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April 16, 1963 B. BERKOWITZ 3,086,205

# RING SCANNING ANTENNA ADAPTED FOR FLUSH MOUNTING

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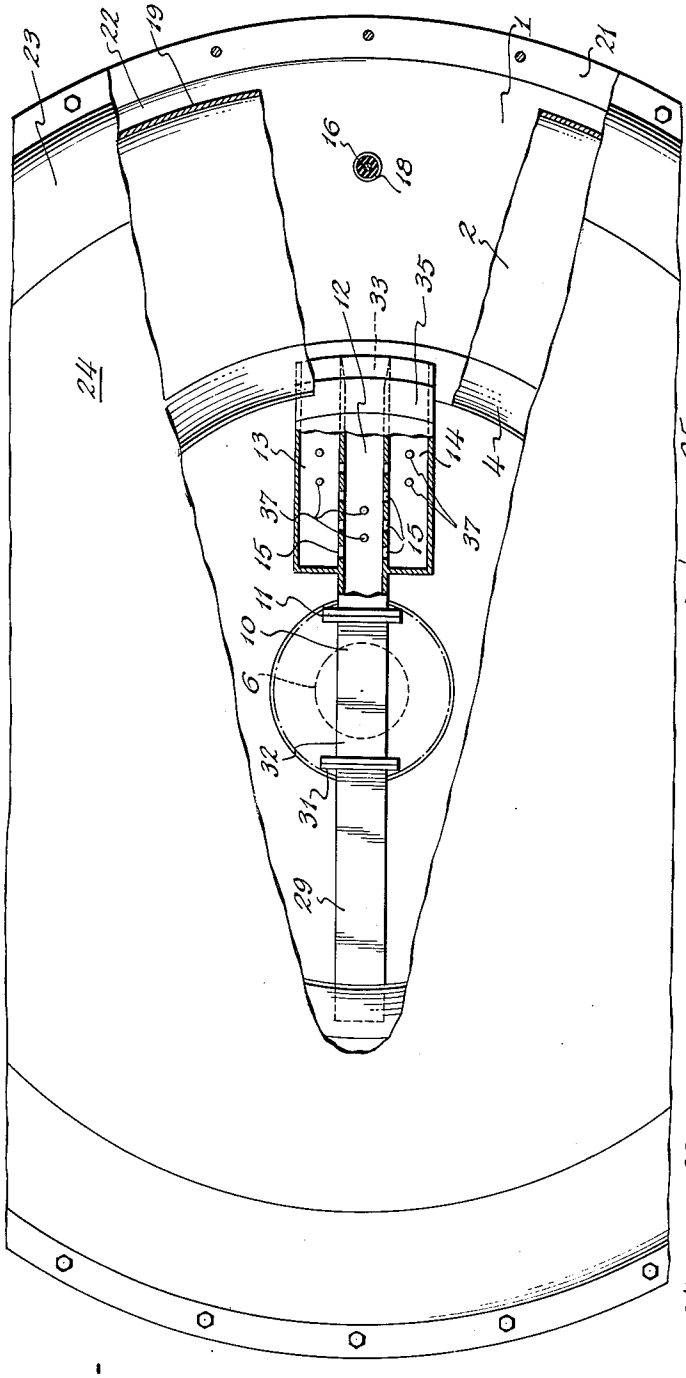


FIG. 2.

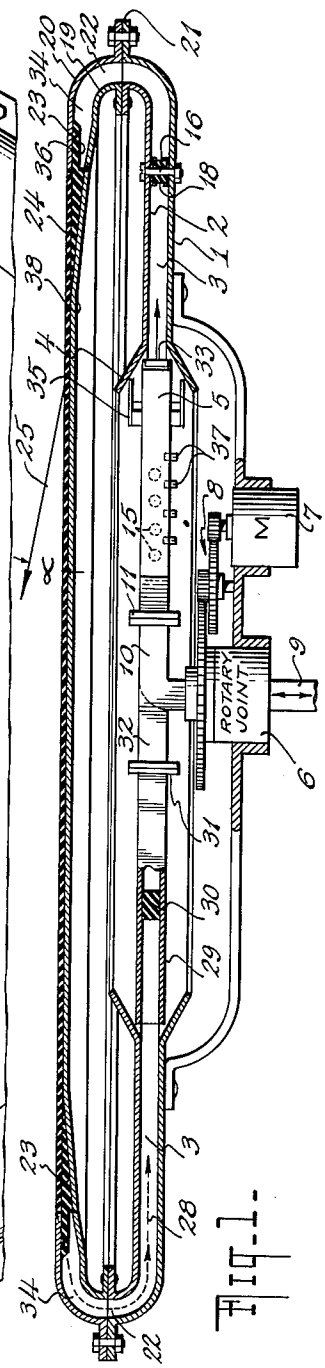



FIG. 1.

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# 3,086,205
# RING SCANNING ANTENNA ADAPTED FOR FLUSH MOUNTING

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This invention relates to antennas for radiating or receiving directional microwave energy and more particularly to such an antenna adapted for flush mounting along the skin of an aircraft.

Prior directional microwave radiators for aircraft installation generally include a reflector type antenna mounted in a nose, tail, dorsal, or ventral location. Of these typical antenna locations, the nose and tail locations are not suitable where 360° azimuthal scanning is required. Only the dorsal or ventral positions may be employed. In slower speed aircraft, the increased drag produced by the radome of a dorsal or ventral antenna may be tolerated. However, with the present trend toward higher speed aircraft such radome protrusions result in a prohibitively large penalty in aircraft performance.

A principal object of the present invention is to provide a directional microwave antenna adapted for flush mounting along the skin of an aircraft.

Another object is to provide a flush mounted aircraft antenna adapted to launch directional microwave energy around a full 360° scanning circle.

An additional object is to provide a flush mounted directional antenna adapted to operate with high azimuth scanning rates.

Yet another object is to provide a continuously scanning directional antenna adapted to launch surface-guided waves of electromagnetic energy.

These and other objects of the present invention, as will appear more fully in the following specification, are accomplished in an illustrative embodiment by the provision of an antenna having upper and lower horizontal parallel plate waveguides interconnected by a vertical parallel plate waveguide. The upper and lower walls of the upper and lower waveguides are centrally-apertured circular plates of electrically conductive material. Each of the walls of the interconnecting vertical waveguide defines a surface of generally cylindrical shape, the cylinders being concentric and of different radii. The longitudinal axis of the cylinders coincides with the axes of the centrally-apertured circular plates of the upper and lower waveguides. The vertical waveguide interconnects the entire outer circumferences of the upper and lower waveguides. The inner circumference of the lower waveguide is adapted to receive directional microwave energy; the inner circumference of the upper waveguide is adapted to radiate microwave energy.

Microwave energy received by the lower waveguide is directed along certain geodesics on a surface median to the horizontal plates thereof and into the vertical waveguide. Energy propagates through the vertical waveguide along geodesics on a surface median to the vertical parallel plates thereof and is then directed into the upper waveguide.

In a preferred embodiment of the invention described in detail in the following specification, provision is made to launch surface-guided waves of electromagnetic energy from the inner circumference of the upper waveguide. Such provision includes the addition of a circular plate of electrically conductive material to the inner circumference of the lower plate of the upper waveguide whereby the aperture of said lower plate is completely closed by the conductive material.

A feature of the surface-wave launching embodiment



of the invention is that the surface-wave launching means may also serve as an integral radome.

For a more complete understanding of the present invention, reference should be had to the following specification and to the appended drawings of which:

FIG. 1 is an elevational sectional view of one embodiment of the present invention adapted to launch surface-guided waves of electromagnetic energy, and

FIG. 2 is a cut-away plan view thereof.

In FIG. 1, the lower horizontal parallel plate waveguide is comprised of sheets **1** and **2**. As shown in FIG. 2, sheets **1** and **2** are centrally-apertured circular sheets of electrically conductive material. The vertical separation between sheets **1** and **2** is preferably adjusted to be less than a half wavelength at the operating frequency when vertically polarized energy (having electric field vectors perpendicular to sheets **1** and **2**) is launched in waveguide **3**. For horizontally polarized energy, the vertical separation is preferably adjusted to be more than one half but less than one guide wavelength.

Microwave duct **3** is adapted at a flared end **4** to receive microwave energy emitted from active feed **5**. In the illustrative embodiment of FIGS. 1 and 2, feed **5** is adapted to rotate throughout a full 360° in a horizontal plane by means of rotating joint **6**, motor **7**, and gearing **8**. A source of microwave energy (not shown) is coupled to input waveguide **9**. Input waveguide **9** is coupled by rotary joint **6** to waveguide **10** which is coupled, in turn, to active feed **5** by flange **11**. Active feed **5** preferably comprises a primary rotating horn to which are coupled two auxiliary horns. The phase and amplitude of the electromagnetic energy emitted by the auxiliary horns, for reasons which will appear in the following specification, are adjusted relative to the phase and amplitude of the energy emitted by the primary horn. The primary horn **12** and auxiliary horns **13** and **14** appear in the cut-away plan view of FIG. 2. The auxiliary horns are coupled to the primary horn by means of coupling apertures **15**. Half-wave choke **35** facilitates maximum energy transfer from active feed **5** to waveguide **3**.

Sheets **1** and **2** are separated from each other in a vertical plane by tuned posts such as tuned post **16**. Post **16** has a central member of appropriate diameter for mechanical support. The inductance of the central member of post **16** is compensated for by the use of capacitive dielectric sleeve **18**. The tuned posts thus are adjusted for minimum reflection of microwave energy propagating through duct **3**.

An upper horizontal parallel plate waveguide **34** consisting of centrally-apertured conductive sheets **19** and **20** is joined to the lower parallel plate waveguide **3** by means of vertical parallel plate waveguide **22**. In the view of FIG. 1, the inner circumference of sheet **19** lies in a plane higher than that of its outer circumference. Waveguide **22** is formed by cylindrically shaped portions of sheets **19** and **2** and sheets **20** and **1**. Sheets **19** and **2** and sheets **20** and **1** are respectively interconnected by circular flange **21**.

Surface-wave launching means including tapered annular dielectric window **23** and circular conductive member **38** terminates microwave duct **34** in the illustrative embodiment of FIG. 1. Member **38** is dished at its outer circumference to match the curvature of lower sheet **19** of waveguide **34**. The flat central portion of member **38** is flush with the upper surface of tapered dielectric **23**. The input of window **23** is matched by means of a stepped transition **36** to minimise reflections from the front surface. The tapered dielectric **23** eliminates the need for supporting posts such as post **16** for separating sheets **19** and **20**. It will also be seen that dielectric **23** readily serves as a radome by totally en-

closing the annular radiating aperture of waveguide **34**. Antenna top loading means **24** which may consist of the same dielectric material as dielectric **23** completely covers the central circular region of conductive sheet **19**. This top loading means serves to minimize the angle $\alpha$ at which rays of microwave energy such as ray **25** departs from the top surface of the antenna of FIG. 1. The length of dielectric **23** is selected to give a maximum end fire pattern where the length L satisfies the condition that

$$L=\frac{\lambda_d\lambda_o}{2(\lambda_o-\lambda_d)}$$

where $\lambda_d$= the wavelength in the dielectric and $\lambda_o$=the wavelength in air.

That portion of the microwave energy not radiated along rays such as ray **25** are guided across the top surface of the antenna by sheet **19** and top loading means **24** and re-enter waveguide **34** through that portion of dielectric **23** lying diametrically opposite the radial direction of the energy emitted by active feed **5**. The re-entrant energy then flows through duct **22** and enters the lower horizontal plate waveguide **3** as indicated by the dashed energy flow arrow **28**. A passive feed horn **29** receives the re-entrant energy leaving duct **3** and dissipates such energy in lossy material **30**. Passive feed **29** is located at the conjugate feed point of the antenna which lies on the same diameter, but opposite radius as does active feed **5**, of the azimuthal scan circle traversed by feed **5**. Passive feed **29** is coupled mechanically to rotating waveguide **10** by means of flange **31** and supporting member **32**.

As previously mentioned, top loading means **24** serves to minimize the departure angle $\alpha$ which angle is reduced as the thickness of means **24** is increased. However, with a reduction in $\alpha$, there is a corresponding increase in coupling to the conjugate feed point. The thickness of dielectric top loading means **24** is therefore selected to produce an acceptable compromise between absolute antenna gain (related to the ratio of radiated energy to the energy coupled to the conjugate feed point) and a minimum value of the angle $\alpha$.

The radial location of the radiating aperture of active feed **5** may be experimentally adjusted so as to produce a relatively flat phase front of the surface wave launched from the top loading means **24**. By holding constant the antenna radius, as measured between the axis of rotating joint **6** and the outer circumference of cylindrical waveguide **22**, and the antenna height as measured between the flat portions of sheets **1** and **20**, and by varying the radial position on the radiating end **33** of feed horn **5**, an optimum radial length for active feed **5** may be chosen to produce a relatively flat phase front of the launched surface wave. As is recognized in the art, the directivity of radiated microwave energy is maximized by producing the flattest phase front of such radiated energy.

Representative values for the parameters mentioned which have been successfully employed in one X-band model of the antenna of the present invention are as follows:

| | Inches |
|---|---|
| Antenna radius | 17.75 |
| Antenna height | 3.75 |
| Radius of active feed | 10.25 |

It will be noted that because of the different geodesic path lengths traversed by the electromagnetic wave propagating through waveguide **22**, the phase front of the wave emitted from dielectric **23** has the shape of a curved surface. This effect is discussed in U.S. Patent 2,633,533 issued on March 31, 1953, in the name of Charles V. Robinson and in U.S. Patent 2,653,239 issued on September 22, 1953, in the names of Lan Jen Chu and Charles V. Robinson. However, tapered dielectric **23** acts as a microwave energy lens to partially correct for such wave front distortion.



It was previously mentioned that active feed **5** preferably comprises two auxiliary horns coupled to a primary horn. The need for the auxiliary horns was demonstrated experimentally by first using a single rotating horn and monitoring the azimuthal pattern of the electromagnetic energy radiated by dielectric **23**. It was ascertained that first azimuthal side lobes of appreciable intensity, relative to that of the main lobe, were produced using a single feed horn. To improve the azimuthal beam pattern of the radiated energy, the triple feed horn shown in FIGS. 1 and 2 was provided.

In the triple feed horn the phase and amplitude of the energy in the two auxiliary horns **13** and **14** is adjusted, relative to the phase and amplitude of the energy in the primary horn **12**, so as to reduce the first side lobes which appear when a single feed horn is utilized. Although the first side lobes may be substantially cancelled by such phase and amplitude adjustment, the second side lobes may be increased in amplitude. Therefore, a compromise must be made in order to obtain the lowest overall side lobe level of the radiated azimuth beam. Tuning screws **37** are located in the horns so as to provide for final adjustments in phase in order to achieve optimum azimuth pattern.

From the preceding specification it will be seen that the objects of the present invention have been accomplished by the provision of a parallel plate antenna adapted to receive microwave energy from a rotatable feed and operative, in one embodiment, to launch said microwave energy in the form of surface-guided waves. The novel design of the antenna facilitates flush installation along the skin of an aircraft thus reducing slip stream drag to an unobjectionable minimum.

While the invention has been described in its preferred embodiments, it is to be understood that the words which have been used are words of description rather than of limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

What is claimed is:

1. An antenna adapted to launch waves of directional microwave energy, said antenna comprising first, second, and third parallel plate waveguides wherein electromagnetic energy flows along geodesics on a surface median to the parallel plates comprising each waveguide, each of said plates of said first and second waveguides being sheets of electrically conductive material conformable to a circle, each of said plates of said first and second waveguides being disposed relative to the others in a respective parallel plane with at least the two outermost plates being centrally apertured, each of said plates of said third waveguide being of electrically conductive material and conformable to a surface of generally cylindrical shape, the cylinders being concentric and of different diameter, the longitudinal axis of the cylinders coinciding with the axes of the sheets comprising said first and second waveguides, said third waveguide interconnecting the entire outer circumferences of said first and second waveguides, the inner circumference of said first waveguide being adapted to receive directional microwave energy directed thereto through the aperture in said outermost plate thereof, and the inner circumference of said second waveguide being adapted to radiate said microwave energy through the aperture in said outermost plate thereof.

2. Apparatus as defined in claim 1 including a sheet of dielectric material conformable to a circle and having a radius equal to the radius of curvature of the inner circumference of said second waveguide for closing the aperture in that plate of said second waveguide which is more distant from said first waveguide.

3. Apparatus as defined in claim 1 including a source of directional microwave energy adapted to rotate about the axis of said plates comprising said first waveguide

for irradiating said inner circumference of said first waveguide.

4. Apparatus as defined in claim 3 further including microwave energy dissipating means connected to said energy source and rotatable therewith for dissipating microwave energy escaping from said inner circumference of said first waveguide at a point diametrically opposite to the point of said inner circumference of said first waveguide irradiated by said energy source.

5. An antenna adapted to launch waves of directional microwave energy, said antenna comprising first, second, and third parallel plate waveguides wherein electromagnetic energy flows along geodesics on a surface median to the parallel plates comprising each waveguide, each of said plates of said first and second waveguides being circular and of electrically conductive material, each of said plates of said first and second waveguides being disposed relative to the others in a respective parallel plane with at least the two outermost plates being centrally apertured, each of said plates of said third waveguide being of electrically conductive material and defining a surface of generally cylindrical shape, the cylinders being concentric and of different diameter, the longitudinal axis of the cylinders coinciding with the axes of the circular sheets comprising said first and second waveguides, said third waveguide interconnecting the entire outer circumferences of said first and second waveguides, the inner circumference of said first waveguide being adapted to receive directional microwave energy directed thereto through the aperture in said outermost plate thereof, and the inner circumference of said second waveguide being adapted to radiate said microwave energy through the aperture in said outermost plate thereof.

6. Apparatus as defined in claim 5 wherein said inner circumference of said second waveguide is terminated by an annular dielectric member.

7. An antenna adapted to launch waves of directional microwave energy, said antenna comprising first, second, and third parallel plate waveguides wherein electromagnetic energy flows along geodesics on a surface median to said parallel plates comprising each waveguide, each of said plates of said first and second waveguides being sheets of electrically conductive material conformable to a circle, each of said plates of said first and second waveguides being disposed relative to the others in a respective parallel plane with at least the outermost plate of



said second waveguide and both of said plates of said first waveguide being centrally apertured, each of said plates of said third waveguide being of electrically conductive material and conformable to a surface of generally cylindrical shape, the cylinders being concentric and of different diameter, the longitudinal axis of the cylinders coinciding with the axes of the sheets comprising said first and second waveguides, said third waveguide interconnecting the entire outer circumferences of said first and second waveguides, the inner circumference of said first waveguide being adapted to receive directional microwave energy directed thereto through the aperture in said outermost plate thereof, and the inner circumference of said second waveguide being adapted to radiate said microwave energy through the aperture in said outermost plate thereof.

8. An antenna adapted to launch waves of directional microwave energy, said antenna comprising first, second, and third parallel plate waveguides wherein electromagnetic energy flows along geodesics on a surface median to said parallel plates comprising each waveguide, each of said plates of said first and second waveguides being circular and of electrically conductive material, each of said plates of said first and second waveguide being disposed relative to the others in a respective parallel plane with at least the outermost plate of said second waveguide and both of said plates of said first waveguide being centrally apertured, each of said plates of said third waveguide being of electrically conductive material and defining a surface of generally cylindrical shape, the cylinders being concentric and of different diameter, the longitudinal axis of the cylinders coinciding with the axes of the circular sheets comprising said first and second waveguides, said third waveguide interconnecting the entire outer circumferences of said first and second waveguides, the inner circumference of said first waveguide being adapted to receive directional microwave energy directed thereto through the aperture in said outermost plate thereof, and the inner circumference of said second waveguide being adapted to radiate said microwave energy through the aperture in said outermost plate thereof.

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