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SELECTIVE MODE TRANSDUCER

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FIG. 1

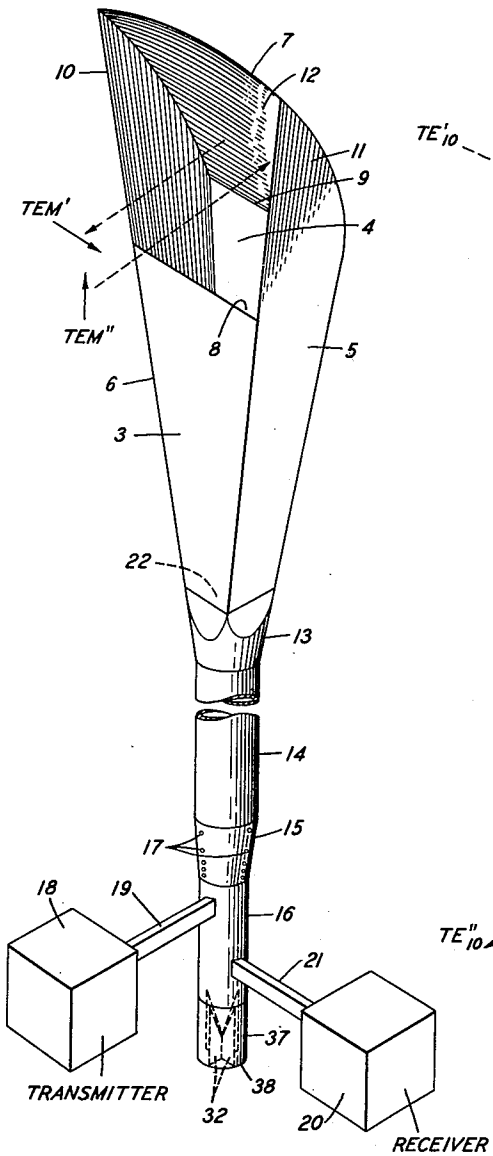
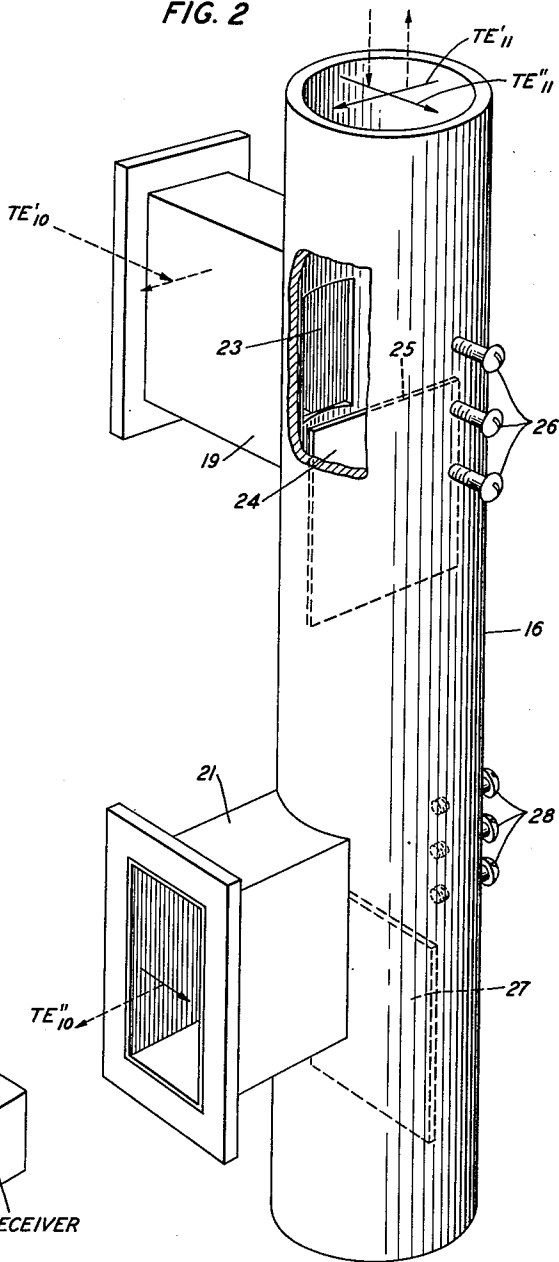


FIG. 2



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SELECTIVE MODE TRANSDUCER

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This invention relates to duplex antenna systems for high frequency electromagnetic wave energy and, more particularly, to selective mode transducers employed in said systems whereby a single antenna means may be simultaneously excited in a first mode of high frequency wave energy propagation for transmission and in a second mode of high frequency wave energy propagation for reception.

Duplex antenna systems in which a single antenna is employed for transmitting and receiving a high frequency signal are well known. In some of these systems means must be provided for disabling the receiving apparatus during the period of transmission, thus obtaining alternate, rather than simultaneous, reception and transmission. In other of these systems reception and transmission are accomplished simultaneously in different frequency bands which greatly burdens the broad band requirements of the antenna.

It is an object of the present invention to simultaneously receive and transmit high frequency electrical wave energy in a given frequency band with a single antenna by different modes of wave energy propagation.

In the specific illustrative embodiment of the invention to be hereinafter described in detail, a horn antenna system which is of the particular type to be disclosed and which is capable of separate excitation by electromagnetic energy in each of two orthogonal polarizations or modes, is connected by a circular wave-guide section designed to suppress undesired higher order modes to a selective mode transducer, in accordance with the invention, the latter being adapted to launch one of said orthogonal modes in said circular guide for transmitting and to select the other of said modes from said circular guide for receiving.

It is a particular object of the invention to minimize interference and cross-talk between signals transmitted in said orthogonal modes.

It is a specific object of the invention to couple to and from the wave energy in one orthogonal mode in a circular wave guide without introducing impedance irregularities or other disturbing effects to wave energy in the other orthogonal mode in said guide.

The last-mentioned object of the invention is realized in a specific embodiment to be disclosed by coupling to the one mode by a shunt connected iris, the plane of the iris being parallel to the electric vector of said one mode and perpendicular to the electric vector of the other mode. A diametrical septum lying in a plane

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parallel to the electric vector of the one mode and a plurality of reactive studs extending perpendicular to the septum are associated with the iris in the manner to be described. As will be shown the effect of the iris in combination with the septum, which alone would appear as an inductive reactance to the one mode, and the studs, which alone would appear as a capacitive reactance to the one mode, is to divert without impedance discontinuity the energy in the one mode through the iris. On the other hand, due to the novel arrangement of these three components, the other mode passes unaffected along the circular guide without reactive effect even though alone the iris would be expected to appear as an inductive reactance to this mode, and the septum and the studs would each be expected to present reactances to this mode.

These and other objects, the nature of the present invention, and its various features and advantages, will appear more fully upon consideration of the various specific illustrative embodiments, shown in the accompanying drawings and in the following detailed description of these embodiments.

In the drawings:

Fig. 1 shows in pictorial representation a duplex antenna system in accordance with the invention; and

Fig. 2 is a perspective cut-away view of the selective mode transducer, in accordance with the invention, as employed in the antenna system of Fig. 1.

In more detail, Fig. 1 illustrates the components comprising one station of a duplex antenna system in accordance with the invention. The antenna of this system may be of the type disclosed in United States Patent 2,416,675, granted March 4, 1947, to A. C. Beck and H. T. Friis. As shown on Fig. 1, this antenna comprises a vertical horn portion, having a front wall 3, back wall 4 and side walls 5 and 6 in the form of an inverted square pyramidal structure having a mouth aperture 8 at the top end and a virtual apex at the other. A parabolic deflector 7 is attached to the back edge 9 of the horn mouth aperture 8 and to the extended wall portions or shields 10 and 11 of walls 6 and 5, respectively. Deflector 7 is positioned so as to face both aperture 8 and the opening 12 which is formed in the plane of the front wall 3 by the front edges of shields 10 and 11, of deflector 7, and of wall 3. At the lower portion of the antenna and slightly above the position of the virtual apex, walls 3, 4, 5 and 6 converge in a square throat aperture 22. A

3 transition section 13 tapers gradually from the square cross-section of the throat aperture to the circular cross-section of a connecting wave guide 14 which has a diameter similar to the cross-sectional dimension of the square aperture 22.

This antenna may be excited by a horizontally polarized signal wave, as indicated on Fig. 1, by a TEM' wave and also by a vertically polarized signal wave represented on the drawing by a TEM'' wave. These two polarized waves appear in the horn portion of the antenna of Fig. 1 as cross-polarized waves, the TEM' induced wave having an electric vector of polarization extending between walls 5 and 6 and the TEM'' induced wave between walls 3 and 4. Either wave may be employed for receiving or transmitting or both may be employed for either receiving or transmitting, but for convenience in explanation, it will be assumed that the TEM' wave is employed for transmission and the TEM'' for reception. These cross-polarized waves are transformed and coupled into a corresponding pair of orthogonal wave polarizations in guide 14 by transition section 13, each wave of the orthogonal pair having a plane of polarization respectively the same as the plane of one wave in the horn portion. It is understood that the plane of polarization of an electromagnetic wave as defined herein according to conventional use, is that plane extending in the direction of the electric vector and in the direction of wave energy propagation. Each of the orthogonal waves in guide 14 are similarly transformed and coupled by means of a conical tapered section 15 to cross-polarized dominant TE₁₁ mode waves in guide 16. The diameter of tapered section 15 is reduced from that of guide 14, to which it is coupled at one end, to the dimension of guide 16 at the other, the latter dimension being chosen so that only the several polarizations of the dominant mode in guide 16 can be propagated in order to avoid undesirable spurious mode generation. In order to minimize loss in tapered section 15 due to the impedance mismatch produced thereby, tuning screws 17 are provided in, for example, four rows, which may be identical, spaced 90 degrees around the periphery of tapered section 15. Diametrically opposite rows of tuning screws 17 can be aligned with the electric field of each of the orthogonal modes.

Guide 16 is joined by wave guides 19 and 21, each of rectangular transverse cross-section, at spaced positions along the length of guide 16. The cross-sectional dimensions of guides 19 and 21 are chosen so that only the TE₁₀ dominant mode in each may be supported. The transverse cross-sectional planes of guides 19 and 21 are mutually perpendicular and are so oriented with respect to the horn portion of the antenna that the transverse plane of guide 19 is parallel to the polarization plane of energy induced by the TEM' wave in the horn portion and the plane of guide 21 is parallel to the polarization plane of energy induced by the TEM'' wave in the horn portion. Thus TE₁₀ wave energy from a transmitter 18 is coupled by guide 19 to a dominant mode in guide 16, which mode will be designated the TE₁₁ mode and which is associated with the transmitting TEM' wave. Likewise, the TE₁₁ mode in guide 16, which is orthogonal to the TE₁₁ mode therein and is associated with the receiving TEM'' wave, is coupled from guide 16 by guide 21 as TE₁₀ wave energy and applied to a receiver 20. Further details of this mode trans-

ducer, the nature of the coupling provided by it between the particular modes of wave energy just designated, and the structural details of the transducer will be considered in detail hereinafter with specific reference to Fig. 2.

The lower end of guide 16 is terminated in a dissipative element comprising four tapered resistive cards or vanes 32 mounted longitudinally at 90 degree intervals around the periphery of a circular wave-guide section 37. These resistive cards may be of the type disclosed in my co-pending application Serial No. 135,759, filed December 29, 1949, now United States Patent 2,656,513, granted October 20, 1953, or in the continuation in part thereof Serial No. 222,006, filed April 20, 1951. This dissipative combination is provided to absorb any energy reaching guide 37 and to prevent possible resonance effects due to reflection from the end wall 38 of guide 37. In order to avoid the trapping of water in guide 37 as a result of seepage from rain or condensation when the antenna system of Fig. 1 is employed in an unsheltered location, a fine mesh screen may be employed at the end of guide 37 in place of the solid wall 38.

Fig. 2 shows in detail an enlarged cut-away view of circular wave guide 16 and its associated rectangular guides 19 and 21. As has been briefly noted, these guides together constitute a selective mode transducer by which the TE₁₀ mode in guide 19 from transmitter 18 is launched as a TE₁₁ mode in guide 16, which in due course excites the transmitting TEM' wave. Similarly, the received TEM'' waves excite a TE₁₁ wave in guide 16 which is orthogonally polarized with respect to the TE₁₁ wave therein. This TE₁₁ wave must travel past the junction of guide 19 and its associated components to be described, unaffected thereby, and pass to the lower portion of guide 16 to be selected by guide 21 and applied as a TE₁₀ wave to receiver 20.

Consider for the moment only the transmitted TE' waves and the coupling provided for them between guides 19 and 16. Guide 19 is joined to circular guide 16 in a shunt or H-plane junction for the TE₁₁ mode, i. e., the narrow transverse dimension of guide 19 is parallel to the electric vector of polarization of the TE₁₁ wave in guide 16 and the longitudinal axis of guide 19 is perpendicular to said vector. Thus, guide 19 will couple only to a polarization in guide 16 which is parallel with the polarization of the dominant TE₁₀ mode in guide 19.

In order to provide complete power transfer through this path, a microwave iris 23 is employed in conjunction with a diametrical septum 24 at the junction. Iris 23 may consist of an aperture in the wall of guide 16, which aperture has cross-sectional dimensions less than the cross-sectional dimensions of guide 19. The factors determining these relative dimensions and the exact values recommended for a specific embodiment will be given hereinafter. Septum 24 comprises a vane of highly conductive material diametrically disposed in guide 16 in a plane parallel to the plane of the iris and, therefore, in the plane of polarization of the TE₁₁ waves. Since it divides guide 16 into two portions, each beyond cut-off for the TE₁₁ wave, septum 24 therefore serves as a completely reflecting piston for this wave energy. Septum 24 should extend along the axis of guide 16 for a sufficient length, for example in the order of one-half wavelength of the energy therein, to prevent leakage of the TE₁₁ power beyond it. Inasmuch as the plane

of septum 24 is perpendicular to the polarity of the TE'_{11} wave, it has only slight effect thereon as will be shown hereinafter.

Certain of the characteristics of a microwave iris, such as iris 23, are well known in the art, including the fact that an iris behaves as a tuned circuit having specific values of inductance and capacitance which depend at a particular frequency upon the physical dimension of the iris aperture. An iris may therefore be made resonant at a given frequency for a range of aperture sizes. In accordance with the present invention, however, the dimensions of iris 23 are not chosen to render it resonant at the frequency of the TE'_{11} wave, but rather these dimensions are chosen to tune iris 23 substantially on the capacitive side of resonance. Septum 24, on the other hand, behaves as an inductive element for the TE'_{11} wave, placed in shunt with iris 23. The value of inductance introduced by septum 24 depends upon the position of the leading edge 25 thereof with respect to iris 23. In accordance with the present invention, the position of edge 25 overlaps iris 23 to such an extent that the inductance of septum 24 tunes the shunt combination thereof with iris 23, slightly past resonance for the frequency of the TE'_{11} wave, the combination remaining very slightly inductive for the reasons to be shown hereinafter. If this minute residual inductive reactance is compensated in the manner to be shown, all of the TE'_{10} energy in guide 19 is efficiently converted to the TE'_{11} wave energy in guide 16 and reflection due to impedance discontinuity is very small. This combination is, of course, bilateral in transmission so that energy may be propagated in either direction through the junction.

Thus far the discussion of Fig. 2 has been restricted to the transmission of the TE' waves between guides 19 and 16. Consider now the transmission of the TE'_{11} mode, polarized at right angles to the TE'_{11} mode. In order to minimize interference and cross-talk between signals carried by these two modes, the TE'_{11} mode must be carried past the junction of guide 19 without having components thereof diverted into guide 19 and without having components reflected by any impedance discontinuity at the junction. Since the only electrical field components which can be induced by the TE'_{11} wave in guide 19 would be polarized across the wide dimension thereof and since the narrow dimension of guide 19 is not sufficient to support this polarization, no components of the TE'_{11} wave will be diverted into guide 19. However, an appreciable inductive reactance would be introduced to this wave by iris 23, which reactance would produce large and undesirable reflections. Since the plane of septum 24 lies along equipotential points in the field of the TE'_{11} wave, septum 24 would have substantially no effect thereon except for a possible small reflection from edge 25. This reflection may be minimized by making the thickness of septum 24 a minimum. In accordance with the invention, however, both the inductive reactance of iris 23 and the reactance of septum 24 to the TE'_{11} wave are tuned out by reactive studs 26. Reactive studs 26 may comprise three tuning screws extending perpendicular to septum 24 within guide 16 in the region of the septum and may be spaced along guide 16 substantially one-eighth wavelength apart. Since screws 26 lie in the plane of polarization of the TE'_{11} wave, they have an appreciable reactive effect thereon and may be tuned to introduce a capacitive reactance equal

to the net inductive reactance of iris 23 and septum 24. In other words, iris 23, septum 24 and studs 26 together constitute a circuit tuned to resonance at the frequency of the TE'_{11} wave so that no impedance discontinuity is presented to this wave during its passage down guide 16 to the junction of guide 21. Studs 26 have only small effect upon the TE'_{11} mode but will nevertheless introduce to it a slight capacitive reactance which, however, compensates the residual inductive reactance reserved above when iris 23 and septum 24 were tuned for the TE'_{11} wave.

Rectangular guide 21, which joins guide 16 in a shunt plane junction displaced 90 degrees from the junction of guide 19, is therefore in the proper position to receive and support energy from the TE'_{11} wave of guide 16. In accordance with the considerations set out above, a septum 27 is associated with the junction iris of guide 21, identical in relationship thereto as was septum 24 to iris 23. Since only one wave component is now present in guide 16, it should be apparent that septum 27 may be positioned to tune the iris of guide 21 precisely to resonance and that tuning studs are not absolutely required. However, commercial considerations are facilitated by making the junction of guide 21 identical in all respects, other than the displacement of 90 degrees around the circumference of guide 16, to that of guide 19, and therefore tuning studs 28 are provided which are adjusted in the manner of studs 26 above.

In summary, therefore, it is seen that the TE' junction and the TE' junction each constitute a tuned circuit comprising an iris, a septum and a set of tuning studs, separately tuned to resonance for each mode of a pair of cross-polarized or orthogonal wave modes, one of which is to be branched and the other of which is to be passed unaffected. Inasmuch as the septum produces a large effect upon the mode to be branched and a small effect upon the mode to be passed, and conversely, the studs produce a large effect upon the mode to be passed and a small effect upon the mode to be branched, both adjustments are readily made in practice.

In a specific embodiment designed for a mid-band frequency of 4040 megacycles, the following related dimensions have been found to produce satisfactory results. At other frequencies proportionally related dimensions should produce equally desirable results. Thus, if guide 16 has a 2.00 inch inside diameter and guides 19 and 21 each are constructed of 1.145 x 2.290 inch rectangular wave guide, the iris may be 1.502 x 0.875 inch in rectangular cross-section and the septum may be 2.8 inches in length and may extend 0.430 inch across the iris aperture.

Should manufacturing tolerances make it difficult to maintain the exact dimensions of the iris or should it be difficult to determine the exact initial dimensions thereof, it should be noted that reactance introducing elements may be located in the rectangular wave guides 19 and 21, adjustment of which will vary the effective inductance and capacitance of the iris presented to wave components in guide 16 without actually requiring minute changes in the dimensions of the iris aperture.

In all cases, it is understood that the above-described arrangement is simply illustrative of one of the many possible specific embodiments which can represent applications of the principles of the invention. Numerous and varied other arrangements can readily be devised in

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accordance with said principles by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In combination, an antenna adapted to support electromagnetic wave energy cross-polarized in a first plane and in a second plane, a section of circular wave guide connected to said antenna to receive said wave energy polarized in said two planes, a pair of branch shielded transmission lines, each of said branch lines being coupled to said circular guide by a microwave iris, the plane of each iris being parallel to a respective one of said polarization planes, one iris of said pair having dimensions such that a reactance of a first sign is introduced to wave energy in said first plane and thereby a reactance of a second sign to wave energy in said second plane, a diametrical septum of conductive material lying in said first plane and positioned in said circular guide to overlap said one iris, the amount of said overlap introducing a reactance of said second sign to wave energy in said first plane, and a plurality of reactive studs extending within said circular guide perpendicular to said first plane, said studs introducing a reactance of said first sign to wave energy in said second plane.

2. 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, said iris having dimensions such that the reactance thereof is of a first sign to wave energy polarized in a first plane parallel to the plane of said iris and thereby of a second sign to wave energy polarized perpendicular to said first plane, a diametrical septum of conductive material interposed in said circular guide and lying in said first plane, said septum positioned longitudinally along said circular guide with respect to said iris to introduce a reactance of said second sign to wave energy in said first plane, and a plurality of reactive studs extending within said circular guide adjacent said iris and perpendicular to said first plane, said studs introducing a reactance of said first sign to wave energy in said second plane.

3. A selective mode transducer for high frequency electrical transmission systems comprising a main shielded transmission line having a circular transverse cross-section, a pair of branch shielded transmission lines of rectangular transverse cross-section, each of said lines adapted to support the dominant modes of wave energy propagation therein, each of said branch lines being connected to said main line with the lon-

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gitudinal axis of each perpendicular to the longitudinal axis of said main line, said branch lines axes lying in mutually perpendicular longitudinal planes and lying in different transverse planes of said main line, a diametrical septum in said main line between said different planes and lying in a plane perpendicular to one of said branch lines axes, and a plurality of reactive studs extending perpendicular to said septum within said main line in the region of said septum.

4. In combination, an antenna adapted to support electromagnetic wave energy in cross-polarizations, a section of circular wave guide connected to said antenna to receive said wave energy in a pair of orthogonal polarizations in said guide, a pair of rectangular wave guides joining said circular guide at different longitudinal positions along said circular guide, the transverse cross-section of each of said rectangular guides being parallel to the polarization of one of said pair of polarizations, a vane of conductive material extending across the diameter of said circular guide at a position substantially between said rectangular guides and in a plane parallel to the transverse cross-section of one of said rectangular guides, and reactive means in said circular wave guide at the junction of said circular wave guide with the one of said rectangular wave guides which is closest to said antenna.

5. In combination, an antenna adapted to support electromagnetic wave energy in cross-polarized planes, a main section of shielded transmission line connected to said antenna to receive said wave energy, a pair of branch shielded transmission lines, each of said branch lines being coupled to said main line by a microwave iris, the plane of each iris being aligned parallel to one of said cross-polarized planes, a vane of conductive material associated with each iris and extending across said main line in a plane parallel to the plane of the iris with which it is associated, and reactive means in said circular wave guide at the junction of said main transmission line with one of said branch transmission lines.

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