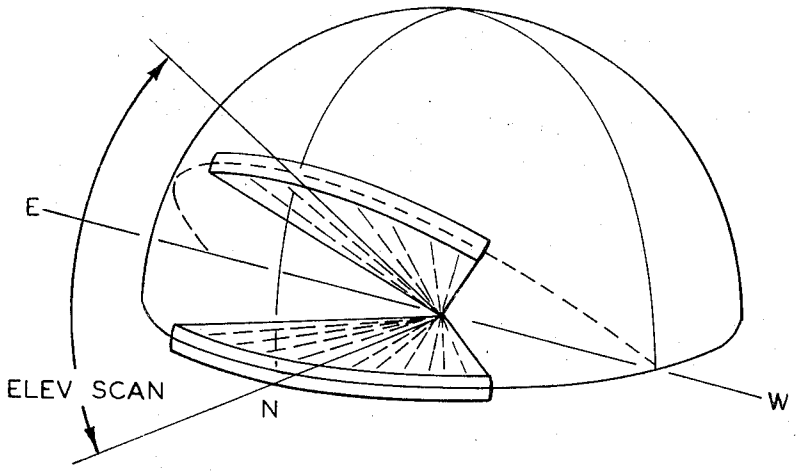

E
ELEV SCAN
N
W

FIG. 1

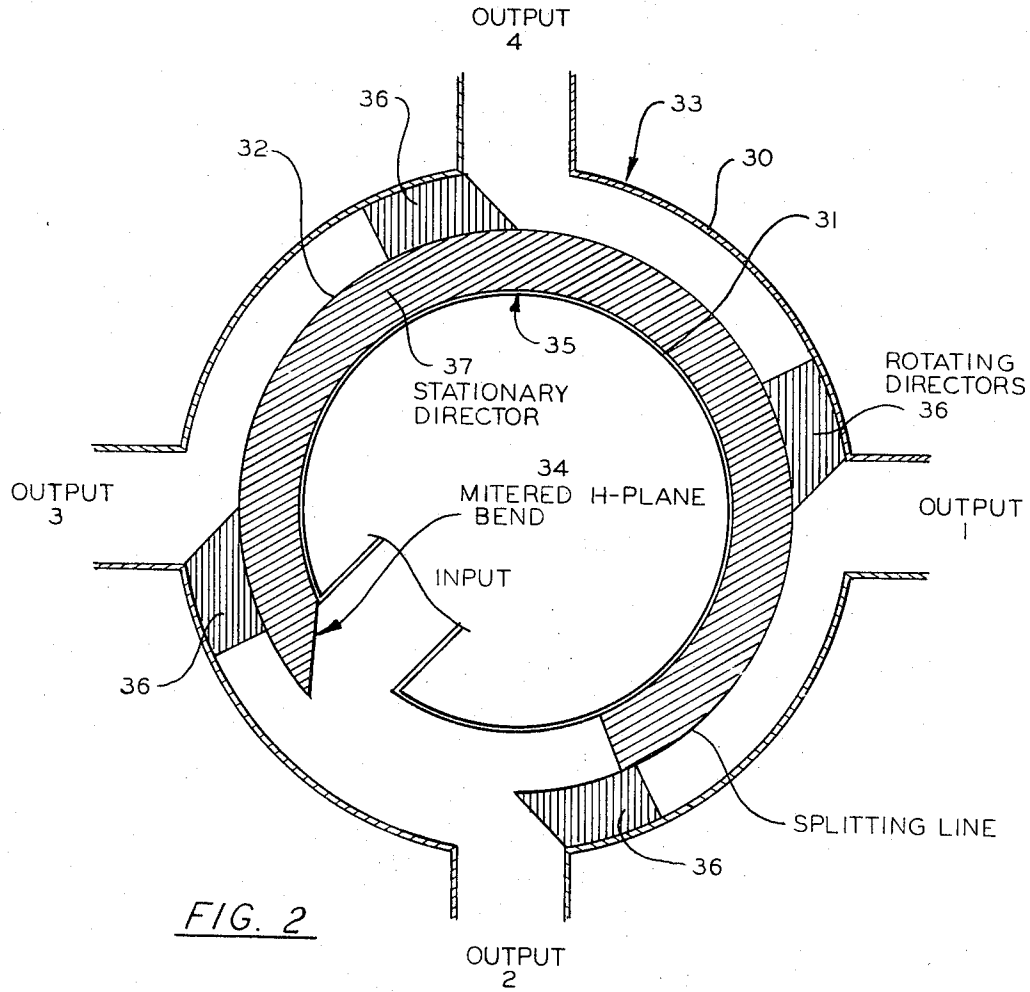

OUTPUT 4
36
33
32
30
31
35
37
STATIONARY DIRECTOR
ROTATING DIRECTORS
36
34
MITERED H-PLANE BEND
OUTPUT 3
OUTPUT 1
INPUT
36
SPLITTING LINE
36
OUTPUT 2

FIG. 2

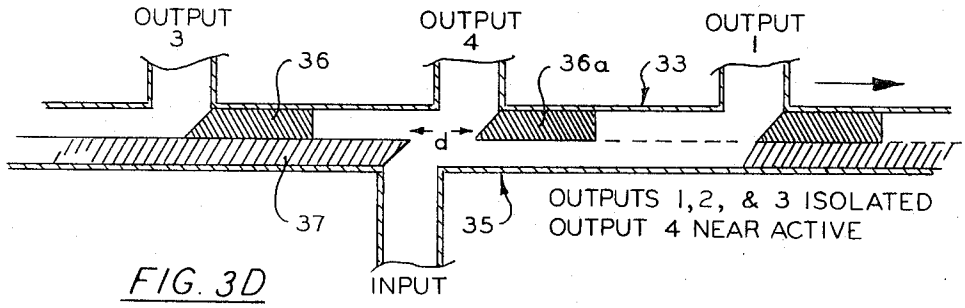


FIG. 3D

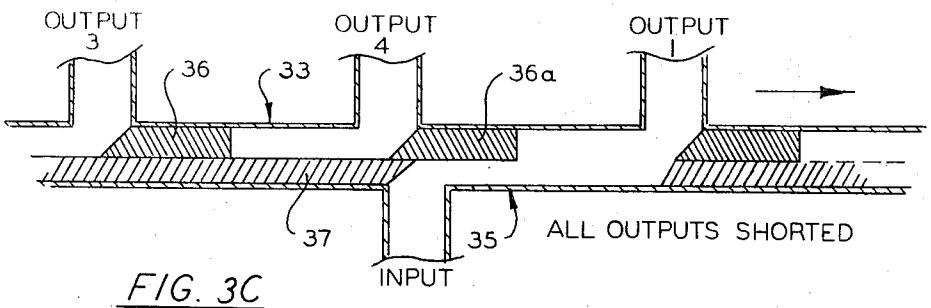


FIG. 3C

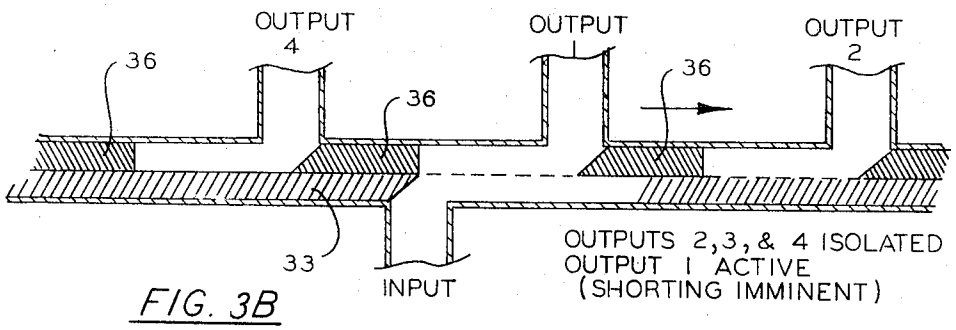


FIG. 3B

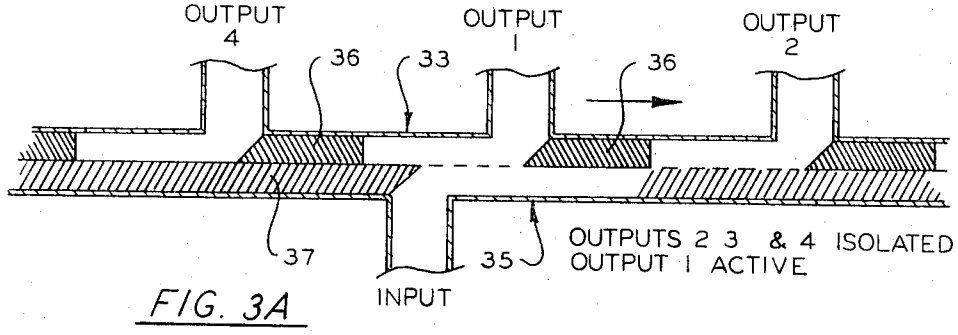


FIG. 3A

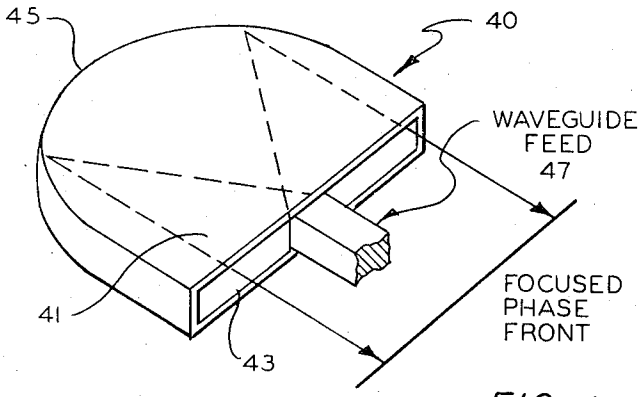


FIG. 4
PRIOR ART

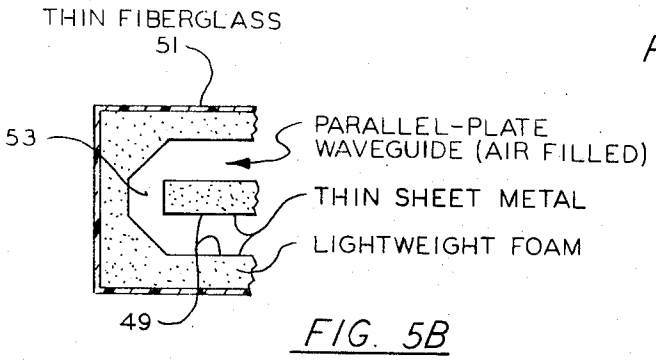


FIG. 5B

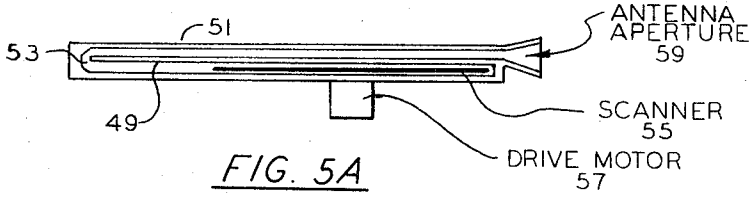


FIG. 5A

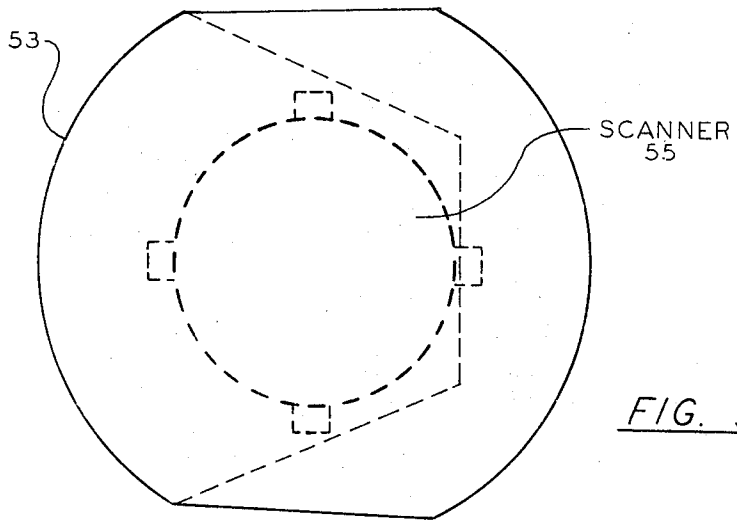


FIG. 5C

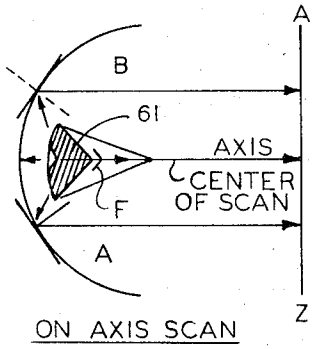


FIG. 6A

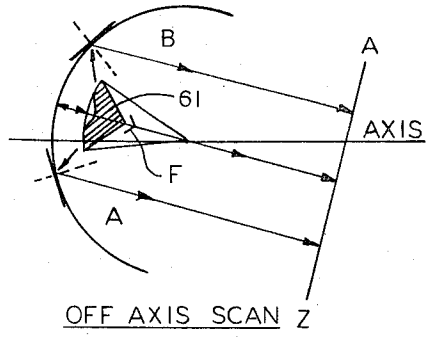


FIG. 6B

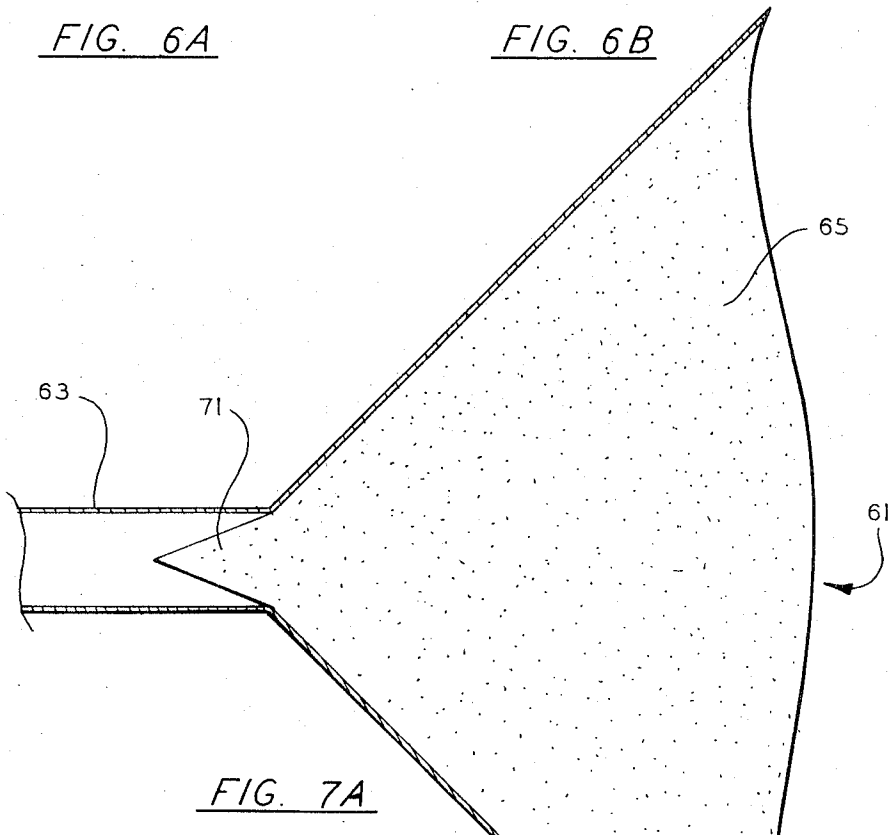


FIG. 7A

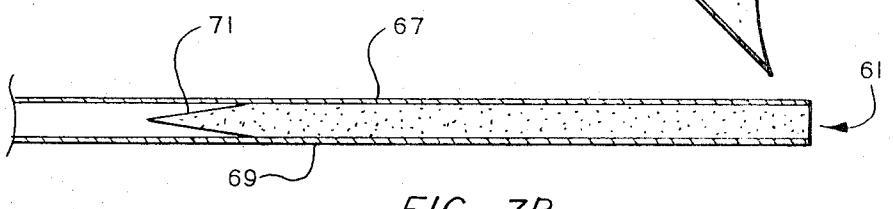


FIG. 7B

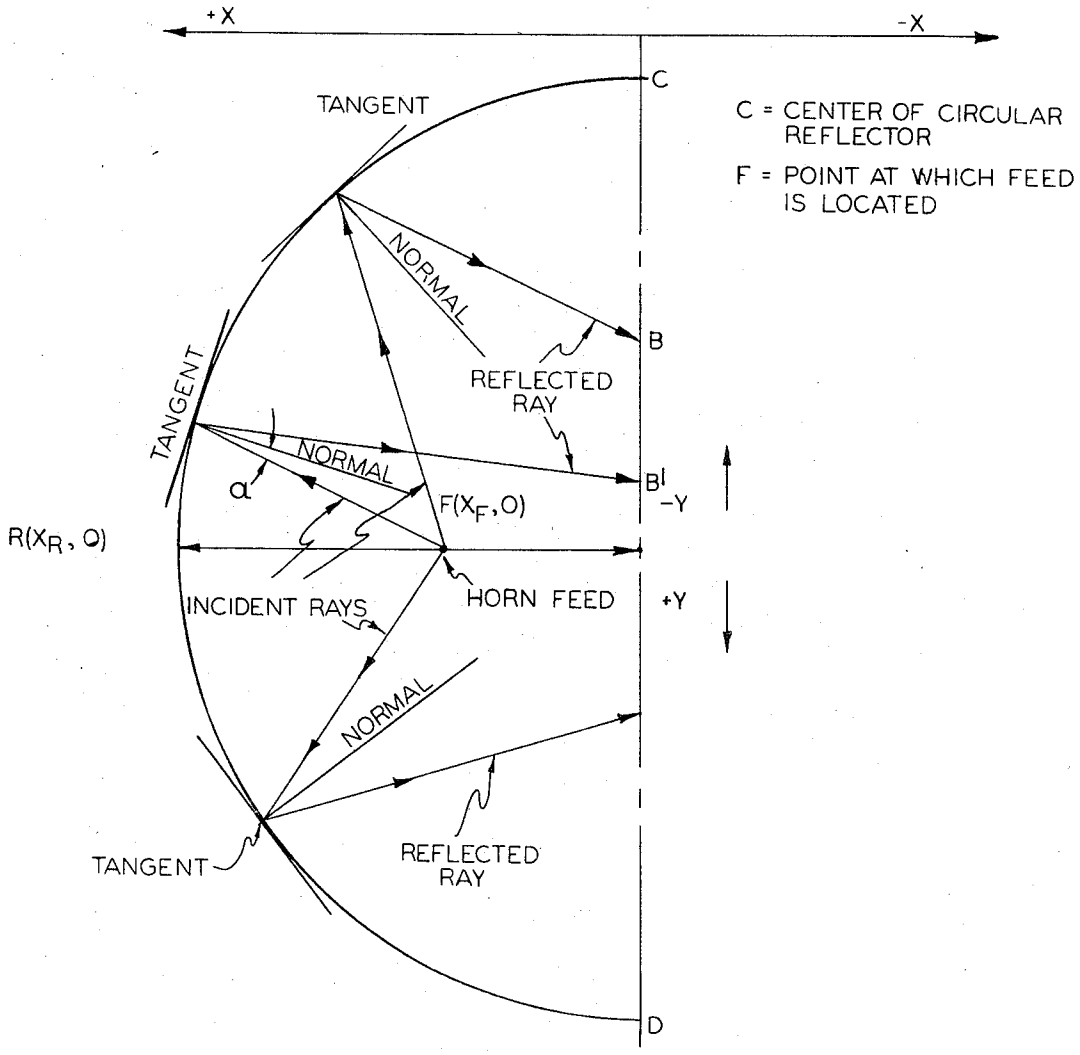

+X
-X
C
TANGENT
C = CENTER OF CIRCULAR REFLECTOR
F = POINT AT WHICH FEED IS LOCATED
NORMAL
B
REFLECTED RAY
TANGENT
NORMAL
α
B'
-Y
F(X_F, O)
R(X_R, O)
INCIDENT RAYS
HORN FEED
+Y
NORMAL
TANGENT
REFLECTED RAY
D

FIG. 8

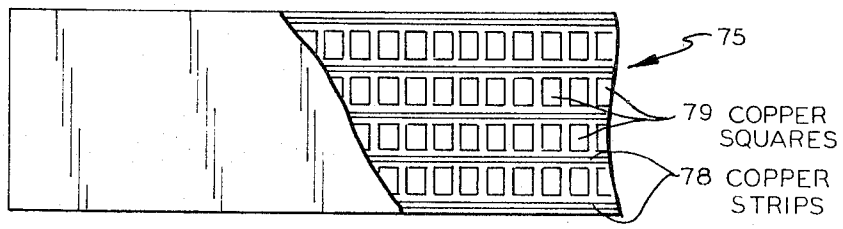


FIG. 9B

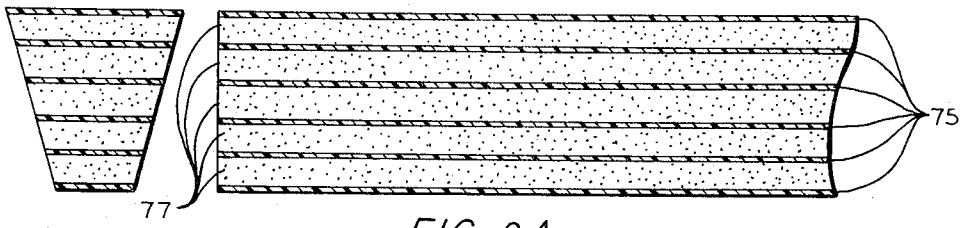


FIG. 9A

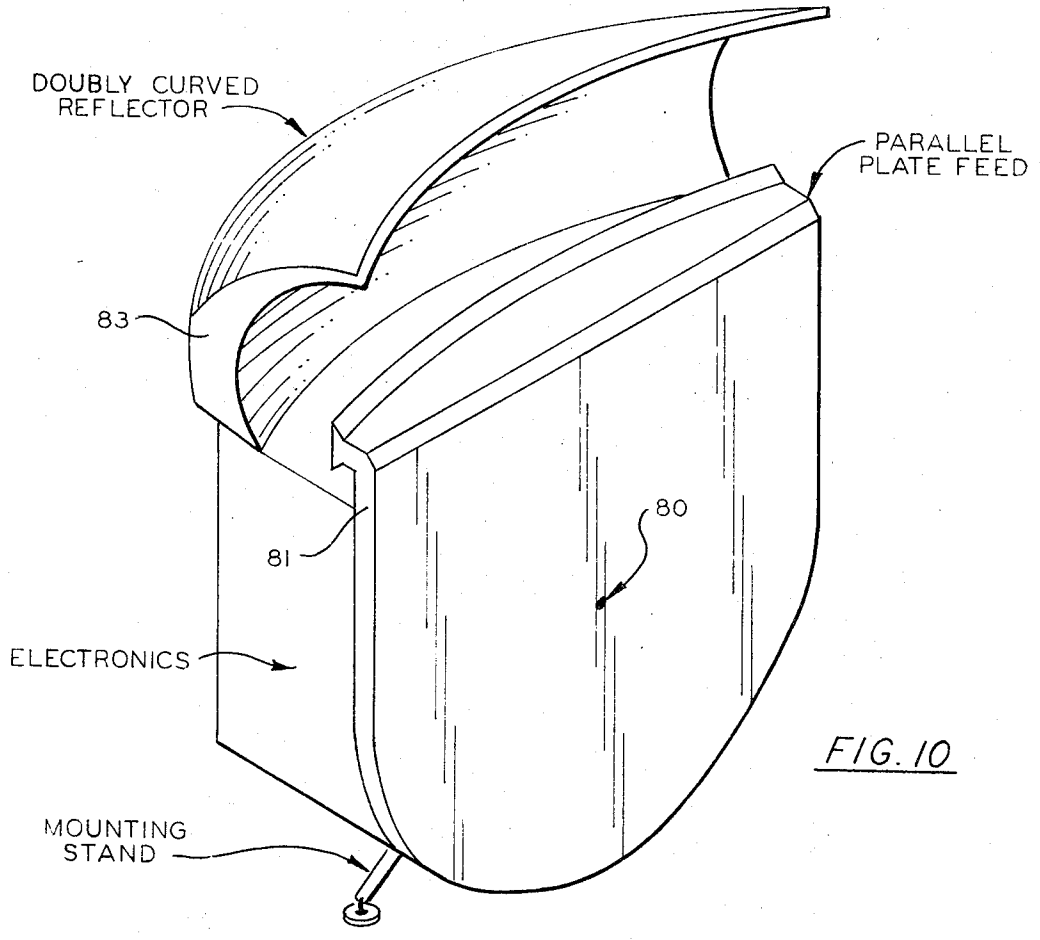


FIG. 10

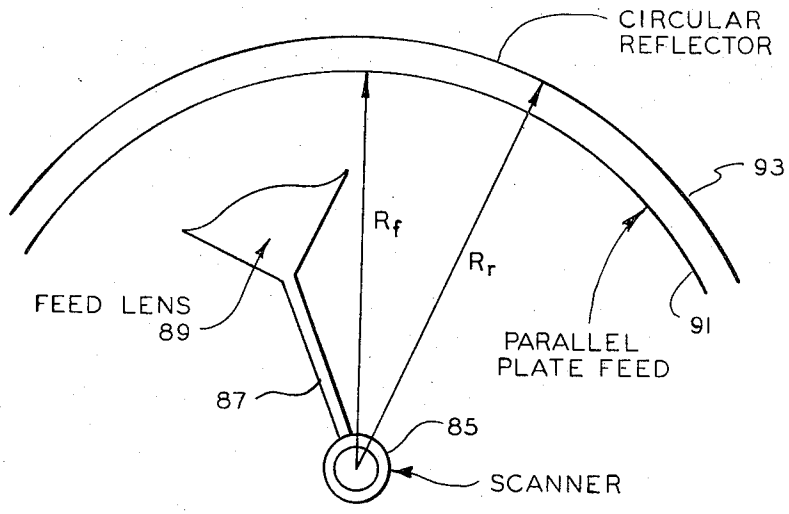


FIG. 11A

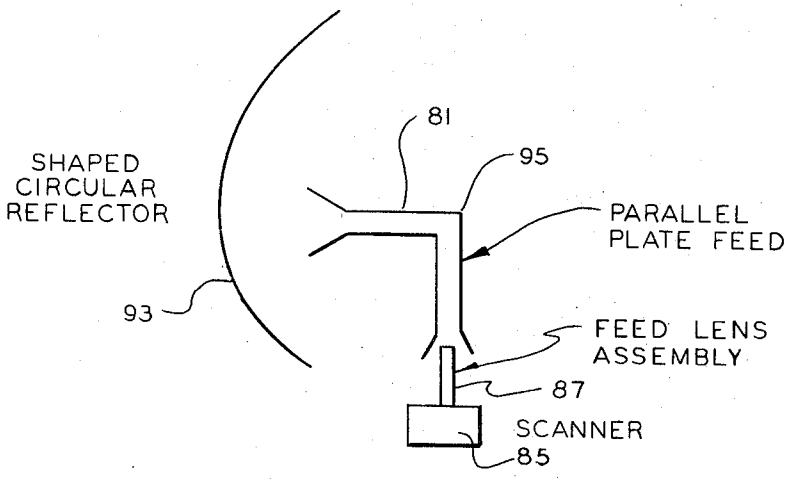


FIG. 11B

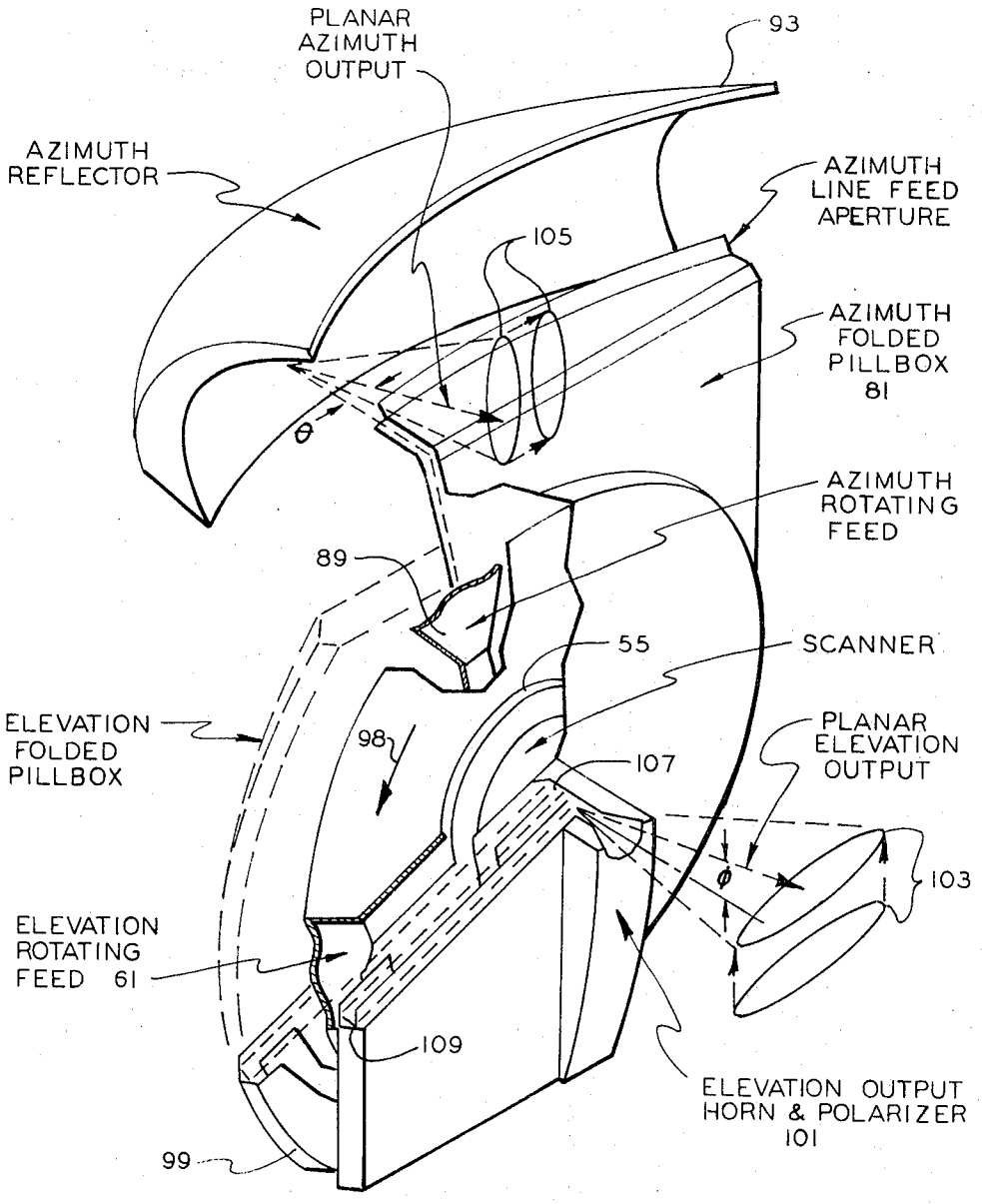

PLANAR AZIMUTH OUTPUT
93
AZIMUTH REFLECTOR
AZIMUTH LINE FEED APERTURE
105
AZIMUTH FOLDED PILLBOX 81
θ
AZIMUTH ROTATING FEED
89
55
SCANNER
ELEVATION FOLDED PILLBOX
98
107
PLANAR ELEVATION OUTPUT
φ
103
ELEVATION ROTATING FEED 61
109
ELEVATION OUTPUT HORN & POLARIZER 101
99

FIG. 12

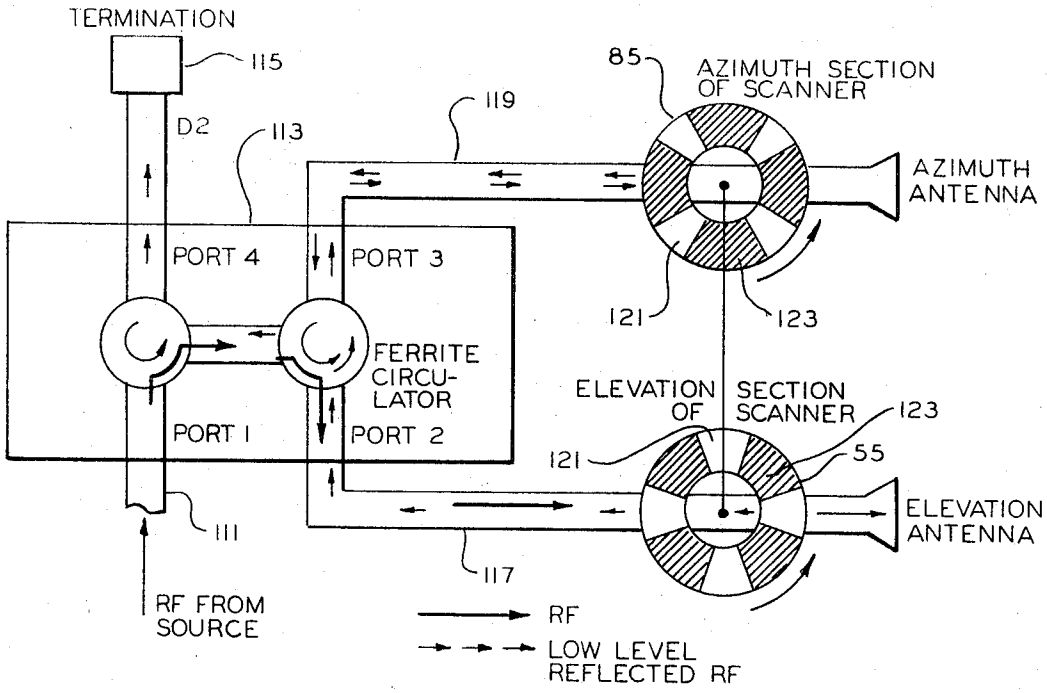

TERMINATION
115
D2
113
119
85
AZIMUTH SECTION OF SCANNER
AZIMUTH ANTENNA
PORT 4
PORT 3
121
123
FERRITE CIRCU-LATOR
ELEVATION SECTION OF SCANNER
123
121
55
PORT 1
PORT 2
ELEVATION ANTENNA
111
117
RF FROM SOURCE
RF
LOW LEVEL REFLECTED RF

FIG. 13

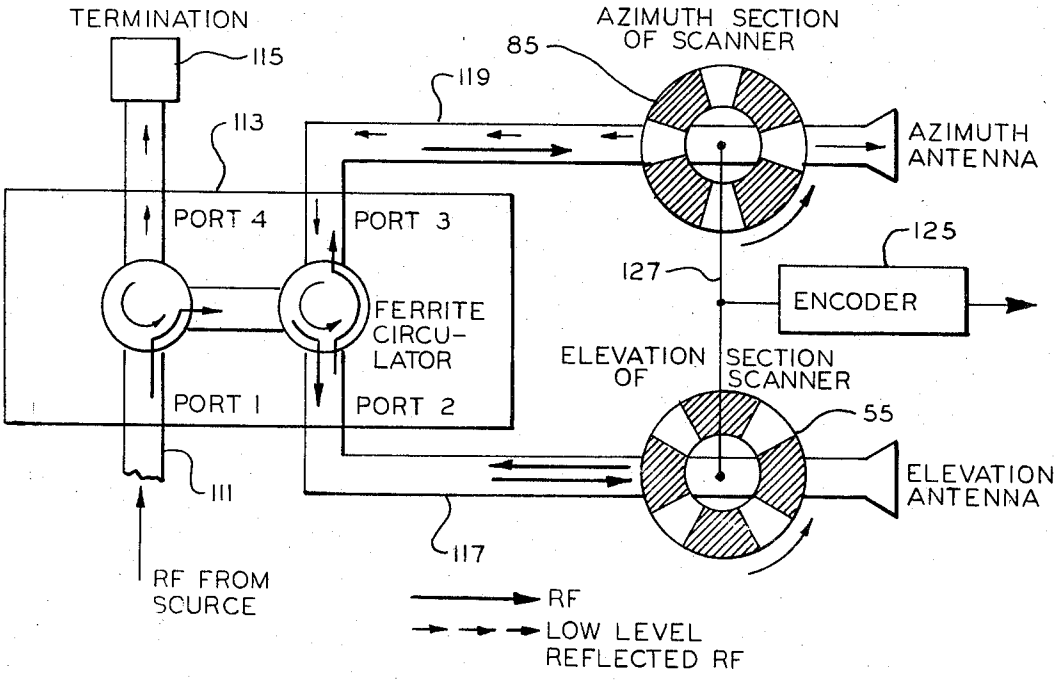

TERMINATION
115
AZIMUTH SECTION OF SCANNER
85
119
113
AZIMUTH ANTENNA
PORT 4
PORT 3
125
127
ENCODER
FERRITE CIRCU-LATOR
ELEVATION SECTION OF SCANNER
PORT 1
PORT 2
55
ELEVATION ANTENNA
111
117
RF FROM SCURCE
RF
LOW LEVEL REFLECTED RF

FIG. 14

SCANNING LENS ANTENNA

BACKGROUND OF THE INVENTION

This invention relates to aircraft guidance in general and in particular to a unique antenna mechanization which is capable of generating radar guidance signals of the proper character suitable for landing various types of aircraft, i.e., conventional fixed wing, short take off and landing (STOL) and helicopter.

With the increase in air traffic, the need to expand instrumented airports, and the variety and types of aircraft to be accommodated, the single approach profile provided by conventional UHF-VHF Instrument Landing Systems (ILS) in use today is not adequate. To satisfy the spectrum of potential airborne users and the increasing variety of airport ground facilities, a new type of scanning beam landing system is required. A variety of requirements and signal formats have been identified for various applications. Much of this data has been summarized in the documentation of the Radio Technical Committee for Aeronautic's subcommittee 117. DO-148 published by RTCA in November 1970 is typical of this data.

Scanning beam landing systems have for the most part employed antennas wherein the entire antenna was physically rotated or nutated to provide, within the approach airspace, the scanning beam spatial motion necessary for landing guidance. This technique, i.e., total antenna motion, has been primarily utilized since it does provide, the most straight-forward means of minimizing any variations to the radiated radar beam pattern as it scans the approach airspace. This type of scanning antenna mechanization does however have numerous limitations associated with it. Key limitations are:

A. The antenna structural supports needed to maintain stable operation in a rotational condition coupled with the high torque mechanical drive subsystems necessary to start-up and rotate the entire antenna result in bulky heavy ground station equipments.

B. Since the entire volume swept by the scanning antenna must be enclosed to protect the antennas, the ground equipments are generally large.

C. When an antenna is scanned, the time period during which received guidance information is available to the approaching aircraft is not continuous. Furthermore, as the number of antenna scans per unit time is increased, the received data (dwell time) per scan is correspondingly reduced.

D. To provide the necessary lateral and vertical landing guidance data dictates that the scanning beams be swept in two orthogonal directions. To provide orthogonal antenna scan requires two antennas resulting in additional ground station volume to accommodate each and additional electronic equipment to insure that these radiated beams sequentially scan the approach volume in order not to contaminate the received date e.g., beam synchronization.

In summary, the key requirements associated with the generation of scan beam data for a scanning beam aircraft landing system are to:

1. provide orthogonal beam scan in the vertical and horizontal planes of the approach volume;
2. generate fan beam scanning data where the beam parameters are invarient throughout the approach volume. This requirement can be simplified as follows: provide planar beam scan;

3. synchronize the scan of the individual beams (vertical and horizontal) to avoid contamination of the received data that would occur if both were received simultaneously; and
4. generate beam data relatively free from distortions that may be caused by terrain elements in proximity to the ground station. That is, generate narrow main beam radiation and low level extraneous beam radiation (sidelobes).

SUMMARY OF THE INVENTION

The objective of scanning lens antenna-microwave (SLAM) of the present invention is to satisfy the above requirements and eliminate the aforementioned difficulties. The SLAM mechanization generates narrow fan beams which scan orthogonally using a single lightweight, fixed antenna and circular lens scan technique.

The unique features that can be realized from this technique are:

1. SLAM produces narrow fan beam scanning from a stationary antenna eliminating the need for rugged structure and large enclosures associated with non-stationary antennas;
2. the SLAM produces two orthogonal beam scans from a single flat plate configuration reducing dramatically the enclosure requirements;
3. the SLAM provides automatic self-synchronized scanning operation without requiring electronic switches, mechanical linkages, or electronic circuitry; and
4. the SLAM permits scan rate of the actual beam in space to be independent of the rotational speed of the internal lens-feed scanner by using multiple feed lens assemblies.

The SLAM consists of an azimuth and elevation antenna each of which uses multiple rotating feeds to generate the planar beam patterns required for landing system applications. The elevation section of the SLAM antenna consists of a rotary scanner which has one fixed input port which sequentially couples to continuously rotating output ports. Connected to the rotating output ports are waveguide fed, dielectric lenses. The scanner lens configuration is so arranged that the excited lens illuminates a folded pill box type microwave antenna which uses a cylindrical reflector-180° bend. The lens reflector combination results in a collimated microwave beam which rotates with the movement of the feed system. The output of the pillbox is a vertical circular horn which is used to output the planar scanning elevation beam.

The azimuth section of the integral antenna employs a rotary scanner similar to the elevation section. Each output of the rotating section of the azimuth scanner is connected to a waveguide fed lens. The lenses, which are coupled to the scanner, rotate inside of a parallel plate transmission line. Lens energy directed from the rotary scanner is fed into a 90° bend. The output of the bent parallel plate transmission line is a circular horn which excites a doubly curved reflector. This feed-reflector system produces a planar azimuth beam whose elevation pattern is determined by the reflector cross section. As the lens rotates, the planar azimuth beam scans the approach volume. The azimuth and elevation rotary scanner are combined into a single mechanical unit and as such both output sections (Az and El) rotate together. The two antenna sections are elec-

tronically isolated so that each antenna's pattern performance is completely independent of the other.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view illustrating the nature of a planar beam scan.

FIG. **2** is a plan view partially in cross section illustrating the rotating scanner of the present invention.

FIGS. **3***a* – **3***d* are schematic illustrations of the operation of the scanner of FIG. **2.**

FIG. **4** is a perspective view of a pillbox antenna used in the present invention.

FIGS. **5***a* and **5***b* illustrate details of the antenna of FIG. **4.**

FIG. **5***c* illustrates the relationship between the pillbox antenna and the scanner.

FIGS. **6***a* and **6***b* are schematic diagrams illustrating the manner in which the dielectric lens of the present invention collimates radiation.

FIG. **7***a* is a plan view illustrating the dielectric lens of the present invention.

FIG. **7***b* is an elevation view in cross section of the lens of the present invention.

FIG. **8** is a diagram illustrating the directions of the rays of radiation in the antenna of the present invention.

FIGS. **9***a* and **9***b* are respectively cross sectional and plan views of a polarizing arrangement used in the present invention.

FIG. **10** is a perspective view of the azimuth antenna of the present invention.

FIG. **11***a* is a plan view and FIG. **11***b* an elevation view illustrating the arrangement of the components within the antenna of FIG. **10.**

FIG. **12** is a perspective view partially cut away illustrating the combined azimuth and elevation antennas.

FIG. **13** is a schematic view illustrating the manner in which radiation is fed to the elevation antenna.

FIG. **14** is a similar view illustrating the manner in which radiation is fed to the azimuth antenna.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A key requirement for landing system antennas is that they generate a fan beam shape as shown in FIG. **1.** A fan or planar beam is a broadside or flat beam which is formed when the direction of radiation is perpendicular to the radiating aperture. In planar beam scanning, the radiation pattern in the scan plane is a broadside beam with no change in the beam shape. In typical feed scan types of beam scanning, the phase front and peak direction deviate from the normal to the radiating aperture as the array is scanned, producing a beam which has a conical shape, where the degree of coning is a function of the scan angle. To achieve planar scanning requires a unique antenna configuration.

The beam of FIG. **1** illustrates the elevation scan. A similar beam must also be generated in the azimuth direction, i.e., it would be rotated 90° from the beam shown on the Figure. In the landing system the beams are scanned in sequence. That is, first an elevation scan is performed and then an azimuth scan and then another elevation scan and so on.

ELEVATION ANTENNA

The elevation antenna comprises a four output scanning device with four wave guide feeds and lens assemblies, a folded pillbox and a polarization rotator. The scanner has one wave guide input and four outputs, each of which are terminated with a feed and dielectric lens assembly. There are no wave guide transitions (i.e., one linear to circular transition and one circular to linear transition as required in the rotating joint). The scanner arrangement is shown in FIG. **2.** This device is based on the field theory of standard rectangular wave guides operating in the TE10 mode. For this mode the current density at the center of the two broad walls will be zero. This means that the wave guide can be split in half without affecting the propagation characteristics of the wave guide, by cutting it along the longitudinal center line. In such a split wave guide the upper half can be shifted with respect to the lower half along the longitudinal axis without affecting the propagation characteristics of the wave guide.

As illustrated by FIG. **2,** the rectangular wave guide which has sides **30** and **31,** is formed into an annulus in the H plane. The dividing line between the halves of the wave guide is the circle **32.** In this way the outer half **33,** having the wall **30,** can be rotated with respect to the inner half **35,** having the wall **31** without affecting the RF fields inside the wave guide. In this particular application, the inner half **35** serves as a stator and the outer half **33** as a rotor. Energy is coupled into the scanner via a mitered H-plane bend **34.** As shown on the figure, the miter extends halfway across the wave guide. In this application, the mitered device is called a director. The director has a length along the wave guide and, in this region the wave guide is below cutoff because the wide dimension is significantly smaller than half a free space wavelength. Four similar directors **36** are placed in the rotor **33** at 90° intervals so that the energy is coupled from the scanner by only one director at a time, since the other directors are separated from the active one by a section of cutoff waveguides. Isolation is further enhanced by extending the input director **37** around the complete annulus except for the region corresponding to the desired scan sector.

Scanner operation is illustrated by FIG. **3.** As shown thereon, when an output director is located opposite the input director, a short is presented at the input and the incident energy is reflected in the direction of the transmitter. The series of diagrams presented on FIG. **3** shows the various positions of the rotor **33** with respect to the stator **35.** In FIG. **3***a*, the relative positions of the upper and lower halves of the waveguide are such that energy is coupled from the input to output **1.** Outputs **2, 3,** and **4** are isolated from the input due to the cutoff properties of the directors **36** and **37.** In *b*, the upper half of the waveguide has been displaced with respect to the lower half such that shorting of the input waveguide is achieved. In *c*, the director **36***a* for output **4** is overlaying the input and the input waveguide is shorted. The input remains in the shorted condition until the direction **36***a* is in the position shown in *d*. The dimension *d* is approximately half a freespace wavelength. In this position energy is now coupled from the input to output **4.**

Higher-order modes are excited within the waveguide in the region of the directors. These higher-order modes excite currents at the centerline **32** of the wave-

guide wall that could result in a small level of energy being leaked from the split in the waveguide. Standard, half-wave, folded chokes are located at the separation between the rotor **33** and stator **35** on both the upper and lower sides of the waveguide. These chokes are continuous around the full waveguide annulus and create an electrical short at the dividing line and these prevent any leakage of RF energy from the waveguide.

The diameter of the waveguide annulus is selected such that the time periods during which energy is coupled to an output and during which the input is shorted, are consistent with the elevation radiation intervals.

The rotating scanner is a waveguide device and is capable of handling, without breakdown, power levels approaching that of a straight section of waveguide. The device also has a frequency bandwidth capacity of greater than 20 percent. The VSWR over the band of frequencies from 15.4 to 15.7 is less than 1.05:1 and the insertion loss is less than 0.5 dB.

FIG. 4 illustrates a typical pillbox antenna **40** which is found in the prior art.

The pillbox antenna illustrated is a parallel plate microwave system in which the radiation is confined to two dimensions between conducting sheets **41** and **43** and a conducting backwall **45** acts as a reflector collimating the microwave energy. In a simple pillbox such as this the feed system **47** is in the path of the radiated collimated energy from the reflector. This results in feed blockage and pattern deterioration. To avoid this blockage a folded pillbox is used. Folded pillboxes have been described in the literature such as the article by W. Rotman entitled "Wide Angle Scanning with Double Layer Pillboxes" Trans IEEE PGAP Jan. 1958.

The folded pillbox used in the present devices and shown on FIG. **5** uses two sets of parallel plates, one indicated as set **49** containing the incident field from the feed and the other the reflected-collimated-field from the reflector. Each set of parallel plates forms a transmission line. The sections are connected by a 180° bend **53** whose back wall forms a circular reflector in the elevation plane.

FIG. **5** also shows some details of the relative location of the scanner with respect to the waveguide. The scanner **55** is placed within the plates **49** and rotated therein by the drive motor **57** in the manner described above. As can be seen more clearly from FIG. *5c*, as the scanner **57** rotates each of the output ports in succession will direct their energy toward the circular reflector of the 180° bend **53** to the set of plates **51** and directed out of the antenna aperture **59.**

To minimize the tolerance requirements and reduce the production costs of the parallel plate pillbox spacing, a TEM propagation mode is excited by the waveguide feed. This mode has its electric field perpendicular to the plates. The wavelength for the TEM mode is independent of the plate spacing and the tolerance is based on impedance mismatch considerations. Propagation of other modes is prevented by holding the plate separation to a dimension less than half a free space wavelength.

Small variations in the separation of the plates are not critical as long as this half-wavelength maximum dimension is not exceeded. Since a sandwich type of construction is utilized, and since the pillbox surfaces are planar, the parallel plate spacing need not be maintained to better than .020 inch throughout the structure for an operating frequency of 15.5GHz.

The use of a TEM mode in the pillbox results in a horizontally polarized radiation field which requires a polarization rotator to change the horizontal polarization in the parallel plate line to a vertically polarized radiating field.

Both a parabolic and circular reflector can be used with the pillbox antenna of FIG. **5.** The circular reflector is preferred due to its superior off axis scanning properties. FIG. *6a* shows that if the parabolic reflector is fed from its point focus, an in phase condition occurs at a plane AZ which is perpendicular to the reflector axis. However, as the feed is scanned off the point focus, the plane AZ tilts but an on focus condition no longer exists on it. This manifests itself in unacceptable sidelobe levels, beam-broadening due to coma and non-planar beam shape (conical). On the other hand a properly fed circular reflector, as shown in FIG. *6b*, will overcome this condition since the center of rotation for the feed and reflector are the same point. Thus the physical relationship between the two, remain constant as a function of rotation. At every feed angular position during the scan, the same broadside aperture is obtained. This constant illumination with scan motion results in a scan pattern having a planar beam shape with constant beamwidth and side lobes.

In order to feed a circular reflector it is necessary to use a lens to compensate for its inherent spherical abberation. This is illustrated by FIG. **8** which shows that the reflected rays of a circular reflector are uncollimated if it is fed from a point source. To overcome this problem, a dielectrically loaded, parallel plate feed lens is used on the output of each of the scanner feed horns. The lens is shaped such that it refracts the rays so that they strike the reflector at an angle which will allow them to be reflected parallel to the antenna axis. The shape of this lens is determined by applying two conditions upon the rays emitted from the lens:

1. that they be reflected off the reflector parallel to the antenna axis; and

2. that in a plane perpendicular to the antenna axis, the rays all have the same electrical path length. If these two conditions are satisfied, energy radiated from the reflector will be collimated in a plane wave of uniform phase which provides a radiation pattern with a 2° halfpower beamwidth. Since the centers of rotation of the scanner and reflector are coincident, the relative configuration of the antenna is invariant as a function of rotation and ture planar-beam scanning is achieved. FIG. *6b* shows that if the feed lens **61** is moved along the arc AB not only do the rays remain collimated but the beam is always perpendicular to generating source which in this case is the circular reflector. This is extremely important if planar beam shapes are to be maintained.

A typical feed lens **61** is shown on FIG. **7.** Energy will be provided out of each of the outputs **1, 2, 3,** and **4** of FIGS. **2** and **3** through a waveguide **63** to a lens **61.** This lens **61** will comprise a parallel plate dielectrically loaded feed lens. The dielectric material **65** is contained between two plates **67** and **69.** The input end of the lens has a tapered matching section **71.** Once the dielectric constant of the lens medium and the position of the feed horn required to obtain the required output aperture size is determined, a lens shape may be found that satisfies the condition noted above. For example, at 15 GHz, a 2° 3DB elevation antenna, the reflector would be a cylinder with the radius of curvature of 20.9

inches. The point of the lens closest to the reflector is located at a radius of 15 inches. The lens thickness is 0.261 inches, less than half a free space wavelength, to prevent higher order mode propagation and the relative dielectric constant of the lens material 1.50.

Since the energy in the folded-pillbox design is propagated in the TEM mode the polarization of the radiated energy is linear in the horizontal direction. However, if vertically polarized energy is required, a polarization rotator can be placed across the aperture to provide vertical linear polarization.

Several techniques for accomplishing the polarization rotation are possible. These include a double array of parallel strips, an array of twisted waveguides, and a double array of printed-circuit inductive and capacitive elements. Any of these methods are suitable for the SLAM antenna. All but the technique incorporating twisted waveguides involve conversion of polarization from horizontal linear to circular and from circular to vertical linear. The first two techniques, arrays of parallel metal strips and a combination of parallel metal and dielectric strips, are both quite heavy and difficult to manufacture. In addition, it is necessary to adequately support the individual strips since their orientation must be carefully maintained under shock and vibration conditions. The method involving the twisted waveguide is a straightforward conversion technique. However, it is difficult to manufacture and even heavier than the first two methods.

The fourth method of conversion provides a very lightweight, reproducible, structurally-sound unit. Such an arrangement is shown on FIGS. **9***a* and *b*. The device consists of six layers **75** of metal circuits photoetched on thin fibreglass sheets. A quarter-wave-thick sheet of very low density polyester foam **77** separates each of the fibreglass sheets.

The printed circuits consist of inductive and capacitive shunt susceptance elements such as copper squares **79** and strips **78** arranged, as shown on FIG. **9***b*, so that an incident linearly polarized signal is split into two orthogonal components and the phase of one element is delayed with respect to the other. The first, third, fourth and sixth sheets are of the same design and the second and fifth sheets are the same. The combination of the first three sheets divides the incident linearly-polarized energy. The combination of the remaining three sheets provides the reverse of this operation because of a 90° physical rotation of the three sheets. In this way the circularly-polarized energy is converted to vertical linear, the desired orientation.

Polarization convertors of this type have been used in many applications. The mismatch of these devices is very small, less than 1.1:1, and the insertion loss is less than 0.5 dB. Frequency bandwidths in excess of **10** percent are readily attained with this approach.

AZIMUTH ANTENNA

The azimuth antenna shown on FIG. **10** utilizes the same scanner as the elevation antenna with similar lens but does not require the folded pillbox. In this case the lenses rotating about a scanner axis **80** feed a section of parallel plate transmission line **81** which is used as the feed for a doubly curved reflector **83** which is the antenna radiating aperture.

As in the case of the elevation antenna the radiating aperture must be curved, in the scan plane, to maintain the planar beam shape. The reflector and the feed both have a circular shape in the azimuth plane whose center of rotation is coincident with the scanner center of rotation as shown on FIG. **11**A.

As shown thereon, there is a scanner **85** such as that described above, with one waveguide **87** shown terminating in a lens **89.** The lens will be within the parallel plate feed **81** shown on FIG. **10** which terminates in a circular shape as indicated by the circle **91.** Energy is then radiated to the circular reflector **93.**

In order to keep the structure compact, a right angle bend **95,** shown on FIG. **11**B, is included in the parallel plate feed **81.** In the elevation plane the reflector **93** is shaped so as to generate a $\csc^2\theta$ pattern which minimizes the energy on the ground while increasing the signal level above the beam peak.

The actual reflector shape is designed using an existing computer program which provides an analytic solution based on geometric optics. This method of calculation has been described in the literature by A. S. Dunbar, "Calculation of Double Curved Reflector for Shaped Beams," Oct. 1948. Proceedings of the IRE-Wave And Electron Section, and consists of transforming the feed radiation into the described reflector radiation pattern using geometric optics equations.

Side lobe control is maintained in a number of ways. In the elevation plane the actual radiation pattern of the parallel plate feed is used to calculate the reflector's shape by the above mentioned method. In the azimuth plane the scanner output feed and lens are carefully designed and constructed in order to maintain the proper phase and amplitude distribution on the reflecting surface. Finally in the parallel plate feed itself, extreme care is used to insure a homogeneous transmission path so that minimum phase and amplitude distortions are introduced.

COMBINED ELEVATION/AZIMUTH ANTENNA

The elevation and azimuth antenna are combined in a single synchronized unit as illustrated by the cutaway perspective view of FIG. **12.** Reference numerals used in the description of FIG. **12** will be the same as those previously used where possible to aid in collating the previously described figures with FIG. **12.** Two scanners, both the elevations scanner and the azimuth scanner will be located on a common axis in the direction of arrow **98.** The elevation antenna is located in the front, with its scanner **55** feeding its four lens **61,** one of which is shown, which then direct the energy to the folded pillbox **99** from which it is directed through a right angle bend to the elevation output horn and polarizer **101.** The resulting elevation scan is illustrated by the energy patterns **103** shown as being emitted from the horn **101.** The azimuth scanner is not shown. However, one of its lenses **89** can be seen which directs the energy through its folded pillbox **81** to the reflector **93** as described above. The azimuth radiation pattern is illustrated by the beams **105** from the reflector **93.** To keep the antenna unit as compact as possible, two right angle bends, respectively, bend **107** and bend **109,** have been added to the elevation antennas folded pillbox resulting in the elevation beam being radiated out normal to the plane of the scanner. Each antenna section provides the required planar beam throughout its scan sector. The scanners for the two antennas may be machined as a common unit and driven by a single motor. Angular position information is provided by a single, directly driven encoder. Synchronization of the azi-

muth and elevation beams is ensured by the inherent design of the switching section. It is unique in that the normal power consuming active RF switch has been replaced with a passive ferrite circulator. The circulator in conjunction with the antenna scanner not only accomplishes the switching function but presents a constant impedance to the RF source. The switching function itself relies on the properties of the ferrite circulator and the antenna scanner. This portion of the operation is illustrated on FIGS. **13** and **14**. RF energy is developed in conventional manner from an RF source and is provided into the system on a waveguide **111**. From the waveguide **111** it enters a ferrite circulator indicated generally as **113**. The circulator **113** contains four ports labelled ports **1** to **4**. Radiation enters through port **1**. A conventional termination **115** is coupled to port **4**. Port **2** is coupled to the elevation scanner and port **3** to the azimuth scanner via waveguides **117** and **119** respectively. On the drawing, as indicated by the key, RF energy is a heavy solid arrow and low level reflected energy by dashed arrows.

The scanner sequentially couples each antenna to the appropriate terminals of the circulator. The combination of circulator/scanner automatically directs the RF energy to the first available active antenna. The nature of the scanner is such that either the azimuth or the elevation antenna is capable of receiving this RF energy. The scanner never permits both antennas to get RF energy simultaneously. Note that both the elevation section **55** and azimuth section **85** of the scanner have four radiating elements, represented by the light areas **121**, spaced 90° apart. The shaded areas **123** separating these elements represents that portion of the scan when a short circuit is presented at the antenna terminals. The relative positions of the elevation and azimuth segments is fixed when the single scanner is fabricated.

On FIG. **13**, the scan cycle has been stopped with the azimuth portion **85** of the scanner in a short circuit condition and the elevation portion in a radiating condition. RF energy from the RF source enters Port **1** of the circulator **113**, rotates around the first circulator junction **125** in a counterclockwise direction to the second circulator junction **127** where it is rotated counterclockwise to Port **2**. At Port **2** it sees the elevation antenna, through the "open" scanner **55** and is radiated. Any low level energy reflected by the elevation antenna ia reflected back into the circulator and rotated to Port **3** where the azimuth portion **85** of the scanner is short circuited. It is once again reflected back into the circulator **113** and rotated to Port **4** where it exits to the RF termination **115**.

FIG. **14** shows the scanner advanced to the azimuth radiate position and the elevation portion **55** of the scanner short circuited.

Azimuth RF energy enters the circulator **113** at Port **1**, is rotated to Port **2** where it encounters the short circuited elevation portion **55** of the scanner and is reflected back into the circulator. Here it is rotated to Port **3** and passes through the open azimuth antenna. Any energy reflected by the radiating antenna is reflected back into the circulator **113** and rotated to and exits from Port **4** to the RF terminator.

When properly indexed, a single encoder **125** coupled to the shaft **127** driving the scanners provides antenna positional information for the entire azimuth/elevation scan cycle. During the interval when neither elevation nor azimuth information is required the scanner automatically presents a short circuit to the RF source which causes the RF to be reflected back through the circulator **113** and into the termination **115** thereby automatically isolating the RF source from the antenna.

As described above, a circular feed aperture into the parallel plates was disclosed which resulted in a planar output scan. It is also possible to obtain a conical scan with the antenna of the present invention by providing a linear feed aperture into the parallel plates.

Thus, an improved scanning lens antenna which provides a planar beam output useful in landing system applications has been shown. Although a specific embodiment has been illustrated and described, it will be obvious to those skilled in the art that various modifications may be made without departing from the spirit of the invention which is intended to be limited solely by the appended claims.

What is claimed is:

1. A scanning lens microwave antenna comprising:

a. a fixed circular reflector;

b. a scanner comprising an annular shaped rectangular waveguide split in half with the inner half containing a fixed inlet port and forming a stator and the outer half containing a plurality of rotatable outlet ports and forming the rotor and means in said waveguide to cause only one output at a time to couple to said input;

c. a parallel plate waveguide directing energy from said scanner to said reflector whereby said scanner will scan energy across said reflector; and

d. a parallel plate dielectric lens located at the end of said parallel plate waveguide, said dielectric lens mounted within a thin metal outer casing which is coupled to said waveguide and having a tapered matching section extending into said waveguide.

2. The invention according to claim **1**, wherein said means to couple one output at a time comprises a stationary director in the stator having a mitered H-plane extending partially across the input port and a plurality of rotating directors in said rotor one being provided for each output port and having a mitered H-plane bend extending partially across its associated output port.

3. The invention according to claim **2**, wherein said stationary director is extended around the major portion of said stator.

4. The invention according to claim **2**, wherein said parallel plate wave guide comprises a pillbox antenna with the end of said pillbox providing said curved reflector.

5. The invention according to claim **4** and further including a polarization rotator at the output of said pillbox antenna.

6. The invention according to claim **5**, wherein said pillbox has additional parallel plate bends and terminates in an output horn which is perpendicular to the plane of the scanning lens within said pillbox.

7. The invention according to claim **5**, wherein said polarization rotor comprises a plurality of printed circuits comprising a pattern in copper on thin fiber glass and a plurality of low density foam dielectric spacers of a thickness of one quarter wave length sandwiched between said plurality of printed circuit boards.

8. The invention according to claim **2**, wherein said curved reflector is a doubly curved surface having a circular shape in the direction of scanning.

9. The invention according to claim **8,** wherein said parallel plates contain bend of essentially 90° to direct energy to said curved reflector.

10. The invention according to claim **9,** wherein said parallel plates have a circular feed aperture to produce a planar output scan.

11. The invention according to claim **9,** wherein said parallel plates have a linear feed aperture to produce a conical scan.

12. A scanning lens antenna for providing alternate orthagonally scanned beams comprising:

a. a first scanning lens antenna comprising:
   1. a pillbox antenna having its end formed to provide a curved reflector;
   2. a rotatable scanner including means to direct energy toward said curved reflector within said pillbox; and
   3. a first parallel plate dielectric lens interposed between said directing means and said reflector to cause the reflected energy to be collimated as it leaves said curved surface;

b. a second scanning lens antenna having its scanner mechanically coupled to the scanner of said first scanning lens antenna such that only one of said first and second lens antennae is able to radiate at one time, said scanning lens comprising:
   1. a double curved reflector having a circular shape in the direction of scanning;
   2. a rotatable scanner including means to direct energy toward said double curved reflector;
   3. a parallel plate wave guide enclosing said scanner; and
   4. a second parallel plate dielectric lens interposed between said directing means and said reflector to cause the reflected energy to be collimated as it leaves said curved surface;

c. means to supply microwave energy to said first and second lens antennae; and

d. means to rotate the scanners of said first and second lens antennae.

13. The invention according to claim **12,** wherein said means to supply microwave energy comprises:

a. an RF source;

b. a first three port ferite circulator having one port coupled to said source and a second opposite port coupled to a terminator;

c. a second ferite circulator having one port coupled to the input of said first scanning lens antenna, a second opposite port coupled to said second scanning lens antenna and a third port coupled to the third port of said first circulator.

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