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CIRCULARLY POLARIZING HORN ANTENNA

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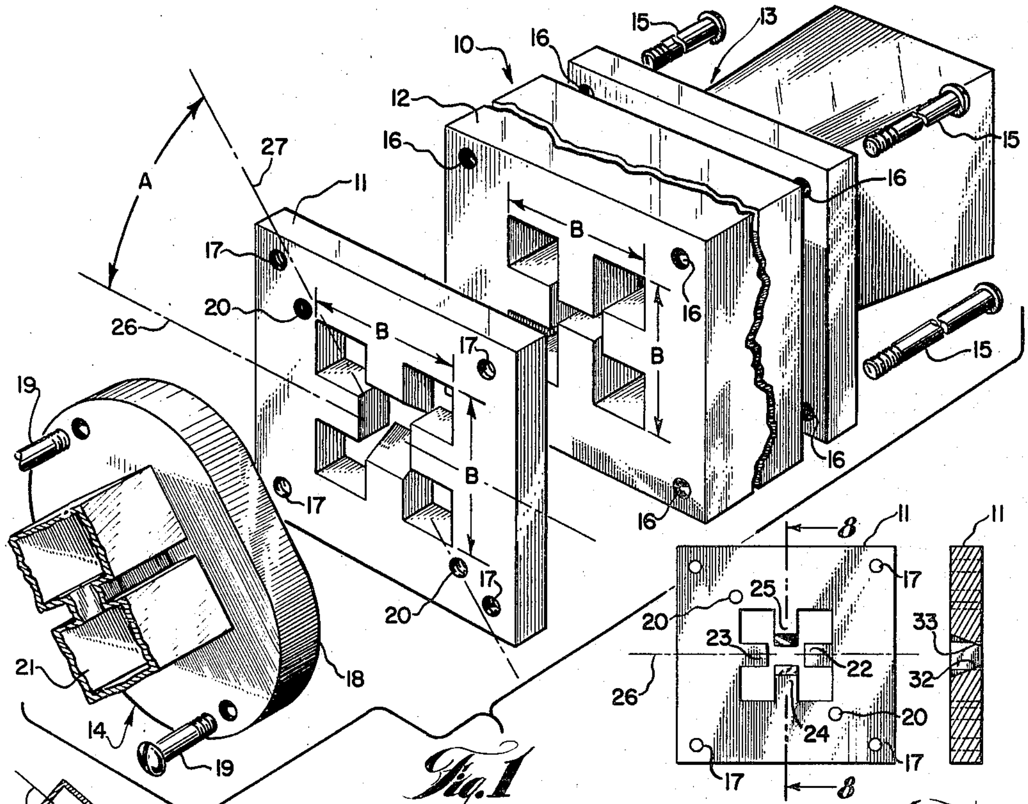

Fig.1

Fig.7 Fig.8

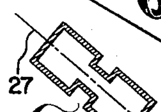

Fig.3

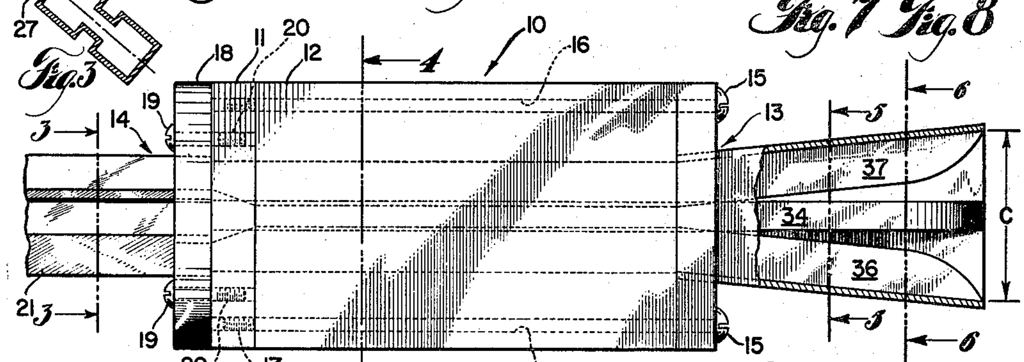

Fig.2

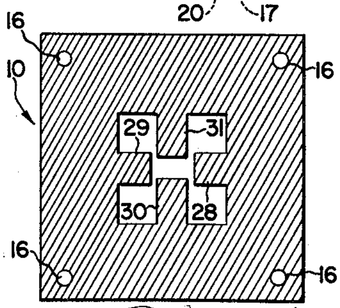

Fig.4

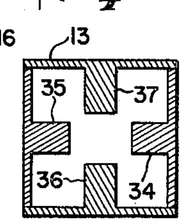

Fig.5

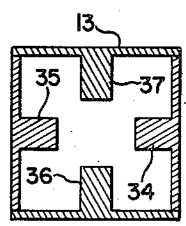

Fig.6

INVENTORS
ERNEST A. JONES,
JAMES D. LEONARD AND
DANIEL F. YAW
BY [signature]
ATTORNEY

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CIRCULARLY POLARIZING HORN ANTENNA

Ernest A. Jones, James D. Leonard, and Daniel F. Yaw, Columbus, Ohio, assignors to North American Aviation, Inc.

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10 Claims. (Cl. 343—756)

Our invention relates to a horn antenna for use in radiating electromagnetic energy, and is especially concerned with a horn-type antenna for providing an essentially circularly polarized electromagnetic field in space.

An important object of this invention is to provide a horn antenna which may be utilized to effectively establish and radiate an essentially circularly polarized radiation field.

Another object of our invention is to provide a horn antenna that may be employed to establish and launch an electromagnetic energy radiation field which is essentially circularly polarized over a comparatively wide frequency bandwith.

Another object of this invention is to provide a horn antenna for utilization with a waveguide feed that normally conducts electromagnetic energy having a single orthogonal electric field configuration.

Another object of this invention is to provide a circularly polarizing horn antenna which may be combined with a waveguide feed of the double-ridged type.

A still further object of this invention is to provide a horn antenna of the circular polarizing type with means for converting electromagnetic energy having a single orthogonal electric field configuration to electromagnetic energy having two orthogonal electric field configurations which are essentially at right angles to each other.

Another object of this invention is to provide a circularly polarizing horn antenna with transition means for converting a single form orthogonal electric field configuration to a dual form orthogonal electric field configuration with an improved electrical conversion efficiency.

Another object of our invention is to provide a horn antenna with means for effecting a phase-shift between the separate configurations of a conducted electromagnetic energy field having two orthogonal electric field configurations essentially at a right angle relative to each other.

Another object of this invention is to provide a horn antenna with a four-ridged type phase-shifting section that obtains substantially a one-quarter cycle phase-shift between the separate configurations of a conducted electromagnetic energy field having two orthogonal electric field configurations of right-angle orientation.

A still further object of this invention is to provide a horn antenna means with a radiation section that effectively and efficiently launches a circularly polarized electromagnetic energy field into space.

Another object of our invention is to obtain a circularly polarizing horn antenna which may be provided with an all-metal construction so as to better withstand high temperature conditions and extreme vibration conditions in its operating environment.

A still further object of this invention is to provide a horn antenna which is particularly useful in connection with aircraft microwave radiation equipments.

Another object of our invention is to provide a horn antenna of the circularly polarizing type which is compact, which may be readily fabricated, and which is comparatively economical to manufacture.

The horn antenna of this invention is fed with electromagnetic energy having a single orthogonal electric field configuration, such as that established and conducted by a wideband, double-ridged waveguide feed, and employs a transition section which efficiently converts the field conducted by the waveguide feed into a field having two orthogonal electric field configurations oriented at right angles to each other. The horn antenna of this invention also utilizes a phase-shifting section which receives the field converted by the transition section, which transforms that field into one of substantially circularly polarized form having a one-quarter cycle time-shift between its separate electric field configurations, and which feeds the circularly polarized field into an adjoining radiator section. The radiator section in turn better radiates the circularly polarized electromagnetic field into space.

Further details regarding our invention are set forth in the drawings and detailed description. Also, other objects and advantages of this invention will become apparent during consideration of such details.

In the drawings:

Fig. 1 is a perspective view of a microwave antenna installation showing components of the horn antenna of this invention in exploded relation, and showing portions of an included waveguide feed;

Fig. 2 is a side view of the horn antenna arrangement of Fig. 1;

Fig. 3 is a sectional view taken at lines 3—3 of Fig. 2;

Fig. 4 is a sectional view taken at lines 4—4 of Fig. 2;

Fig. 5 is a sectional view taken at lines 5—5 of Fig. 2;

Fig. 6 is a sectional view taken at lines 6—6 of Fig. 2;

Fig. 7 is an end view of the transition section component illustrated in Figs. 1 and 2; and

Fig. 8 is a sectional view taken at line 8—8 of Fig. 7.

Figs. 1 and 2 illustrate an all-metal horn antenna **10** comprised essentially of transition section **11**, phase-shifting or mode-shifting section **12**, and radiator section **13**. Antenna **10** is intended for combination with the waveguide feed assembly referenced generally as **14**. Sections **11** through **13** may be fabricated of brass, and are assembled as a unit (Fig. 2) through the use of the threaded fastener means **15** which cooperate with holes **16** contained in sections **12** and **13** and with threaded openings **17** provided in section **11**. Other types of fastening means may be employed if desired. The assembled horn antenna **10** is attached (Fig. 2) to the flange portion **18** of waveguide assembly **14** by means of the threaded fasteners **19** that pass through portion **18** and that cooperate with threaded holes **20** in component **11**.

The waveguide component **21** of waveguide feed assembly **14** conducts an electromagnetic energy field from a generating device (not shown) to the antenna assembly **10**. In the form shown, waveguide component **21** is arranged to conduct such energy in the $TE_{1,0}$ mode throughout a frequency bandwidth of about 3:1; the exact frequency band will depend upon the actual interior dimensions and actual ridge dimensions of the waveguide feed. Such may be selected for a particular application by persons skilled in the art. In further describing the horn antenna installation of our invention, reference will be made to Figs. 1 through 8 as relating to an arrangement wherein the waveguide feed and horn antenna are intended for operation within the nominal wideband transmission frequency range of from approximately 6,000 megacycles per second (mc.) to approximately 18,000 megacycles per second.

The requirements for launching of a substantially circularly polarized electromagnetic field require that three parameters be closely controlled. First, it is preferred that the single orthogonal electric field configuration of the energy transmitted by the double-ridged waveguide 21 be divided into two orthogonal electric field configurations of equal amplitude and at right angles to each other. Second, a time phase difference of ninety degrees (one-quarter cycle) must be established as between the two electric field configurations previously-mentioned. Lastly, the resulting circularly polarized electromagnetic energy field should be efficiently and effectively launched into free space by means of a suitable radiating device. Such parameter controls are accomplished by the antenna sections designated 11, 12, and 13, respectively.

Transition section 11 is provided to convert the field transmitted in waveguide feed 21 into a new or different field having two modes, at right angles to each other, for processing through mode-shifting section 12. For optimum effectiveness, the new two-configuration field established by transition section 11 should have its separate modes at right angles to each other and of equal amplitude. The interior of transition section 11 is provided with ridge portions 22 through 25 (Fig. 7) to obtain the field conversion, and further accomplishes the required conversion by being mounted to waveguide 21 with cross-axis 26 rotated, relative to cross-axis 27 of waveguide 21, through the angle A. Or conversely, cross-axis 27 of waveguide assembly 14 is rotated to a mid-point between angularly adjacent ridge members of transition section 11 and phase-shifting section 12. Essentially, transition commences or occurs adjacent or at the butting surfaces of waveguide feed assembly 14 and transition section 11. For an antenna installation intended for operation throughout the nominal wideband range of from 6,000 mc. to 18,000 mc., an angle A of fifty degrees has proved particularly effective. Referring also to the Fig. 2 arrangement, transition section 11 is arranged in butting relation to waveguide assembly 14 to additionally provide for an efficient conversion of electrical energy through improved impedance matching.

The symmetrical square-like interior of section 11 has a dimension B (Fig. 1) which, with the hereinafter discussed ridge dimensions, should be determined in accordance with good waveguide antenna design practices to establish a proper cut-off frequency for the bandwidth of the transmitted field. For a circularly polarizing horn antenna assembly transmitting energy nominally from 6,000 mc. to 18,000 mc., a dimension B of approximately 0.72″ will prove adequate.

Correction of the converted field to provide for equal amplitude in its separate orthogonal electric field configurations is accomplished in antenna 10 by providing a taper on certain of the ridge portions contained in transition section 11. In the illustration of Fig. 8, surface portions 32 and 33 of ridges 24 and 25 are angled to provide the required taper. For the hereinbefore discussed 6,000 mc. to 18,000 mc. installation, a rise of approximately 0.09″ in 0.25″ of longitudinal distance has proved satisfactory.

Ridge portions 28 through 31 of phase-shifting section 12 are provided, as will later be described, to obtain essentially a ninety degree shift between the separate field configuration portions established by transition section 11, and are arranged in pairs of unequal depth. Ridge portions 22 through 25 of section 11 are paired, with ridges 22 and 23 being of less overall depth than ridges 24 and 25. Referring again to a nominal 6,000 mc. to 18,000 mc. wideband circularly polarized horn antenna installation, ridge portions 22 and 23 are typically 0.18″ wide and project a distance of 0.22″ from the adjacent interior surface, whereas ridge portions 24 and 25 are of the same width but project a distance of 0.29″ from their adjacent interior surface. It may be considered that ridge portions 22 through 25 are, respectively, extensions of ridge portions 28 through 31 and vice versa.

Mode-shifting section 12 is provided to establish the circularly polarized field to be transmitted from the antenna assembly. The electric field configurations established at right angles to each other and given equal amplitude by transition means 11 are processed to obtain a one-quarter cycle time difference therebetween. Such phase difference is accomplished by having the component portions travel at different velocities in the phase-shifting section. This in turn is accomplished by making the ridge portions 28 through 31 of different depths to establish a different cut-off frequency for each field configuration portion. The width and projecting dimensions set forth above in connection with the discussion of ridge portions 22 through 25 pertain also to the corresponding ridge portions utilized in phase-shifting section 12.

Horn radiator section 13 is provided to launch the circularly polarized electromagnetic energy field established by section 12 into space, and has a four-ridge arrangement comprised of ridge portions 34 through 37. The aperture provided at the connecting end of section 13 corresponds to that established for section 12. The opening provided at the opposite end of horn 13 is dimensioned for the desired radiation pattern and for improved impedance matching with space. In the specifically described horn antenna installation, the dimension C of section 13 is about one inch, and the half power beamwidth radiation pattern extends about sixty degrees for mid X-band frequencies. The contour of each ridge portion 34 through 37 is arranged for linear impedance variation at infinite frequency. Such ridge portions are tapered to zero at the open end of section 13.

It is to be understood that the form of the invention herewith shown and described is to be taken as a preferred embodiment of the same, but that various changes in the shape, size, and arrangement of parts may be resorted to without departing from the spirit of the invention or the scope of the subjoined claims.

We claim:

1. A microwave horn antenna assembly in combination with a waveguide feed which has two ridge members that are opposed, which has a cross-axis extended transverse said ridge members, and which conducts electromagnetic energy with a single orthogonal electric field configuration, and comprising: a transition section located adjacent said waveguide feed and transforming the electromagnetic energy conducted by said waveguide feed into electromagnetic energy having two orthogonal electric field configurations at right angles, and a phase-shifting section positioned adjacent said transition section and converting the electromagnetic energy transformed by said transition section into electromagnetic energy which is circularly polarized, said transition section being provided with a hollow interior having four equally angularly-spaced ridge members therein and having a cross-axis aligned with the projection of two of said transition section ridge members located in opposed relation to each other, and said transition section being located adjacent said waveguide feed with said transition section cross-axis rotated relative to said waveguide feed cross-axis to provide the electromagnetic energy transformed by said transition section with two orthogonal electric field configurations located at right angles.

2. The microwave horn antenna assembly defined in claim 1, wherein said transition section includes means which provide the electromagnetic energy field transformed thereat with two orthogonal electric field configurations of equal amplitude, said means comprising a tapered portion provided on each of another two of said transition section four ridge members, said another two transition section ridge members being located in opposed relation to each other.

3. The microwave horn antenna assembly and combined waveguide defined in claim 1, wherein substantially flat end surfaces are provided for each said waveguide feed and said transition section at right angles to the

longitudinal axis of the horn antenna assembly, said waveguide feed and transition section end surfaces being placed in butting relation to each other to thereby provide for improved efficiency in the transformation of electromagnetic energy.

4. A microwave horn antenna connected to a waveguide feed which conducts electromagnetic energy having a single orthogonal electric field configuration, and comprising: a transition portion located adjacent said waveguide feed and transforming the electromagnetic energy conducted by said waveguide feed into electromagnetic energy having two orthogonal electric field configurations at right angles, and a phase-shifting portion provided with a hollow interior having four spaced-apart ridge members therein located adjacent said transition portion, each of two of said phase-shifting portion ridge members being opposed and of one height and each of the other two of said phase-shifting portion ridge members being opposed and of a lesser height to thereby convert the electromagnetic energy transformed by said transition portion into electromagnetic energy which is circularly polarized.

5. The assembly defined in claim 4, wherein said horn antenna includes a radiator portion located adjacent said phase-shifting portion, said radiator portion having four spaced-apart ridge members that flare radially outwardly and that constitute extensions of said phase-shifting portion four ridge members to radiate the circularly polarized electromagnetic energy established by said phase-shifting portion into space with improved impedance matching.

6. A microwave horn antenna installation radiating electromagnetic energy which is characterized as having two electric field modes at right angles and phase-shifted approximately one-quarter cycle relative to each other, and comprising: a waveguide feed conducting electromagnetic energy which has a single electric field mode, an all-metal hollow transition means placed immediately adjacent said waveguide feed and having inwardly projecting ridge portions which transform the electromagnetic energy conducted by said waveguide feed into electromagnetic energy having two electric field modes at right angles relative to each other, and an all-metal hollow mode-shifting means placed immediately adjacent said transition means and having inwardly projecting ridge portions which phase-shift said two electric field modes established at said transition means relative to each other, said mode-shifting means ridge portions projecting inwardly different depths to phase shift said two electric field modes established by said transition means approximately one-quarter cycle with respect to each other.

7. The installation defined in claim 6, wherein said transition means and said mode-shifting means are each provided with four inwardly projected and equally angularly spaced ridge portions, two of said four ridge portions being opposed and of the same greater height, and the other two of said four ridge portions being opposed and of the same lesser height to thereby accomplish the phase-shift between said two electric field modes established by said transition means.

8. The installation defined in claim 7, wherein said transition means and said mode-shifting means are each provided with a square-like interior having four sidewalls, each said sidewall being provided with a ridge portion located adjacent the midpoint of the cross-section thereof.

9. The installation defined in claim 7, wherein there is included a hollow-radiation means located adjacent said mode-shifting means, said radiation means having four inwardly projected and equally angularly spaced ridge portions, each said radiation means ridge portion comprising a flared extension of a mode-shifting means ridge portion to radiate the two electric field modes phase-shifted by said mode-shifting means into space with improved impedance.

10. A microwave horn antenna coupled to a waveguide having two diametrically opposed inwardly projecting ridges, and comprising: a hollow all-metal transition section located adjacent said waveguide and having a uniformly square interior cross-section with four sides which are each provided with a symmetrically-positioned ridge member projected inwardly therefrom, a hollow all-metal mode-shifting section located adjacent said transition section and having a uniformly square interior cross-section with four sides which are each provided with a symmetrically-positioned ridge member projected inwardly therefrom and aligned with a transition section ridge member, and a hollow all-metal radiator section located adjacent said mode-shifting section and having a non-uniformly square interior cross-section with four sides which are each provided with a symmetrically-positioned ridge member projected inwardly therefrom and aligned with a mode-shifting section ridge member, said transition section being placed adjacent said waveguide so that the waveguide cross-axis oriented transverse the projection of said waveguide two opposed ridges is rotated to an angular mid-position relative to axes defined by diametrically opposed ridge members of said transition section, and said mode-shifting section having two diametrically opposed ridge members of a first projected depth and two other diametrically opposed ridge members of a different projected depth, said transition section, said mode-shifting section, and said radiator section combining to radiate electromagnetic energy conducted by said waveguide as a circularly polarized electromagnetic field having right angled modes relatively phase-shifted one-quarter cycle.

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