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3,233,241

HORN FOR RADIATING CIRCULARLY POLARIZED WAVES

Filed May 25, 1955

4 Sheets-Sheet 1

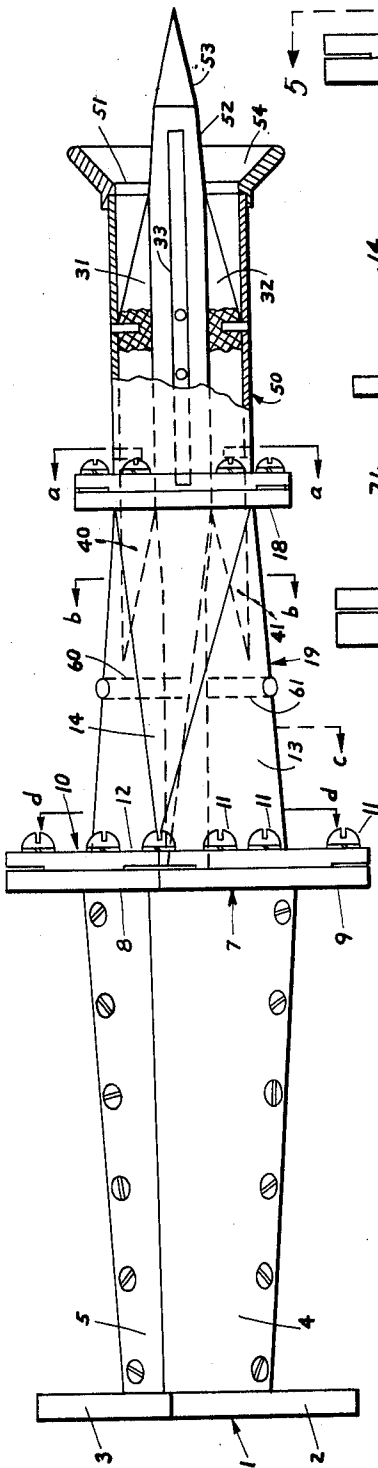


FIG. 1

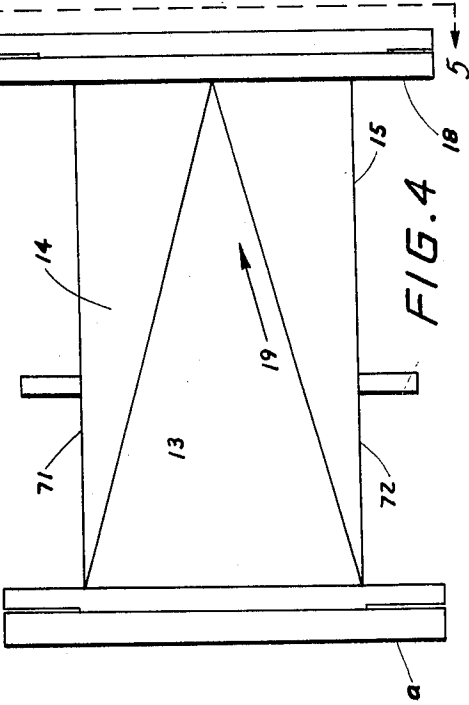


FIG. 4

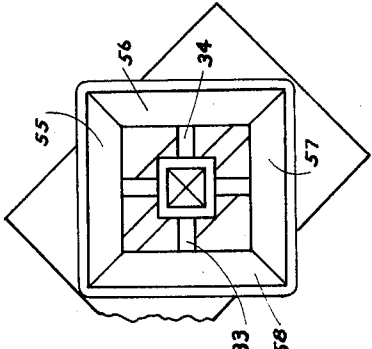


FIG. 2

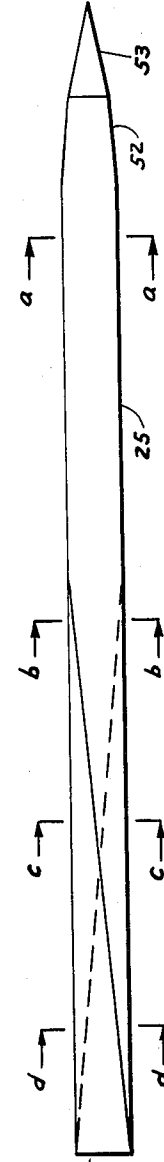


FIG. 3

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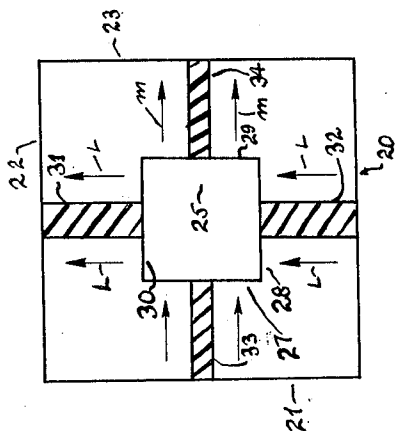


FIG. 6

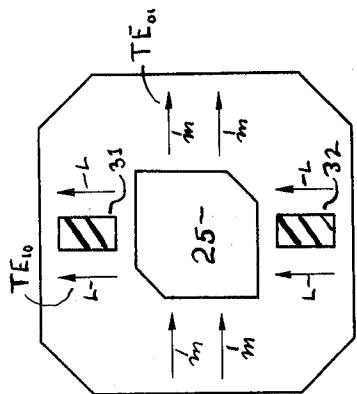


FIG. 7

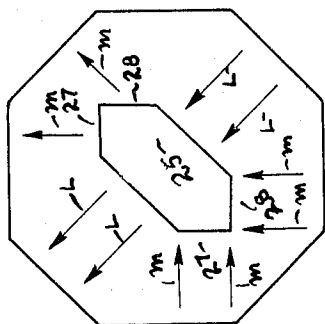


FIG. 8

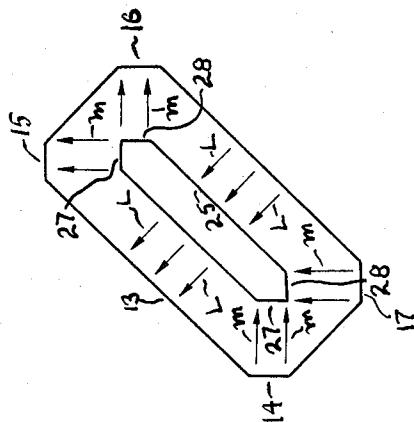


FIG. 9

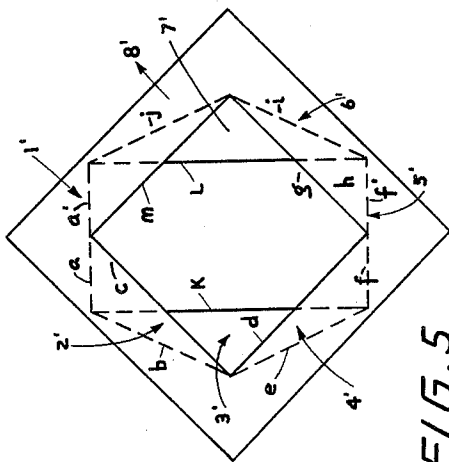


FIG. 5

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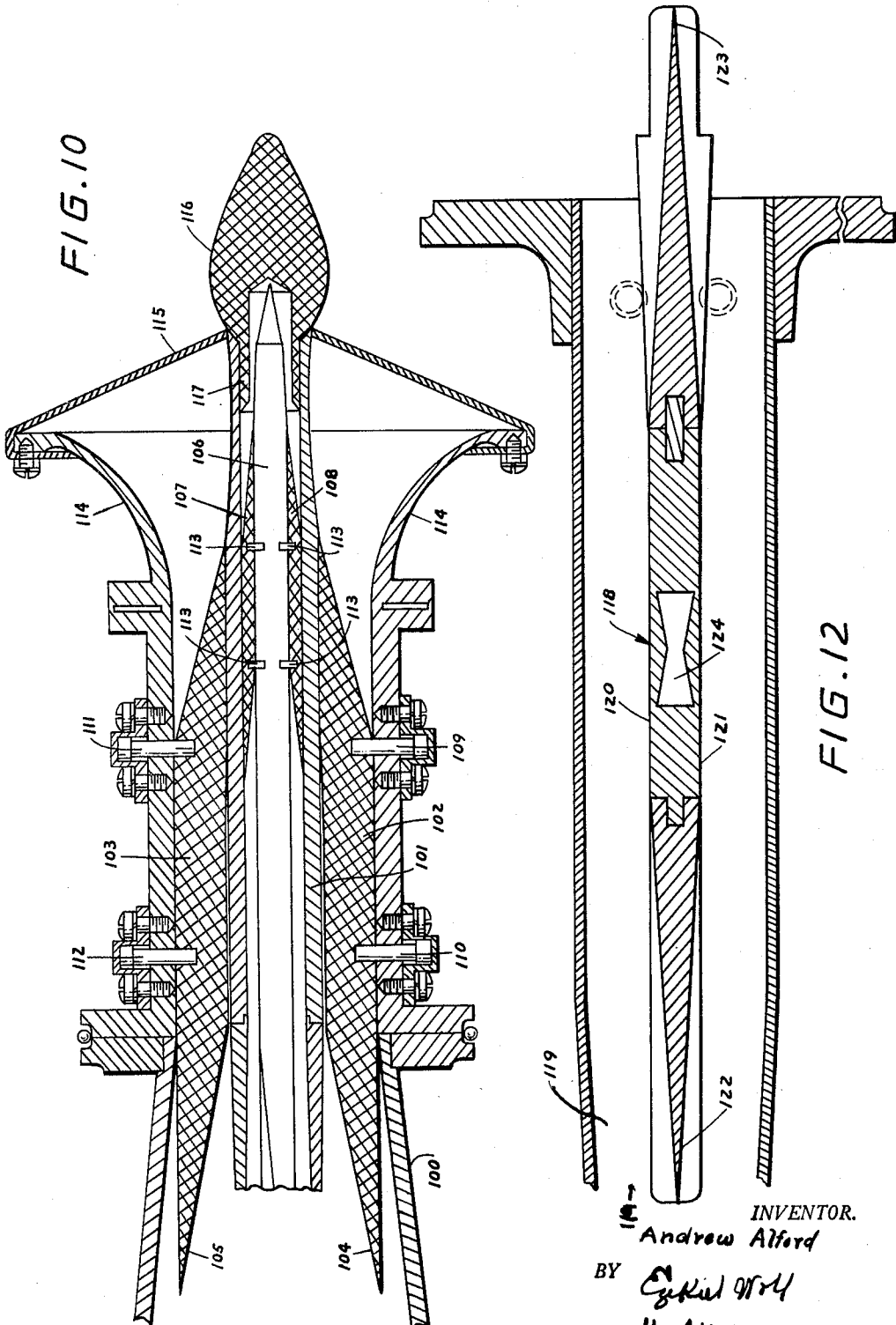
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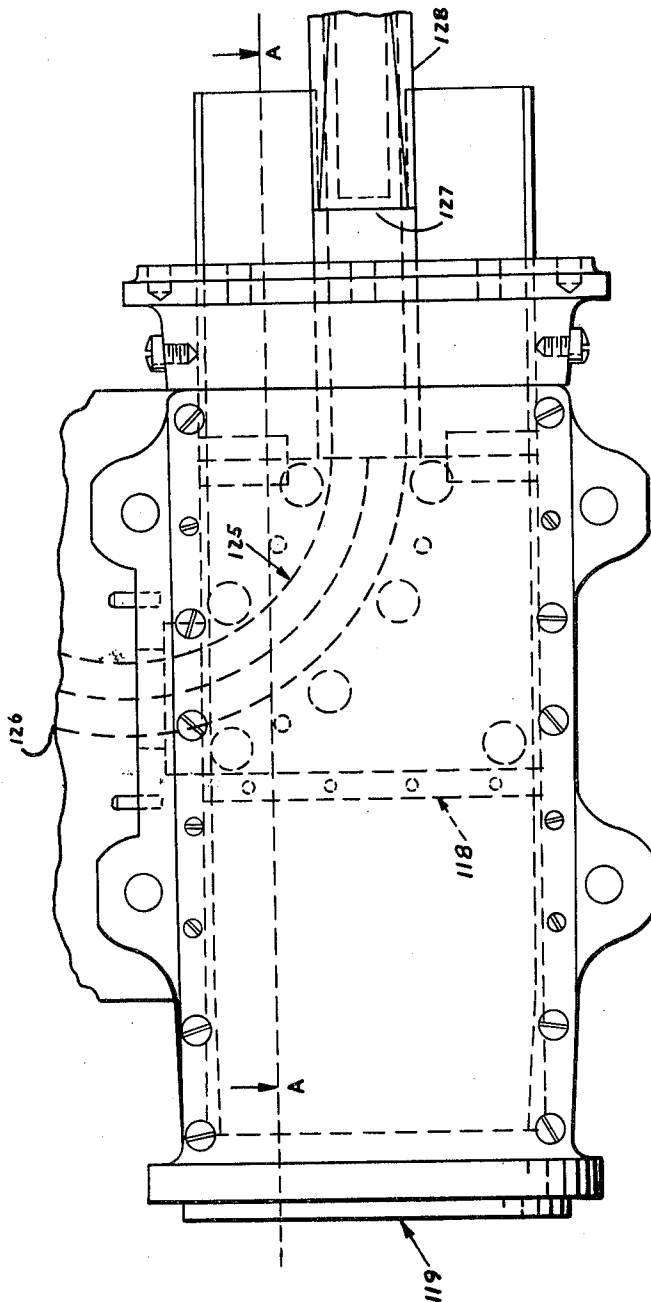


FIG. 11

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15 Claims. (Cl. 343-756)**

The present invention relates to a horn for radiating circularly polarized waves and is an improvement over the prior art, not only in obtaining a broader frequency range, but also in reduction in size of the horn.

One of the features of the present invention is the use in the horn of a metal insert and also the use of dielectric elements in retarding the phase of one mode of propagation with respect to the other.

Further and other advantages will be understood and appreciated from the description of the specification set forth below in connection with the drawings illustrating an embodiment thereof in which:

FIGURE 1 shows a longitudinal elevation of the wave guide and horn with portions broken away to show the interior construction.

FIGURE 2 shows an end view as viewed from the right end of FIGURE 1.

FIGURE 3 shows a longitudinal view of the spear used in the horn as indicated in FIGURE 1.

FIGURE 4 shows a side elevation or longitudinal view of a section of the horn shown in FIGURE 1.

FIGURE 5 shows an end view as viewed from the right end of the section of the horn shown in FIGURE 4.

FIGURES 6, 7, 8, and 9 show successive diagrammatic sectional views taken substantially on the lines *a-a*, *b-b*, *c-c*, and *d-d* of FIGURES 1 and 3, the like labeled section lines in FIGURES 1 and 3, corresponding. These views are 90° displaced in clockwise rotation from the views of FIGURES 1 and 3.

FIGURE 10 shows a section of a modification of FIGURE 1 in which the horn is provided with an outer and an inner spear. The outer spear formed as a horn with the inner spear within it.

FIGURE 11 relates to the modification shown in FIGURE 10 showing more particularly how the inner horns is fed and

FIGURE 12 shows a section taken on the line *a-a* of FIGURE 11.

In the present invention the ordinary rectangular wave guide which propagates TE_{10} mode is converted into a square wave guide propagating both TE_{10} and TE_{01} modes by a gradual transitional section of the wave guide from a rectangular section to a square section through an intermediate form which may be an eight-sided wave guide. The transitional section is so arranged that it provides a change or "twist" in the wave guide in its transition from a rectangle to a square section so that the wave twists. The change referred to above may be 90° as shown in FIGURES 4 and 5.

The applicant has found that a spear of metallic material supported by dielectric plates mounted between the spear and the side walls of the square wave guide may be used to effect the desired retardation of phases to produce the circularly polarized radiation from the horn. The dielectric, in particular, provides the delay between the TE_{01} mode and the TE_{10} mode. The effect of the metallic spear in the square wave guide is such as to make the necessary dimensions of the horn smaller because it will decrease or lower the cut-off frequency.

In the present invention the spear within the square wave guide may also comprise another square wave guide for providing transmission within the inner spear which will extend the operating range over a much broader

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frequency band than a solid spear as will be illustrated later.

In the present invention, it has been found that the particular type of spear used as an insert within the wave guide and the particular shape of transformation in the structure of the walls in the guide provides improved results in the ultimate coaxial horn antenna structure, whereby operation over a wider frequency band may be obtained.

The present invention in particular relates to a structure in which a rectangular form of wave guide is transformed into a square formed wave guide propagating both TE_{10} and TE_{01} modes, which is equivalent to a transducer for establishing both types of mode propagation. This transducer effect or transformation takes place in one section of the horn, while in the same section and a subsequent section, a retardation is effected between the two modes of propagation so that one mode will become 90° out of phase with the other mode with the resultant effect that a true circular radiation is obtained at the output of the horn.

In the longitudinal view of the structure, shown in FIGURE 1, at the left of the figure the input wave guide has a flange composed of the two opposite sides 2 and two opposite sides 3, which as shown in FIGURE 1 are tilted diagonally. The larger wave guide surface is shown with two opposite walls 4, one of which is shown in FIGURE 1, and two opposite walls 5, one of which is shown in FIGURE 1, forming a rectangular wave guide.

This wave guide section 1 is enlarged from the smaller end at the left of FIGURE 1 to an enlarged section terminating in a flange 7 which is also in the shape of a rectangle having two opposite larger side walls and flange edges 9 and two smaller flange edges 8. The flange 7 is faced by a somewhat similar flange 10, the two flanges being held together by a group of screws 11, 11, 11, positioned around the periphery of the flange clamping the flanges 7 and 10 together. The walls 4 and 5 terminate on the inside of the flange 7 where they are secured by soldering or some other positive means. The flange 10 is formed as a hollow rectangle and has attached at its inner edges two adjoining walls 12 and 13 and two opposite walls opposite respectively to the walls 12 and 13, forming the other sides of the rectangle. Beginning at the flange 10, at each side of the pairs of walls 12 and 13 there are inserted pairs of other walls 14, 15, 16, and 17, which are shown more clearly in FIGURE 9 which are shaped as triangles and form the corners of the transformation of the wall sections between the flange 10 and the flange 18 which has been designated in FIGURE 1 as the section 19. These walls 14, 15, 16, and 17, gradually enlarge from the left end of the section 19 until at the right end of the section 19 they form four complete walls which are labelled in FIGURES 6, 20, 21, 22 and 23. These in effect are the ends respectively of the walls 17, 14, 15 and 16 FIGURE 9.

What actually happens in the transformation in this section is shown somewhat diagrammatically successively in FIGURES 9, 8, 7, and 6. In FIGURE 9, it will be seen that the arrows L, L, L, L, etc., show the polarization of one mode of propagation while the arrows M, M, M, M, etc., show the polarization of the second mode of propagation in the wave guide.

FIGURE 8 shows the further progress in the direction of the guide to the right in FIGURE 1 as this transformation occurs and in FIGURE 7, it will be seen that practically two individual modes TE_{10} and TE_{01} are established in two opposite perpendicular directions and that these modes of propagation are completely established in the section taken in FIGURE 6 on the lines *a-a* of FIGURES 1 and 3.

It will also be noted in examining FIGURES 1, 3, 6, 7, 8, and 9 that the internal element, namely the spear, 25 in FIGURE 3, is formed with a flat tongue 26 at the lower end, the flat tongue 26 becoming slightly thicker and having two pairs of side walls 27 and 28, one pair on either side of the tongue which becomes wider as the thickness of the spear increases until at the section $c-c$, it appears as shown in FIGURE 8 with the side walls 27 and 28 larger and with the thickness of the spear increased. The side walls 27 and 28 gradually are transformed as shown in FIGURE 6 until the section of the spear becomes rectangular with the adjoining walls coming to a point as indicated at 29 and 30, so that the transformation of the spear begins with a flat tongue and goes through a six-sided figure gradually emerging at the right end of the section 19 into a spear of the shape shown in FIGURE 6.

The spear as indicated in FIGURES 3, 6, 7, 8, and 9 is supported within the square wave guide by opposite dielectric fins or plates. These opposite dielectric fins or plates are indicated in FIGURE 1 as 31, 32, 33, and 34. At the right end termination of the section 19, the two modes of propagation TE_{10} and TE_{01} are fully and completely established and some retardation has been effected on TE_{10} mode by the extension of the dielectric elements 31, and 32 into this section comprising the end sections 40 and 41 of these supporting dielectric elements respectively which are shown in FIGURE 1 as fin-like in effect and formed with the two sides inclined towards one another coming together at a point somewhere towards the middle of the section 19. This retardation of the TE_{10} mode is continued through the section 50 of the circular polarized horn by means of the dielectric supporting plate or fins 31 and 32 which extend in a vertical direction and 33 and 34 which extend in a horizontal direction. These two pairs of plates or fins serve the two purposes of supporting and locating the spear within the horn and also for the purpose of effecting the proper retardation through the horn so that the TE_{10} mode and the TE_{01} mode at the outlet of the horn in the mouth 51 provides a circularly polarized mode of propagation.

The spear 25 at the right end of the horn is terminated in a slightly decreasing square section 52 and then just outside of the end of the horn is tapered off to a point as indicated in a section 53. The horn itself is preferably flared out on all sides by a flared section 54 which flare is extended outwards on each side by the walls 55, 56, 57 and 58. It will be noted that the dielectric supporting the interior spear in the vertical direction as indicated in FIGURE 1 is thicker and/or longer or both than the dielectric which furnishes the support for the spear in the horizontal direction. The thicker support in the vertical direction furnishes a greater retardation of the TE_{10} mode propagated in the horn than the thinner support provided by the horizontal dielectric material which furnishes the retardation for the TE_{01} mode of propagation. The object of the dielectric, as has been stated before, is to obtain the retardation of phase of 90° between the two modes of propagation so that the circularly polarized radiation may be effected. There is also a support for the left end of the spear near its tail by the dielectric pins 60 and 61 which extends through the outer wall of the horn and into recesses formed in the narrow inclined side walls of the spear opposite each other.

It has been found that the arrangement indicated in the drawings provides a substantially circularly polarized wave transformation over a considerable range of frequency which is greater than a two-to-one ratio. The dielectric supporting elements used for supporting the internal spear may be any suitable dielectric, but the applicant has found that "Teflon" is quite suitable for this purpose.

FIGURES 4 and 5 show a side view of the section 19 and an end view of the section 19 respectively with the flange included.

As indicated in FIGURES 4 and 5, the view shown in FIGURE 4 is a view looking squarely at the section 19, wherein the wall 14 at the left end comes to a point of a triangle in the side of the rectangular guide and the adjoining edges of the triangle merely shown by the line 71 which corresponds with the line 72 which diverges slightly outward to the opposite flange 18.

In FIGURE 5, the full lines indicate the flange on the right hand side of the guide section in FIGURE 4 and the dotted lines indicate the various walls formed between the two end flanges 18 and 19.

In FIGURE 5, for instance, the boundary surface of the surface 1' is formed by the lines $a-a'$. The boundary surface of the surface 3' is formed by the lines k, b, e . The boundary surface of the surface 4' is formed by the lines d, e, f . The boundary surface of the surface 5' is formed by the lines f, f' . The boundary surface of the surface 6' is formed by the lines g, f', i . The boundary surface of the surface 7' is formed by the surface 1, i, j . The boundary surface of the surface 8' is formed by the lines n, j, a' .

It will be evident from FIGURES 4 and 5 how the transformation is effected between the rectangular wave guide and the square guide and how the insert element shows a conversion of the single mode to the two rectangular modes, namely TE_{10} and TE_{01} .

It has been previously mentioned in connection with the embodiment shown in FIGURES 1 to 9 inclusive that a spear within a spear may be used. Fundamentally, this will increase the frequency range of operation of the horn. With a horn and a spear within, the frequency range of the present invention may be extended to 2 to 1. With the spear within formed as a horn and a spear within this inner horn, the frequency range of operation may be extended to 4 to 1 in operation which gives an extremely wide latitude for operation for many commercial and military purposes.

In FIGURE 10, the outer guide structure or wall section 100 corresponds to the section 19 of FIGURES 1 and 4 and shows within the "twisted" guide an inner hollow horn 101 which itself acts as a wave guide for polarizing waves transmitted through it from the left end of the guide as will be explained. The inner hollow guide or horn 101 shown in FIGURE 10 is supported against the walls of the outer hollow guide by opposite dielectric elements 102 and 103 which at their forward end taper to opposite sides of the horn 101 and at their rear end come to points 104 and 105 in the free guide space.

While not shown in FIGURE 10, the horn 101 is also supported from the other two opposite walls of the guide 100 similarly as shown in FIGURES 1 and 2. The dielectric elements 103 and 102 between the inner horn's outer wall and the inner wall of the outer horn correspond to the dielectric elements 32 and 31 respectively while the dielectric elements 33 and 34 correspond to the horizontally supported dielectric elements not shown in FIGURE 10.

The inner hollow horn 101 is constructed similarly as the outer guide or horn and provides a twist as indicated in FIGURES 1 to 9 to transform a TE_{10} mode into a TE_{10} mode and TE_{01} mode. At the same time, the shape of its outer wall, that is the inner horn, is the correct shape of a spear to transform the TE_{10} mode between the inner horn and the outer horn into a TE_{10} mode and a TE_{01} mode in the space between the inner and outer horns.

It will also be noted that the spear 106 within the inner horn is substantially similar in shape to the spear 25 in FIGURES 1 to 9, and that it begins at the left with a flat tongue and gradually twists through an eight-sided figure to a square at an angle of 45° with the original axis. The spear 106 is supported from the walls of the inner horn by dielectric plates 107 and 108 extruding in a vertical direction and similar but smaller horizontal plates or dielectric supports of other shape which are not shown in FIGURE 10. These dielectric plates furnish not only

support for the inner spear 106, but as in the case of the outer horn or inner horn with the outer spear provide the necessary relative phase retardation to produce circular radiation.

The dielectrics 102 and 103 and the two not shown in the horizontal plane are each supported by pins 109, 110, 111, and 112 extending through the walls of the outer horn. Similarly, the inner dielectric plates 107 and 108 and the horizontal two plates not shown are supported by pins 113 which extend into the inner spear 106.

The outer horn may be flared outward at the sides as indicated by the four flared sections 114, and the inner horn is preferably extended outward beyond this flare with the spear within the inner horn being decreased in its square section outwardly and finally tapered to a point. The horn may be capped at the end by a non-conductive plate 115 which extends over the flared section and terminates at the center of the cap at a bulbous tip 116 symmetrical about a center axis with a hollowed out inner side and a terminating flange 117 which snugly fits into the inner wall of the inner horn.

FIGURES 11 and 12 show how the inner guide is fed through the wall of the outer guide. FIGURE 12 shows how an island structure 118 is formed within the guide section 119. This island section is made of fitted sections 120 and 121 which themselves may be made of two or more joined or fitted pieces providing tapering ends lengthwise of the guide as shown at 122 and 123 and a heavier section between the ends providing within the section a hollow space 124 within the island which forms a guide of a somewhat hour glass shape. This guide is actually pinched in the center as it extends in an arc of about 90° from the input end 126 (FIGURE 11) to the direction of the guide itself where it again takes the usual form of a rectangular guide. The pinching has the effect of preserving the same TE₁₀ mode as the guide curves in an arc.

In the inner guide sections commencing at the line 127 the guide walls become twisted to established both the TE₁₀ and the TE₀₁ mode and in the outer section to the right of line 127 and twisted guide 128 goes through the same general types of changes the forms as shown for the guide in FIGURES 1 to 9.

It will be apparent from FIGURES 10, 11, and 12 that the feed for the outer horn will be through the end 119 of the guide while the feed for the inner horn will be through the guide 126 entering through a side wall of the guide 119. The island formed in the outer guide has for one of its chief purposes the prevention of reflection, and for this purpose the shape of the island is tapered in the direction of the guide.

Thus, the structure described above comprises two horns coaxially arranged, one within the other. Each is fed by its own wave guide. The input of the outer horn is a rectangular wave guide 119 (see FIGURES 11 and 12). The input of the inner horn is a wave guide of hour glass cross section at 126 in FIGURE 11. The outer horn is operated over a frequency range which is lower than the frequency range over which the inner horn is operated. The frequency range of the two horns may be overlapped. The two horns may be operated simultaneously. A common reflector may be used to reflect the power radiated or received by both horns.

Having now described my invention, I claim:

1. A horn for radiating circularly polarized waves including a rectangular wave guide section adapted to propagate a TE₁₀ mode, a guide section connected to said rectangular wave guide section for converting the rectangular section into a substantially square section for the propagation of TE₁₀ mode, and TE₀₁ mode including a metallic insert therein approximating in shape said guide section, and means connected to said guide section for retarding one mode with respect to the other.

2. A horn for producing circularly polarized waves comprising a length of wave guide of substantially square

cross section, a means for simultaneously exciting two mutually orthogonal modes of propagation in said square wave guide, a metallic insert substantially coaxially located in the square wave guide and a plurality of dielectric bodies placed in the electromagnetic field between said metallic insert and the walls of the square wave guide for delaying the phase of one mode with respect to the other.

3. A circularly polarized horn having an input end for receiving a TE₁₀ mode of propagation, a wave guide section connected to said input end providing a substantially 90° twist for changing said TE₁₀ mode into TE₁₀ and TE₀₁ modes of propagation, a subsequent wave guide section connected to said previously mentioned section having dielectric elements positioned substantially at right angles to each other in the guide section for delaying the phase of the modes with respect to each other.

4. A circularly polarized horn having an input end for receiving a TE₁₀ mode of propagation, a wave guide section connected to said input end providing a substantially 90° twist for changing said TE₁₀ mode into TE₁₀ and TE₀₁ modes of propagation, a metallic conductive member axially positioned in said guide section, and dielectric means supporting said conductive member from the walls of the guide for retarding the phase of one mode with respect to the other.

5. A circularly polarized horn having an input end for receiving a TE₁₀ mode of propagation, a wave guide section connected to said input end providing a substantially 90° twist for changing said TE₁₀ mode into TE₁₀ and TE₀₁ modes of propagation, a metallic conductive member axially positioned in said guide section and dielectric means extending in planes at right angles to each supporting said metallic conductive member from the inner walls of the guide for retarding the phase of one mode with respect to that of the other.

6. A circularly polarized horn having an input end for receiving a TE₁₀ mode of propagation, a wave guide section connected to said input end providing a substantially 90° twist for changing said TE₁₀ mode into TE₁₀ and TE₀₁ modes of propagation, a metallic conductive member axially positioned in said guide section and dielectric plate members narrower than said metallic conductive member mutually orthogonally positioned supporting said conductive member from the walls of the guide for retarding the phase of one mode with respect to that of the other.

7. A circularly polarized horn having an input end for receiving a TE₁₀ mode of propagation, a wave guide section connected to said input end providing a substantially 90° twist for changing said TE₁₀ mode into TE₁₀ and TE₀₁ modes of propagation, a metallic conductive member axially positioned in said guide section and dielectric plate members narrower than said metallic conductive member mutually orthogonally positioned and tapering away from said metallic conductive member at one end and towards said metallic conductive member at the other end for supporting said conductive member from the walls of the guide for retarding the phase of one mode with respect to that of the other and for preventing backward reflections.

8. A circularly polarized horn having an input end for receiving a TE₁₀ mode of propagation, a wave guide section connected to said input end providing a substantially 90° twist for changing said TE₁₀ mode into TE₁₀ and TE₀₁ modes of propagation, a metallic conductive member axially positioned in said guide section and providing walls substantially parallel with the 90° twist and dielectric means supporting said conductive member from the walls of the guide for retarding the phase of one mode with respect to that of the other.

9. A circularly polarized horn having an input end for receiving a TE₁₀ mode of propagation, a wave guide section connected to said input end providing a substantially 90° twist for changing said TE₁₀ mode into TE₁₀

and TE_{01} modes of propagation, a metallic conductive spear axially positioned in said guide formed at one end with a flat tongue shape, gradually developing along its length through a flat shaped hexagonal and at its other end into a square with sides parallel to the inner walls of the guide and dielectric means supporting said conductive member from the walls of the guide for retarding the phase of one mode with respect to that of the other.

10. A circularly polarized horn having an input end comprising a guide section having a rectangular shape at one end with a twist along the guide to a square section, a metallic conductive spear axially positioned in said guide, formed with a flat tongue at the rectangular end and merging at the other end into a square section with a twist along the spear corresponding in cross section shape to the twist in the guide, and dielectric means supporting said conductive member from the walls of the guide for retarding the phase of one mode of propagation in the horn with respect to its orthogonal mode.

11. A circularly polarized horn having an input end comprising a guide section having a rectangular shape at one end with a twist along the guide to a square section, a metallic conductive spear axially positioned in said guide formed with a flat tongue at the rectangular end and changing in shape along its length to conform substantially to the shape of the surrounding guides to a square section and dielectric means supporting said conductive member from the walls of the guide for retarding the phase of one mode of propagation in the horn with respect to its orthogonal mode.

12. A circularly polarized horn having a rectangular input guide end for receiving a TE_{10} mode of propagation, a wave guide section connected to said input end providing a substantially 90° twist for changing said TE_{10} mode into a square wave guide section for propagating both TE_{10} and TE_{01} modes, a metallic conductive spear axially positioned in said guide, formed with a flat tongue at the rectangular end and merging at the other end into a square section with a twist along the spear corresponding in cross section shape to the twist in the guide, and dielectric means supporting said conductive member from the walls of the guide for retarding the phase of one mode of propagation in the horn with respect to its orthogonal mode.

13. A circularly polarized horn having a rectangular input guide end for receiving a TE_{10} mode of propagation, a wave guide section connected to said input end

providing a substantially 90° twist for changing said TE_{10} mode into a square wave guide section for propagating both TE_{10} and TE_{01} modes, a metallic conductive spear axially positioned in said guide, formed with a flat tongue at the rectangular end and changing in shape along its length to conform substantially to the shape of the surrounding guide to a square section and dielectric means supporting said conductive member from the walls of the guide for retarding the phase of one mode of propagation in the horn with respect to its orthogonal mode.

14. A wave guide comprising means providing an inner conductor and an outer conductor for producing two modes of propagation in which in one mode the predominant lines of electric force are perpendicular to the predominant lines of electric force in the other mode including a rectangular wave guide section adapted to propagate a TE_{10} mode, a guide section connected to said rectangular wave guide section for converting the rectangular section into a substantially square section for the propagation of TE_{10} mode and TE_{01} mode including a metallic insert therein approximating in shape said guide section, and means connected to said guide section for retarding one mode with respect to the other.

15. A wave guide section adapted to propagate a TE_{10} mode, a guide section connected to said first guide for converting said section into a substantially square section for the propagation of TE_{10} and TE_{01} modes including a metallic insert therein and means included in said guide section for retarding one mode with respect to the other mode.

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