Feb. 10, 1953 J. F. ZALESKI 2,628,278

APPARATUS FOR ROTATING MICROWAVE ENERGY

Filed Sept. 20, 1951

Fig. 4

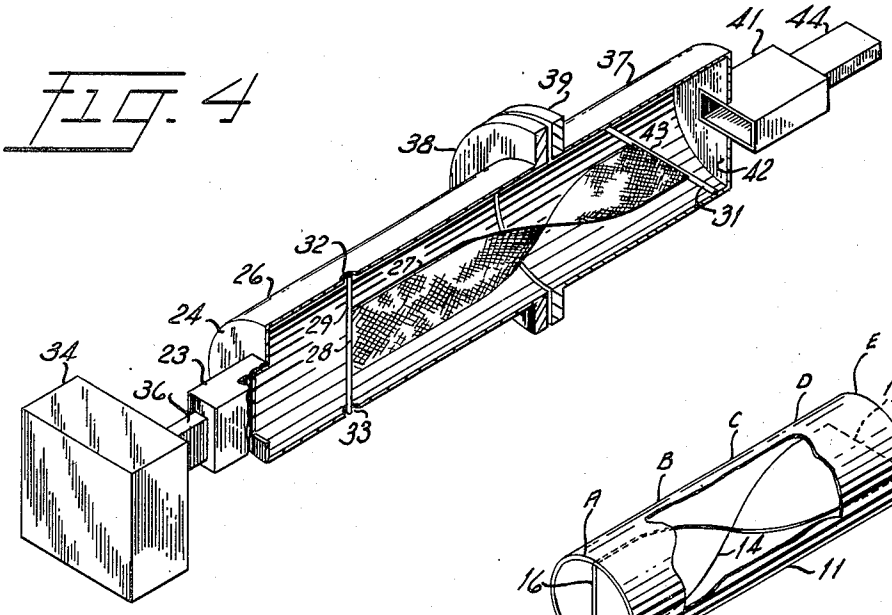


Fig. 1

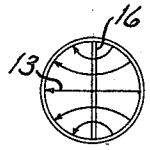


Fig. 2A



Fig. 2B

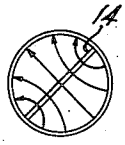


Fig. 2C

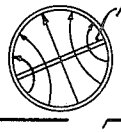


Fig. 2D

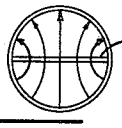


Fig. 2E

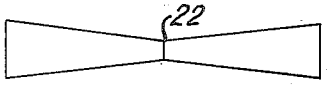


Fig. 3

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APPARATUS FOR ROTATING MICROWAVE ENERGY

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1 Claim. (Cl. 178—44)

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This invention pertains to apparatus for rotating the polarization of microwave energy in microwave transmitting guides and to microwave rotatable joints utilizing such apparatus.

It is frequently desirable, in systems involving the utilization of microwave energy, to be able to rotate the plane of polarization thereof in order that the various system components may be properly positioned as respects each other with a minimum of waste space. Likewise it is frequently desirable to provide an arrangement whereby relative rotational movement may be attained between components, as for example, in applying energy to or deriving energy from a movable antenna structure.

The instant invention provides an arrangement for accomplishing these desired results which at the same time is simple, compact, broad band and efficient.

In general the apparatus of the invention consists of a section of round microwave guide suitable for excitation therein of microwave energy in any non-symmetrical mode such as $TE_{1,1}$. The round guide section contains a centrally-placed septum extending longitudinally so as to include the axis of the guide, and bisecting the volume of the interior of the guide either partly or completely. At the end of the guide section at which the microwave energy is introduced the septum is positioned so as to be transverse to the direction of the electric field. The septum therefore has no effect whatever at this point upon the field. The septum is twisted or warped along its length, the twist being relatively gradual, continuous and in the same sense throughout the guide section. By reason of this twist, the septum effectively compels the plane of polarization of the microwave field to twist in concert therewith so that the microwave field leaves the guide section with its electric field normal to the plane of the septum at that point, and without suffering appreciable loss in the process.

The septum may be made of flexible material and combined with a round guide rotatable joint, or two of them, in the vicinity of one end anchorage of the septum to form an adjustable polarization changing device.

The material of the septum is preferably highly conductive, but a similar effect is obtained, although not as marked when the septum is composed of dielectric material.

Tests indicate that the introduction of such a septum into a round microwave guide neither appreciably increases the attenuation therein nor reduces the bandwidth characteristics thereof.

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The invention is applicable for use in connection with all type of microwave transmission lines, techniques being well known for designing transitions between the necessary round guide section required by the invention and any other type or types of transmission lines that may be required to be connected to the ends thereof.

An object of this invention is to provide a simple broad-band device for changing the direction of plane polarization of microwave energy carried by a wave guide.

Another object of this invention is to provide an improved broad-band rotatable joint for hollow microwave guide.

A further object of this invention is to provide a broad-band hollow round wave guide device for adjustably controlling the direction of polarization of microwave energy passing therethrough in any field mode which is not of circular symmetry.

A still further object of this invention is to provide a broad-band hollow round wave guide section containing a longitudinal septum whereby the polarization of microwave energy in any non-circular mode transmitted therethrough is controlled. A further understanding of this invention can be secured from the detailed description and accompanying drawings in which:

Figure 1 illustrates one embodiment of the invention.

Figures 2A, 2B, 2C, 2D and 2E diagrammatically illustrate the principles of operation of the invention.

Figure 3 is an illustration of one form of septum employed in the invention.

Figure 4 illustrates another embodiment of the invention together with associated equipment.

Referring now to Fig. 1, a round metal tube 11 serves as a round hollow guide for microwave transmission in say, the dominant $TE_{1,1}$ mode. Such microwave energy is applied at the end 12 with an orientation or plane polarization so that the average direction of lines of electric field, commonly termed the average direction of the E-vectors, is horizontal as illustrated in the figure. Fig. 2A is a field diagram showing the field distribution at the end 12, with the average field direction shown as vector 13. A diametral metallic septum 14 is centrally placed in the tube of Fig. 1 so that its longitudinal center line coincides with the axial line of the round guide 11. The leftmost element 16 of the septum is placed vertically at the left end of the tube, and the septum is twisted along its length so that its far end terminates in the final element 17 at the far

end 18 of the tube 11. At this point the final element of the septum is horizontal, having made a 90° clockwise rotation in the length of the section of round tube.

It is well known in the art that if a small-diameter rod be placed in such a guide so that the rod is perpendicular at all points to the electric field, there will be no interaction whatever between the field and the rod. No current will flow in the rod and no distortion of the field will be caused, nor loss of the energy carried by it. In Fig. 2A the end element 16 of the septum 14, Fig. 1, constitutes such a rod placed dimetrally from wall to wall of the guide cross section.

It has been shown by experiment that if a gradually-twisting septum be placed as described, with its initial element such as 16 at right angles to the applied electric field, the field polarization is rotated by the septum and the microwave energy leaves the guide section with little, if any, more loss of energy than would be occasioned in such a section without a septum. This is illustrated in Fig. 1. The electric field remains for all practical purposes exactly normal to the septum throughout its length, and leaves the tube at the end 13 normal to the end septum element 17, having thus been rotated 90° This operation is depicted in steps by the Figs. 2B, 2C, 2D and 2E, representing the septum orientation and field orientation at the successive corresponding sections B, C, D and E of Fig. 1.

The septum has no frequency-sensitive elements and its principle of operation is not that of cancellation of reflections from phase-sensitive elements. This both accounts for and is proven by test results indicating that such a device is extremely broad-band. It has, in fact, bandwidth comparable to that of a plain, straight piece of hollow guide containing no septum.

Obviously this method of rotating the field orientation can be employed to effect a total rotation of less than 90° or greater than 90° as the situation requires. In order to limit losses to a negligible amount, however, the rapidity of the twist is preferably limited to not more than 90° rotation for each length of septum approximately equal to $2\lambda_g$ in which λ_g is wavelength of microwave energy in the guide.

Experiment has shown that it is by no means necessary for the septum to extend all of the way across the guide, although in all cases it should be centrally placed in the guide throughout its length. The septum width in fact can be made relatively small without any appreciable loss of efficiency, the minimum width depending on the circular wave guide diameter. For example, it has been found satisfactory to reduce the width to a value as small as ⅓ the circular wave guide diameter. The septum is preferably made of a solid metal sheet, plated flexible material, or of a woven metal strap such as flattened flexible wire shielding braid of high surface conductivity. However, the septum may also be composed of conductive plastic with some sacrifice in loss of efficiency due to poor conductivity of such material compared to metal. The septum may also be composed of a good dielectric instead of a good conductor, likewise with some sacrifice of efficiency. In this latter case the effects produced depend upon the difference in dielectric constant between the septum and the gas filling the guide.

The thickness of the septum is preferably small, a thickness equal to 2½ per cent of the microwave length in free space having been experimentally found to cause no appreciable loss of energy due to end reflections.

The septum may be made of a thin metal sheet which varies in shape along its length in order to minimize transverse curvature when the septum is warped into a longitudinal twist. For example, it may be desirable to make the septum narrow at its middle while preserving its full width at the ends. Such a shape, developed as a plane surface, is illustrated in Fig. 3. The waist 22 of the septum may be as narrow as ⅓ of its maximum width. In such a case the transverse curvature which occurs has been found to be so small as to cause only immeasurably small loss.

The septum can be designed to be either adjustable or nonadjustable. If nonadjustable, it may be made of fairly thick and stiff sheet metal, and extending the whole distance across the guide. It can then be secured to the guide by soldering or brazing at its edge. The amount of field orientation change in the section of guide containing the septum is then of a selected and invariable amount. On the other hand, the device may be made adjustable so that the amount of field orientation change can be manually varied within wide limits during use. In order to accomplish this result the septum is made flexible and one end is secured to the guide, while the other end of the septum is secured to a collar or guide section which is rotatable in relation to the guide, so that manual rotation of the collar rotates one end of the septum relative to the other, thus changing the degree and/or direction of twist.

In making a connection between an end of the round section of guide and microwave guide of some other type, such as rectangular guide now widely used for microwave transmission, it is of course obvious that the appropriate orientation relationship must be preserved between the rectangular guide and the near end of the septum. This relationship requires the septum and element to be parallel to the broad faces of the rectangular guide, so that the rectangular guide electric field is normal to the septum end element. The required relation is clearly shown in Fig. 4, in which the rectangular guide section 23 is joined to the end wall 24 of the hollow round guide 26 containing a septum 27, the end element 28 of the septum being parallel to the broad faces of the rectangular guide section 23.

In the case of a septum which does not extend entirely across the diameter of the round guide, and particularly when the septum is made of flexible material, such as wire mesh screen, it is convenient to anchor the ends of the septum to metal bars and to fit the bars into holes in the walls of the round guide. When the septum is rotatably adjustable it is desirable to elongate these holes so that the anchor bars can move toward or away from each other as the distance between them is changed by the warping of the septum. In Fig. 4 the anchor bars are indicated at 29 and 31, the elongated shape of the retaining holes for bar 29 being visible at 32 and 33.

In Fig. 4 a microwave generator 34 generates microwave energy having a wavelength suitable for transmission through the round hollow wave guide 26. The output energy of the generator is transmitted through suitable rectangular hollow guide 36 to the round guide end plate 24, a suitable transformer 23 being interposed to match the impedance of the rectangular guide to that of

the round guide. In place of the transformer 23 any other suitable type of transition may be used such as a taper joint.

The round guide section 26 is continued in a second round guide section 37 which is rotatable relative to section 26, the flanges 38 and 39 schematically representing the rotating joint between the two sections. When the section 37 is rotated through an angle the section 37 carries the anchor rod 31 with it, warping the septum 27, which in turn compels the $TE_{1,1}$ field to rotate through a like angle. The output rectangular guide transformer 41 is fixed to the round guide section 37 and comprises the transition between the end plate 42 of the round guide section 37 and the rectangular guide 44. The transformer 41 and output guide 44 are rotated with the round guide section so that the proper orientation relation is preserved between the rectangular component and the terminal element 43 of the septum nearest to it.

The described adjustable arrangement of Fig. 4 is suitable for installation adjustment of the orientation of two rectangular guides and for feeding an antenna or other rotatable component. In some cases, where the output guide or other component is mechanically fixed, a requirement for adjustability of field orientation will necessitate two rotating joints, one on either side of the end of the septum. The anchor rod 31 of the septum will then be secured in a collar which is rotatably adjustable relative to the guide structures on both sides of it.

It is obvious that the described device can be connected by suitable transitions to any type of wave guide, and may also be connected between two different types of guide or between guides carrying different field modes. In such use the device is particularly advantageous because, since it contains no frequency-sensitive elements, it is as broad band as the circular guide employed would be alone.

What is claimed is:

A device for rotating the plane of polarization of microwave energy comprising, a first section of hollow metal circular wave guide, a second section of hollow metal circular wave guide, a rotatable joint connecting said first and second sections of hollow wave guide in axial alignment, a flexible conductive longitudinal septum contained within said first and second wave guides comprehending said axis and positioned symmetrically therewith, one end of said septum being diametrically fixed at the distal end of said first section and the other end of said septum being diametrically fixed at the distal end of said second section.

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