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2,961,618

SELECTIVE MODE TRANSDUCER

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This invention relates to electromagnetic wave energy transmission systems and, more particularly, to selective mode transducers for selectively coupling between one of two orthogonally polarized modes in a circular wave guide and a rectangular side arm guide.

Microwave communications systems are well known that depend upon the transmission of two electromagnetic wave signals at a common frequency in a wave guide of circular cross section by utilizing both of the two cross-polarized dominant modes that may be propagated without mutual interference in such a guide. A typical system that utilizes this principle to employ a single antenna and feed therefor for both transmitting and receiving is disclosed in U.S. Patent 2,682,610 granted June 29, 1954, to A. P. King. The most important component of any system of this type is the selective mode transducer by which the mode of one polarization is coupled to and from the circular guide to the exclusion of the mode of the other polarization. In said King patent a transducer is described in which a rectangular guide to receive the selected mode is coupled to the circular guide by a shunt-connected iris, the plane of the iris being parallel to the electric vector of this mode and perpendicular to the electric vector of the excluded mode. Such an iris has been discovered, however, to introduce a substantial and undesirable reactance to the excluded mode due to interception by the iris of the longitudinal wall currents of this mode and the accompanying distortion to its electric field. While this reactance may be satisfactorily tuned out by resonant elements over a narrow band, the requirement of very broadband transmission renders these methods unsatisfactory.

It is, therefore, an object of the present invention to couple to and from the wave energy of one orthogonal mode in a circular wave guide to the exclusion of the other orthogonal mode without introducing band narrowing resonance characteristics and other disturbing effects to wave energy in the other orthogonal mode transmitted past the point of coupling in said guide.

In accordance with the present invention, an odd plurality of thin plates, or vanes, are disposed in the end of the rectangular guide adjacent to the iris to complete the conduction path for longitudinal currents of the excluded mode and to provide means upon which the electric field of this mode may terminate without disturbing the coupled mode. In particular, an edge of each vane extends longitudinally and is aligned with the inside surface of the circular guide; and at least the major part of each vane extends into the rectangular guide at least one-eighth wavelength. Specific features of the invention reside in the proportioning and tapering of these vanes and of the faces of the iris to eliminate resonance to interfering spurious modes. Another feature of the invention resides in special precautions taken within the circular guide to prevent generation of spurious modes therein. A properly designed transducer involving these novel features produces high isolation between the po-

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larizations and minimum reflections from the polarization transmitted past the point of coupling over a bandwidth of more than three octaves.

These and other objects and features of the invention, its nature and advantages, will appear more fully upon consideration of the specific illustrative embodiment shown and described with reference to the accompanying drawings in which:

Fig. 1 is a perspective view of an illustrative transducer in accordance with the invention; and

Figs. 2 and 3 are cross-sectional views of Fig. 1 taken as indicated.

Referring more particularly to Fig. 1, an illustrative embodiment of a transducer in accordance with the invention is shown comprising a conductively bounded wave guide 10 capable of supporting orthogonal polarizations of microwave energy. As illustrated, guide 10 is of circular cross section having a diameter such that orthogonal polarizations of the dominant TE_{11} mode at the lowest frequency to be transmitted can be supported; however, its cross section may be square. One of the two orthogonal polarizations of interest to the present disclosure is represented schematically by the vector E_1 indicating the electric field direction of one mode having a plane of polarization extending in the direction of this vector and in the direction of propagation. The other polarization of interest is represented by the vector E_2 representing the electric field direction of a mode polarized at right angles to E_1 .

Guide 10 is joined by wave guide 11 of rectangular transverse cross-sectional dimensions such that only the dominant TE_{10} mode may be supported. The junction with guide 10 is made in a shunt or magnetic plane junction for the E_2 polarization, i.e., the narrower transverse dimension of guide 11 is parallel to the polarization E_2 in guide 10 and the longitudinal axis of guide 11 is perpendicular to the axis of guide 10. Thus, guide 11 will couple only with the E_2 polarization in guide 10, the polarization therein that is parallel with the polarization of the dominant TE_{10} mode in guide 11.

In order to provide complete power transfer through this path, techniques familiar to the art are employed including a microwave iris 13 in conjunction with a diametrical septum 12 at the junction. Iris 13 may constitute an aperture in the wall of guide 10, which aperture has cross-sectional dimensions less than the cross-sectional dimensions of guide 11. Septum 12 comprises a vane of highly conductive material diametrically disposed in guide 10 in a plane parallel to the cross-sectional dimensions of iris 13 and, therefore, in the plane of polarization of E_2 . Since it divides guide 10 into two portions each beyond cutoff for E_2 , septum 12 serves as a complete reflecting piston for this wave energy.

Septum 12 should extend along the axis of guide 10 for a sufficient length, for example, in the order of one-half wavelength, to prevent leakage of E_2 power beyond it. Inasmuch as the plane of septum 12 is perpendicular to the polarization of E_1 , it has only a slight effect thereon.

Certain of the characteristics of a microwave iris such as 13 are well known in the art including the fact that it behaves as a tuned circuit having specific values of inductance and capacitance which depend at a particular frequency upon the physical dimensions of the iris aperture. Septum 12 on the other hand behaves as an inductive element placed in shunt with iris 13. The value of this inductance depends upon the position of the leading edge of septum 12 with respect to iris 13. Therefore, the dimensions of iris 13 are chosen and the position of the septum edge is adjusted to overlap iris 13 to such an extent that the shunt combination thereof is tuned sub-

stantially to resonance for the frequency of the E_2 polarization.

Thus far discussion has been restricted to transmission of E_2 between guides 10 and 11. Consider now the transmission of E_1 polarized at right angles to E_2 . In order to minimize the interference and cross-talk between signals carried by these two modes, E_1 must be carried past the junction of guide 11 without having components thereof diverted into guide 11 and without having components reflected by any impedance discontinuity at the junction. Since the only electrical field components which can be induced by E_1 in guide 11 would be polarized across the wide dimension thereof and since the narrow dimension is not sufficient to support this polarization, no components of E_1 will be diverted into guide 11. However, an appreciable inductive reactance would be introduced to this wave by iris 13 producing large and undesirable reflections.

In accordance with the invention, this undesirable reactance is substantially eliminated by disposing an odd plurality of thin plates, septa, or vanes 14 in the end of rectangular guide 11 adjacent to iris 13 in planes that are parallel to each other and to the wide dimension of guide 11. In particular, as seen more clearly in the cross-sectional views of Figs. 2 and 3 the lower edges 15 of vanes 14 are aligned with the inside surface of guide 10, thus completing the conduction path for longitudinal wall currents and providing a conductive surface upon which substantially all of the lines of electric field of the E_1 polarization may terminate. As may be seen from Fig. 2 on which the electric field distribution of E_1 is represented by lines 21, the lines on either side of the medial plane are curved. In the absence of vanes 14 they tend to bend up into guide 11 to terminate somewhere upon the inside surfaces thereof causing appreciable distortion of the pattern. With vanes 14 in place, however, the lines are intercepted by the vanes and terminated more nearly in the region of iris 13 without substantial distortion. Conduction currents associated with the polarization E_1 are completed through the vanes thereby substantially replacing the normal longitudinal wall currents of guide 10 that were interrupted by the presence of the iris. Since the plane of the vanes is always normal to the electric field of E_2 , they have little effect on this polarization.

It has been found that in order to terminate all E_1 field lines, vanes 14 should extend more than one-eight wavelength into guide 11. In doing so, however, vanes 14 make it possible for the vane-containing portion of guide 11 to support and be excited by the double rectangular guide mode represented by field lines 22 on Fig. 2. This mode cannot exist in the absence of vanes 14. Therefore, if the vanes end in a sharp discontinuity, this mode will be suddenly reflected and set up a resonance effect in guide 11. This effect is avoided in accordance with the invention by tapering the ends of the vanes opposite edge 15. As may be seen in the cross-sectional view of Fig. 3, a preferred shape for vanes 14 is triangular with edge 15 serving as the base of the triangle. By properly proportioning the altitude of this triangle, the inherent residual discontinuity of iris 13 can be substantially eliminated.

In the above-described operation it has been assumed that the frequency of the E_1 polarization was within the band for which guide 10 is dominant. However, it should be noted that the exclusion properties of the disclosed structure are so complete that the frequency of E_1 may be extended even to such high frequencies that guide 11 may support other modes. The reactive discontinuity introduced to this polarization is so small that there is little tendency to generate undesired spurious modes.

In one embodiment of the invention designed for broadband use from 3.7 to 11.7 K mc., three vanes having an altitude of 0.9 inch were found satisfactory. More than three vanes, but always an odd number thereof, may be employed if accompanied by a corresponding decrease

in their altitude. Other important dimensions of this embodiment are:

	Inches
Thickness of vanes 14	0.01
Diameter of guide 10	2.12
Cross section of guide 11	1.14 x 2.29
Dimension of iris 13	1.14 x 1.65

Having thus described the principal features of this embodiment in accordance with the invention, several refinements thereof may be pointed out. In certain bands, spurious resonances appear to be set up within the iris itself. If these effects occur, they may be minimized by chamfering the faces of iris 13 as shown by 17 on Fig. 3.

Should manufacturing tolerances make it difficult to maintain the exact dimensions of iris 13, reactance-introducing elements may be employed to eliminate the requirement of minute changes in the dimensions of the iris aperture. For example, reactive studs 18 comprising two pairs of twin screws extending through guide 10 parallel to the plane of iris 13 may be employed. These screws have an appreciable effect on the E_2 polarization without substantially affecting the E_1 polarization. Alternatively or additionally, pairs of screws 19 may be located following the iris in guide 11.

In certain very broadband embodiments, a narrow band transmission spike is observed at a frequency associated with the cutoff of the TM_{31} mode in guide 10. Any means that inhibits the excitation of this mode in guide 10 may be used to eliminate this spike, if and when it occurs. For example, a thin resistive strip 23 suitably supported, as upon a ridge 24 of polyfoam or other low dielectric material, to extend longitudinally through a region of maximum longitudinal electric field intensity of the TM_{31} mode will suppress it. A suitable region is located asymmetrically in the cross section of guide 10 at about one-third the guide diameter in from the wall directly across from aperture 13. Thus, strip 23 introduces loss to the TM_{31} mode without substantially disturbing the TE_{11} mode in either the polarization E_1 or E_2 .

In all cases it is understood that the above-described arrangement is simply illustrative of one of the many possible specific embodiments which represent applications of the principles of the invention. Numerous and varied other arrangements can readily be devised in accordance with these principles by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A selective mode transducer for electromagnetic wave energy comprising a section of circular wave guide for supporting electromagnetic wave energy in first and second modes having their planes of electric polarization at right angles to each other, a rectangular wave guide forming a junction with said circular guide such that the dominant mode supported in said rectangular guide has an electric polarization that is parallel to the polarization of said first mode in said circular guide, and an odd plurality of conductive vanes disposed at said junction in planes that are parallel to the plane of polarization of said second mode in said circular guide and in such proximity to the electric field of said second mode that said vanes complete the wall current path for said mode across said junction and provide a means upon which the electric field of said mode may terminate, said vanes being perpendicular to the plane of polarization of said first mode in said circular guide whereby said first mode couples unimpeded by said vanes with the mode in said rectangular guide.

2. A transducer for electromagnetic wave energy comprising, first means for supporting electromagnetic wave energy in first and second modes having their planes of electric polarization at right angles to each other, second means for supporting electromagnetic wave energy in a third mode having an electric polarization parallel to the polarization of said first mode in said first means,

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said first and second means forming a junction in which said first and third modes are coupled, and conductive means disposed at said junction parallel to the plane polarization of said second mode and perpendicular to the plane of said first and third modes, said conductive means extending into the region in which the electric field of said second mode will terminate upon said conductive means and the induced currents in said first supporting means will cross said junction through said conductive means.

3. The transducer in accordance with claim 2 wherein said conductive means comprises a plurality of vanes each lying in a plane parallel to the plane of polarization of said second mode.

4. The transducer in accordance with claim 3 wherein there are an odd number of said vanes.

5. The transducer in accordance with claim 3 wherein each of said vanes is triangularly shaped.

6. The transducer in accordance with claim 2 wherein said first wave supporting means is a conductively bounded wave guide of circular cross section and wherein said second supporting means is a wave guide of rectangular cross section.

7. The transducer in accordance with claim 6 wherein said guides join to form a magnetic plane junction.

8. The transducer in accordance with claim 7 including a microwave iris in said junction.

9. The transducer in accordance with claim 8 in which the faces of said iris are chamfered.

10. The transducer in accordance with claim 6 including conductive means disposed within said circular guide in a plane parallel to plane of polarization of said first mode.

11. The transducer in accordance with claim 6 includ-

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ing a thin resistive member supported asymmetrically in the cross section of said circular guide and extending longitudinally therein.

12. A selective mode transducer for electromagnetic wave energy comprising a section of circular wave guide, a rectangular wave guide, said rectangular wave guide being coupled to said circular guide by a microwave iris, the wider dimension of said rectangular guide being in a plane parallel to the longitudinal axis of said circular wave guide and parallel to the plane of electric polarization of wave energy in a first mode and perpendicular to the plane of electric polarization of wave energy in a second mode propagating in said circular wave guide, an odd plurality of conductive septa having a major portion thereof disposed in said rectangular guide and an edge thereof extending into said iris in planes parallel to said wider dimension of said rectangular guide, and a diametrical septum of conductive material interposed in said circular guide adjacent to said iris, said septum being in a plane parallel to the plane of electric polarization of said second mode.

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