

Jan. 26, 1960

S. D. ROBERTSON

2,922,961

FINLINE COUPLER

Filed Feb. 2, 1955

2 Sheets-Sheet 1

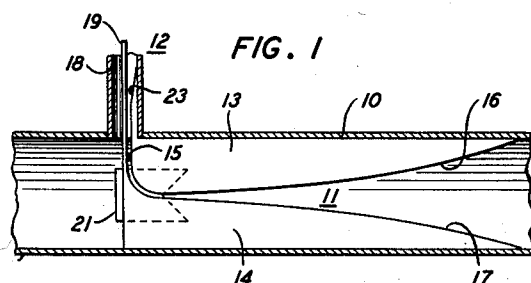
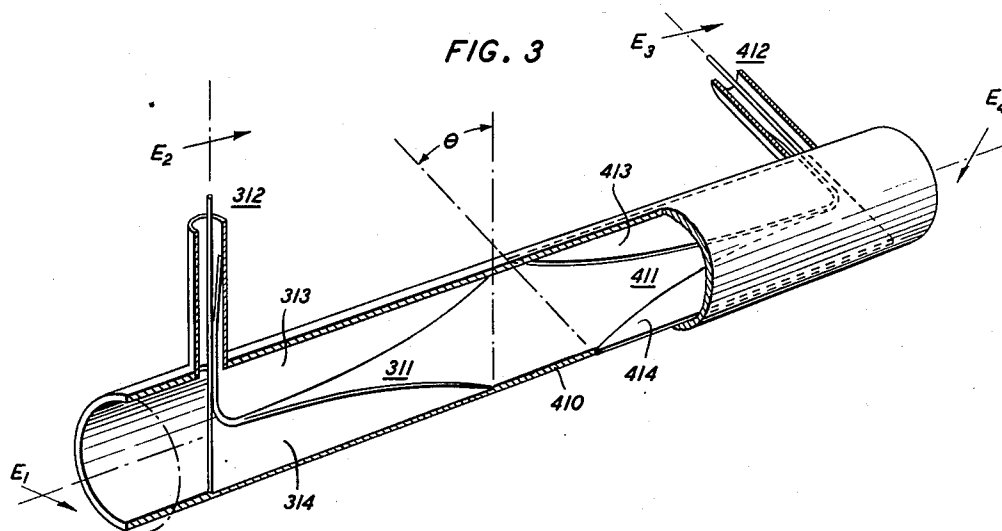


FIG. 1A

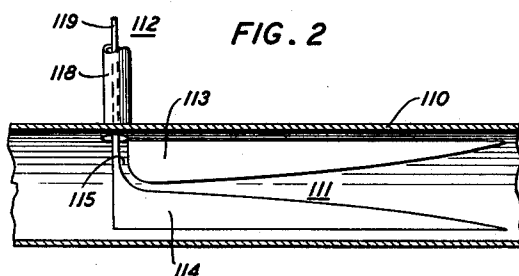
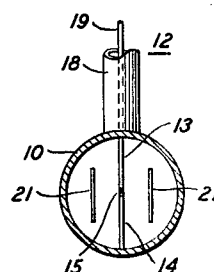
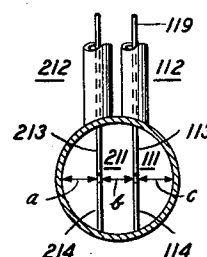


FIG. 2A



INVENTOR
S. D. ROBERTSON

BY *Arthur J. Tomiglieri*
ATTORNEY

Jan. 26, 1960

S. D. ROBERTSON

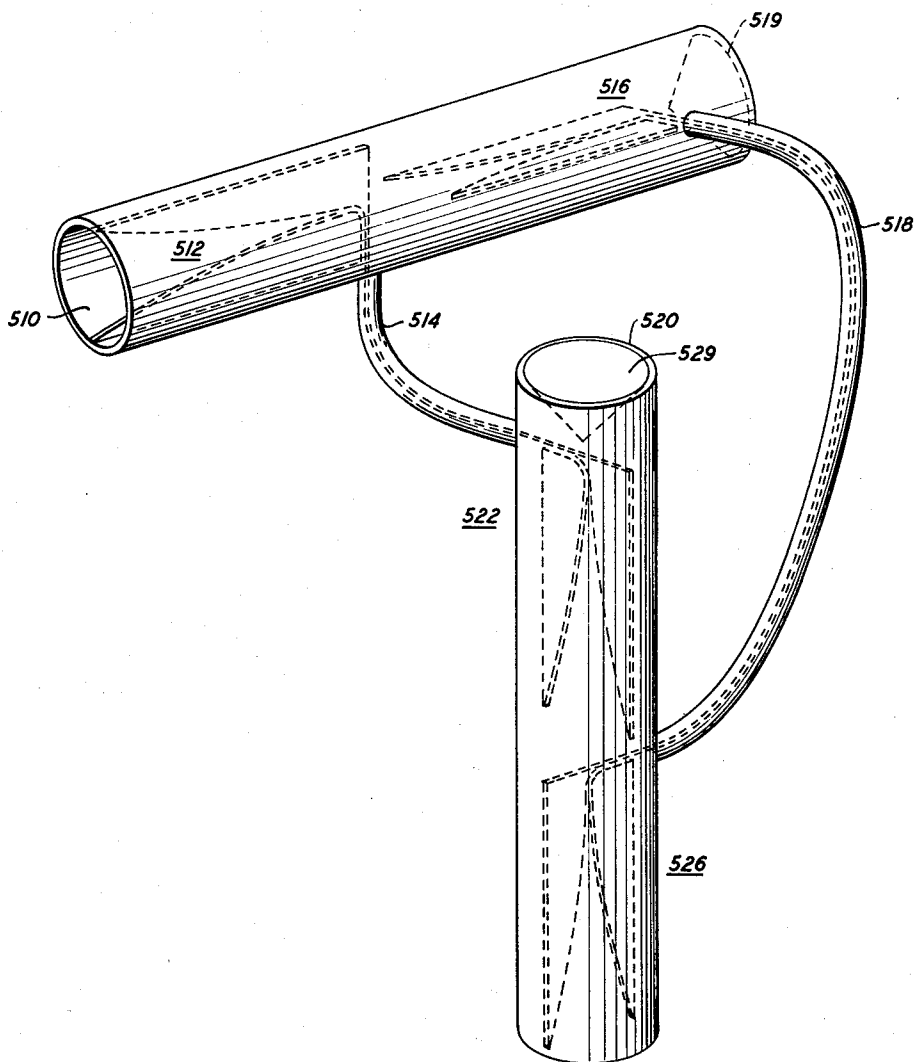
2,922,961

FINLINE COUPLER

Filed Feb. 2, 1955

2 Sheets-Sheet 2

FIG. 4



INVENTOR
S. D. ROBERTSON

BY
Arthur J. Toasiglieri
ATTORNEY

1

2,922,961

FINLINE COUPLER

Sloan D. Robertson, Fair Haven, N.J., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Application February 2, 1955, Serial No. 485,671

9 Claims. (Cl. 333—6)

The present invention relates to extremely wide band coupling elements for use in wave guiding channels, and more particularly to such coupling elements having polarization selective characteristics.

Significant progress in modern communication technology has been made possible principally by the development of communication equipment capable of operating at very high frequencies and over broad frequency bands. By the development of equipment capable of operating at progressively higher frequencies and progressively broader frequency bands, more progress is anticipated. To this end, amplifiers and oscillators of the traveling wave tube type have been developed which are capable of operating over extremely wide frequency bandwidths. For example, forms of these devices have been built which can operate readily over bandwidths of the order of two or more to one in frequency. However, further progress in the direction of increasing bandwidths is being inhibited by the lack of sufficiently wide band high frequency coupling elements capable of transmitting faithfully the signal derived from these devices to the various utilization circuits.

It is a principal object of the present invention, therefore, to improve the technique for coupling high frequency wave energy over extremely broad frequency bands.

Moreover, it is found that the amount of signal information which can be transmitted along a given wave path can be enhanced by transmitting simultaneously a plurality of separate signals of the same frequency range, each signal carrying a distinct message. In particular, it is found that two separate messages can be transmitted simultaneously without intermodulation along a single hollow wave guide by launching the two signal waves to be transmitted so that their electric field vectors are mutually perpendicularly polarized. Then by selectively coupling on the basis of the direction of polarization of the electric vector to only one of the two signal waves, the message contained in this signal will be derived. A coupling arrangement adapted for selecting a particular signal wave on the basis of the direction of polarization of its electric field vector shall be referred to as a polarization selective coupler. It is generally characteristic of prior art polarization selective couplers that they do not achieve sufficiently broad band operation.

In one aspect, a broad object of the invention is to increase the frequency range over which polarization selective coupling may be achieved.

There has heretofore been proposed for coupling wave energy of a single frequency into a hollow wave guide, a polarization selective coupler which comprises fin-like elements which are joined together at a predetermined point along their length. Wave energy is then coupled to these fins at a point which is a quarter wavelength at the operating frequency from the junction of the two fins. The narrow band characteristics of couplers of this type may be advantageously utilized to provide frequency selectivity for wave energy passing into the hollow wave

2

guide. However, such couplers cannot be employed where extremely broad band coupling is required. Moreover, such couplers are characterized by abrupt geometric discontinuities along the wave path provided through the coupler, which further precludes their use in broad band applications.

A feature of this first aspect of the invention is a coupling arrangement utilizing a pair of fins in a way to provide a smooth curved wave path which both eliminates any abrupt geometric discontinuities along the wave path and obviates the necessity for a quarter wavelength section along the finline wave path.

It is found in high frequency wave transmission that a serious obstacle to faithful wave propagation in hollow wave guides has been the inability to effect a bend in a wave guide, and particularly a circular wave guide, without exciting spurious modes. A wave propagating along a circular wave guide in the dominant electric mode tends to degenerate into higher order spurious modes when traversing a bend in the wave guide or, if the dimensions of the guide are such as to inhibit the excitation of higher order modes, a portion of the wave energy disadvantageously tends to be converted to a transverse state of polarization resulting in the formation of an elliptical or circular mode. A transfer of energy from the dominant mode to the various spurious modes is thereby effected. This results not only in a loss of energy from the dominant mode which contains the desired information to be transmitted, but substantial interference of the spurious modes with the dominant mode and hence a considerable loss in the fidelity of transmission of the signal intelligence.

In another aspect, a further object of the present invention is to effect a change in direction of propagation of the energy propagating along a hollow wave guide without the excitation of spurious modes.

Furthermore, it is important in many communication applications to divide the wave energy from two separate sources into two distinct channels, each channel receiving one half of the wave energy from each source, and no interchange of energy taking place between the sources. Such division is important in many well known devices, such as balanced converters and modulators. A wave guide coupler for dividing the wave energy in such a fashion is generally designated a hybrid coupler, or hybrid junction, and shall be so referred to herein. Continued experience with the various hybrid junctions proposed heretofore has proved these devices to be generally narrow band devices capable of operating only over a very limited frequency bandwidth.

A further object of the present invention therefore is to provide a power dividing junction capable of operating over extremely broad frequency bands.

In accordance with the broad principles of the present invention, wave energy propagating along a hollow wave guide is coupled to a second wave guiding path by use of a finline structure which forms a continuous wave path between the wave guide and the second wave guiding path. The finline structure includes two very thin metal fins spaced apart along their entire length for forming a continuous wave path along the interspace therebetween, the opposing surfaces of the two fins serving as the boundaries of the continuous wave path. The opposing surfaces are spaced to form two tapered sections of wave path and a narrow section of wave path intermediate the two tapered sections along the continuous wave path. The tapered section at one end of the finline extends into the hollow wave guide and matches the characteristic impedance of the narrow section to the characteristic impedance of the hollow wave guide; the tapered section at the other end of the finline

extends into the second wave guiding path and matches the characteristic impedance of the narrow section along the finline wave path to the characteristic impedance of the second wave guiding path. The narrow section of wave path preferably extends through the boundary of the hollow wave guide.

In an illustrative embodiment of the present invention for use as a coupling arrangement, a finline structure is utilized for coupling wave energy between a hollow conductive wave guide and a coaxial line. The finline structure comprises two thin coplanar conductive fin elements spaced apart along their entire length and having their opposing surfaces serve as boundaries to form a continuous wave path between the hollow wave guide and the coaxial line. The opposing surfaces are spaced to form first and second tapered sections of wave path and a narrow section of wave path intermediate the tapered sections along the continuous wave path. The first tapered section extends along a longitudinal plane within the hollow wave guide and is tapered gradually from the transverse dimension of the hollow wave guide to the transverse dimension of the narrow section of wave path, the second tapered section extends into the coaxial line and is tapered gradually from the radial dimension between the inner and outer conductors of the coaxial line to the transverse dimension of the narrow section of wave path. It is especially important to have a smooth continuous wave path between the hollow wave guide and the coaxial line connector if broad band operation is desired. Furthermore, it is essential for broad band operation that the two fins forming the finline structure be spaced apart along their entire length.

In a second illustrative embodiment of the present invention for negotiating a bend in the direction of wave propagation in a circular wave guide system, a plurality of finline structures are combined to effect such a bend. In this embodiment two finline structures, each comprising two coplanar fins closely spaced over a portion of their length and tapered at one end for impedance matching, are positioned in substantially mutually perpendicular planes within a first wave guide and spaced apart along the wave guide axis. The closely spaced region of each of the finline structures is coupled through a smooth wave path to separate coaxial transmission lines. Each of the coaxial lines, which is coupled at one end to a different one of the first two finline structures, is coupled at the other end to a different one of a second pair of finline structures which are positioned within a second circular wave guide. The second pair of finline structures is positioned in substantially mutually perpendicular planes within the second wave guide and spaced apart along the axis of this wave guide. It will be convenient for purposes of explanation to consider the finline structures as positioned in the horizontal and vertical planes of the first and second circular wave guides. In such a case, electromagnetic wave energy propagating along the first wave guide will be divided between the two finline structures associated therewith according to the polarity of the wave, that is, the horizontal component of such a wave will be coupled to the horizontally positioned finline structure and the vertical component will be coupled to the vertically positioned finline structure. The horizontal and vertical components of the wave are then transferred by way of the separate coaxial lines to the horizontally and vertically positioned finline structures in the second wave guide. The energy propagating along the coaxial lines is made to follow any convenient path for effecting the desired bend, and after effecting the desired bend the horizontal and vertical components of the wave are thereafter recombined in the second wave guide to form the original wave. It is important, however, in order to obtain the original wave undistorted, that the electrical length of the wave path used for executing the bend be the same for each of the two components of the wave.

A more complete understanding of the nature of the invention, together with a better appreciation of its features and advantages, will best be obtained by a study of the following detailed description when read in connection with the accompanying drawings, in which:

Fig. 1 shows a longitudinal section of a wave guide to coaxial line finline coupler in accordance with the present invention;

Fig. 1A is an end view taken from the right end of the finline coupler of Fig. 1;

Fig. 2 shows a longitudinal section of a second embodiment of the present invention forming a wave guide to coaxial line finline coupler;

Fig. 2A is an end view taken from the right end of the finline coupler of Fig. 2;

Fig. 3 is a cut-away perspective view of an embodiment of the finline structure used to form a power dividing junction in accordance with the present invention; and

Fig. 4 is a perspective view of an embodiment of the finline structure used to form a flexible connection between a pair of hollow wave guides, in accordance with another aspect of the present invention.

Referring now more particularly to the drawings, Figs. 1 and 1A illustrate an extremely broad band finline coupler for coupling electromagnetic wave energy between the circular hollow wave guide 10 and the coaxial line 12. This coupler comprises two thin coplanar conductive fins 13 and 14 which are spaced apart along their entire length. This arrangement of these two fins shall be referred to herein as a "finline" or "finline structure" and the wave path provided therealong shall be referred to as a "finline wave path." The two fins are closely spaced along a portion of their length to form along the interspace therebetween a narrow wave path 15 in this region. Each of the fins is tapered away from the closely spaced region 15 to form an impedance matching section between this closely spaced region and the hollow wave guide. The tapers 16 and 17 are preferably several wavelengths long at the lowest operating frequency, their optimum contour may be computed for any given set of operating conditions according to well known design formula. Advantageously, the fins taper to merge smoothly with the walls of the wave guide. Moreover, the smooth tapered sections may be replaced by a succession of steps which form successive quarter wavelength matching sections, approaching the characteristics of the tapered section as the number of steps along the finline is increased.

Fins 13 and 14 project through an aperture in the wall of the wave guide 10 to connect with conductors 18 and 19, respectively, of coaxial line 12. The closely spaced section 15 of finline 11 extends outside of the confines of wave guide 10 and is terminated by a tapered section 23 wherein fin 13 is smoothly tapered outwardly toward the inner surface of conductor 18. By extending the closely spaced region outside of the hollow wave guide the energy propagating along the finline path is maintained confined in the extremely narrow path and is substantially unaffected by the discontinuity presented by the transition at the aperture in the wave guide. To this end the wave energy may be more closely confined to the closely spaced section 15 by the insertion of dielectric material between the fins along this section. Moreover, by positioning the transition from the finline to the coaxial transmission line outside of the confines of the hollow wave guide, the geometric discontinuity occasioned by this transition will tend not to excite spurious modes along the wave guide.

Mode killers such as thin plates 21 of lossy material may advantageously be provided on either side of the finline structure for further inhibiting the excitation of any spurious modes along the curved portion of the finline wave path. It will be apparent to one skilled in the art, that there may be substituted other forms of mode killers such as the tapering of the hollow wave guide in

5

the region of the finline to obtain a narrow guide dimension transverse to the plane of the finline adjacent the curved region of the finline wave path. In such a case the tapered guide may be simulated by the insertion of wedge-shaped conductive elements to taper effectively the inner surface of the hollow wave guide.

In operation an electromagnetic wave propagating along wave guide 10 whose electric field vector is parallel to the plane of finline 11 will pass along the finline wave path being smoothly coupled to coaxial line 12, whereas a wave whose electric field vector is perpendicular to finline 11 will continue along wave guide 10 substantially unaffected by the finline. The long tapered sections 16 and 17 of the finline effect a gradual change in the field configuration of the wave polarized in the plane of the fins from the mode of propagation characteristic of the circular wave guide, which ordinarily will be the dominant mode for a circular guide, to the mode of propagation characteristic of the narrow wave path 15, which is similar to the mode of propagation along a parallel two-conductor line. The field configuration along wave path 15 is then gradually changed to the mode for propagation characteristic of a coaxial line by tapered section 23.

In a circular wave guide of two inches diameter, coupling over a frequency band from 3,750 to 12,300 megacycles has been obtained using fins having a thickness of approximately one-sixteenth of an inch and spaced approximately one-sixty-fourth of an inch along their closely spaced section. This fin thickness corresponds to less than two percent of the wavelength of the lowest frequency wave which can propagate through the guide; i.e., the cut-off wavelength of the guide.

Although the finline structure of Fig. 1 has been shown for purposes of illustration in coupling relation with a circular wave guide, it may also be advantageously utilized in coupling relation with a rectangular wave guide in accordance with similar principles. Additionally, in accordance with the invention a finline structure may be utilized for coupling between a hollow wave guide and wave guiding means other than a coaxial transmission line, such as a two-conductor balanced line, a single wire helix, a bifilar helix, or a second hollow wave guide. A wave guide to wave guide finline coupler is disclosed specifically in a copending patent application Serial No. 485,672 by H. T. Friis and S. D. Robertson.

The term "finline coupler" as used herein shall designate any coupling arrangement which includes a finline or finline structure. Thus, each of the figures shall be referred to as a finline coupler, the coupler of Fig. 1 utilizing only one finline, whereas the couplers shown in Figs. 2 and 3 utilize two finlines and the circular bend coupler of Fig. 4 utilizes four finlines.

A second embodiment of the present invention is the finline coupler shown in Figs. 2 and 2A. In this embodiment two finline structures are positioned to be coextensive along a hollow wave guide. A first finline 111 is positioned to extend along a longitudinal plane parallel to the axis of wave guide 110 but displaced to one side of the wave guide axis. This finline comprises two fins 113 and 114 closely spaced along a portion of their length and tapered in a direction away from the closely spaced section 115 for matching the characteristic impedance of the closely spaced section to the characteristic impedance of the hollow wave guide. Fins 113 and 114 are connected to conductors 118 and 119, respectively, of coaxial line 112 in the manner described above with reference to Fig. 1. A second finline structure 211 of the same type is positioned parallel to finline 111 and coextensive therewith along wave guide 110 but on the other side of the wave guide axis. The second finline is connected to a second coaxial line 212 as above.

By maintaining each of the finlines 111 and 211 sufficiently thin, polarization selectivity will be obtained as explained with reference to Fig. 1. Furthermore, by appropriately displacing finlines 111 and 211 from the wave

6

guide axis the excitation of spurious modes can be effectively inhibited. For example, by positioning the finlines at the nodal points for the TE_{12} mode (that is, appropriately adjusting dimensions a , b , and c of Fig. 2A) excitation of the TE_{12} mode will be severely impeded. As is known to workers in the art, these nodal points represent points of minimum coupling to the TE_{12} mode and yet are points of high coupling for the dominant TE_{11} mode of a circular guide. Moreover, not only is the excitation of the TE_{12} mode effectively impeded by positioning the two finlines at nodal points for this mode, but there are inhibited other higher order modes, such as the TE_{01} , TE_{21} , and TE_{31} modes, whose field configuration is such that their electric vector is oppositely directed at the positions of the two finlines. These oppositely directed vectors, being equal in magnitude, act to cancel one another as the outputs from the two finlines are combined.

It can be appreciated by one skilled in the art that by a proper choice of the number and location of a plurality of parallel finlines the coupling to any particular mode of propagation can be minimized. Likewise, by the appropriate choice of these parameters the coupling to any particular mode can be maximized. The output from each of the parallel finlines is then combined by any suitable means (not shown) for transmission to a utilization circuit. It can be appreciated further that the tapered sections of the finlines 111 and 211 of Fig. 2 may be oppositely directed so that one of the finlines couples to wave energy passing in one direction along the wave guide and the other finline couples to wave energy passing in the opposite direction along the wave guide. Such a system is useful in measuring techniques where a portion of the energy passing along a main wave guide to a given load is coupled via one of the finlines to monitoring equipment, the remaining portion of the wave energy continuing on to the load. Thereafter, a portion of the wave energy reflected from the load, and therefore passing in the opposite direction along the main wave guide, is coupled via the second finline to additional monitoring equipment for measuring the amount of energy reflected. In this manner, the standing wave ratio and other characteristics of a transmission path can readily be determined.

In accordance with another aspect of the present invention, two finlines are spaced apart along a hollow wave guide as shown in Fig. 3 to form a power dividing finline coupler. In this figure a first finline 311, comprising fins 313 and 314, is positioned to extend along a longitudinal axial plane within a hollow wave guide 410, as explained with reference to Fig. 1. A second finline 411, comprising fins 413 and 414, is spaced apart from finline 311 along the wave guide axis and is positioned to extend along a second longitudinal axial plane within wave guide 410, the plane of the second finline being rotated a predetermined angle θ with respect to the plane of the first finline. The angle θ may be made either adjustable or fixed in accordance with the end to be effected.

By fixing the angle of rotation between the two finlines at 45 degrees a hybrid junction will be obtained. In such an arrangement wave energy propagating from left to right along wave guide 410 and polarized as shown by vector E_1 will pass by finline 311 undisturbed and upon reaching finline 411 half of the wave energy will be coupled via the finline wave path to coaxial line 412, as shown by vector E_3 , and half of the wave energy will continue propagating along wave guide 410 undisturbed by finline 411, as shown by vector E_4 . The wave represented by vector E_1 , being polarized at an angle of 45 degrees from finline 411, may be thought of as comprising two electric field vector components, each having a magnitude of .707 time the original vector, one being in the plane of finline 411 and one being perpendicular thereto. It can be seen that the component parallel to the finline will be coupled via the finline to a second

wave path whereas the perpendicular component, which is represented by vector E_4 will pass substantially unaffected through the region of the finline and continue along the wave guide. Thus, for a wave having an electric vector 45 degrees from the plane of the fins, the finline serves as a 3 db coupler, coupling half the wave energy to the coaxial line and allowing half the wave energy to continue propagating along the hollow wave guide.

In a similar manner wave energy propagating from right to left along wave guide 410 and represented by vector E_4 will be divided in two, half of the wave energy being coupled to coaxial line 312 as shown by vector E_2 and half of the wave energy continuing along the wave guide, polarized as shown by vector E_1 . Likewise wave energy introduced at the coaxial line terminals 312 as shown by E_2 will be divided in half and propagate as E_3 and E_4 , and wave energy introduced at coaxial line 412 as shown by vector E_3 will be divided in half and propagate as E_1 and E_2 . The circular wave guide 410 of Fig. 3 may be connected at each end to a section of rectangular wave guide, the wide dimension of the rectangular wave guide being perpendicular to the electric vectors E_1 and E_4 at the respective ends of wave guide 410. In such an arrangement a transition section may advantageously be interposed between the rectangular and the circular wave guide sections for smoothly changing from the rectangular mode propagation to the circular mode propagation along the power dividing coupler.

In another aspect of the present invention, as shown by Fig. 4, the finline structure of Fig. 1 may be embodied in a finline coupler for forming a flexible section which can be used for by-passing a bend in a hollow wave guide. As previously discussed, the problem of effecting a bend without experiencing a degeneration of the wave into spurious modes has been particularly severe in a circular wave guide. Hence the illustrative example of Fig. 4 has been shown for use in connection with circular hollow wave guide. Moreover, although the bend of Fig. 4 is shown to be approximately 90 degrees for convenience, it can be appreciated by one skilled in the art that this coupler will provide a bend of any angle. In the embodiment shown in Fig. 4 a finline 512, of the type shown in Fig. 1, is positioned to extend along a longitudinal axial plane within wave guide 510. A second finline 516 is spaced apart longitudinally from finline 512 along the wave guide axis and positioned to extend along a second longitudinal axial plane within the wave guide, the plane of finline 516 being substantially perpendicular to the plane of the finline 512. The two finlines 512 and 516 are coupled via two coaxial lines 514 and 518, respectively, to a second pair of mutually perpendicular finlines 522 and 526, respectively. The two finlines of the second pair are positioned to extend along wave guide 520 in two mutually perpendicular axial planes and are spaced apart longitudinally along the wave guide axis. For applications where space is a premium, it is feasible to telescope the two finlines in each of the wave guides to the point where they overlap a substantial amount. Wave guides 510 and 520 are advantageously terminated by the tapered impedances 519 and 529, respectively, for preventing reflection of any wave energy from these terminals. However, such terminations usually can be omitted.

In operation a wave propagating from left to right along wave guide 510 and polarized in the plane of finline 512 will be coupled to wave guide 520 via finline 512, coaxial line 514, and finline 522. Likewise a wave propagating in the plane of finline 516 will be coupled to wave guide 520 via finline 516, coaxial line 518, and finline 526. Thus two distinct waves having mutually perpendicularly polarized electric vectors can be effectively coupled simultaneously between two angularly disposed sections of circular hollow wave guide. In such a case, however, it is important that the electric vector of

each of the two waves be closely aligned with the corresponding one of the mutually perpendicularly positioned finlines.

The finline coupler of Fig. 4 may also be used to couple a single wave whose electric field vector lies neither in the plane of finline 512 nor finline 516 but is somewhere between these two planes. In such a case the component of the wave which lies in the plane of finline 512 is coupled to wave guide 520, via finline 512, coaxial line 514, and finline 522. Likewise the component of the wave which lies in the plane perpendicular to finline 512, and therefore in the plane of finline 516, will be coupled to wave guide 520 via finline 516, coaxial line 518, and finline 526. The two components are then recombined in wave guide 520 to form the original signal wave. The separation of the components of the wave takes place in wave guide 510 at the beginning of finline 512, where one of the components separates to follow the path of finline 512, and the recombination of the components takes place in wave guide 520 at the termination of finline 526. It will be observed from Fig. 4 that each of the wave paths for each of the components of the wave, after the separation and before the recombination, includes a section of hollow wave guide, two finlines, and a section of coaxial line. By making the electrical length of these two wave paths equal, the signal wave will be faithfully transmitted to the second wave guide. Advantageously, this condition can be met, independent of frequency, if corresponding elements of the two wave paths be equal, that is, if the lengths of each of the finlines be made equal, the lengths of the section of coaxial line be made equal, and the lengths of the sections of hollow wave guide in the wave paths be made equal.

It can be appreciated that a number of separate signal waves of different frequencies and polarized at various angles propagating simultaneously along wave guide 510 may be transmitted therefrom to wave guide 520 by the finline coupler of Fig. 4, one component of each wave being coupled through finline 512 and the perpendicularly disposed component being coupled through finline 516.

It can be appreciated further that it is not necessary in the arrangement described in Fig. 4 that the planes of finlines 512 and 516 be parallel, respectively, to the planes of finlines 522 and 526. However, to the extent that they are not parallel, there is introduced a rotation in the plane of polarization of the signal wave. In particular, if the planes of finlines 522 and 526 are at an angle of 90 degrees with the planes of finlines 512 and 516, respectively, a rotation of 90 degrees in the plane of polarization of the signal wave will be achieved.

It is understood that the above described specific embodiments are merely illustrative of the general principles of the invention. Various other arrangements may be devised by one skilled in the art without departing from the spirit and scope of the invention. In particular mode killers, such as the resistive plates 21 of Fig. 1 may advantageously be utilized in the embodiments of both Figs. 3 and 4. In these embodiments the resistive plates will be positioned as shown in Fig. 1. Moreover, the embodiment of the finline coupler shown in Fig. 2 may advantageously be incorporated in the embodiments of Figs. 3 and 4. For example, the finline 311 of Fig. 3 may advantageously be replaced by a number of parallel coextensive finlines as shown by Fig. 2. Likewise, if desired, finline 411 of Fig. 3 may be replaced by a number of parallel coextensive finlines for minimizing coupling to spurious modes, the parallel planes of the finline replacing finline 411 being rotated a predetermined angle with respect to the parallel planes of the finlines replacing finline 311. Similarly, a number of parallel coextensive finlines, as taught by Fig. 2, may advantageously replace one or more of the finlines of Fig. 4. Furthermore, dielectric material may advantageously be positioned along the narrow section of finline wave path in each of the embodiments disclosed for more effectively confining the

electric field propagating along the finline, as discussed with reference to Fig. 1.

What is claimed is:

1. In a coupling arrangement for effecting a broad band wave energy transfer, conductive bounding means defining a hollow wave guide and forming a first waveguiding path, a coaxial transmission line defining a second waveguiding path to be coupled to said first waveguiding path, said coaxial line comprising an inner and an outer conductor with a predetermined separation therebetween, said first and second waveguiding paths each having a spatial orientation and a transmission mode, at least one of the characteristics of said first path differing from the corresponding characteristic of said second path, and coupling means for forming a physically smooth and continuous wave path from within said hollow wave guide to the interior of said second waveguiding path comprising a pair of thin coplanar conductive fin elements extending axially along a portion of the hollow wave guide, the thickness of the two fin elements being no more than several percent of the cut-off wavelength of the wave guide, the two elements being spaced along their entire length and the interspace therebetween forming said smooth and continuous wave path, the transverse dimension of said continuous wave path initially being equal to the transverse dimension of said hollow wave guide, then being tapered therefrom to a smaller dimension along the portion of said continuous wave path which extends outside said hollow wave guide, and finally being tapered from said smaller dimension to said separation between said inner and outer conductors of said second waveguiding path.

2. In combination, a hollow wave guide having a predetermined transverse dimension, inner and outer coaxially disposed conductive members forming a coaxial transmission line having a predetermined separation between said inner and outer conductive members, and means for coupling wave energy between said hollow wave guide and said coaxial line comprising two thin coplanar conductive elements spaced apart along their entire length, the thickness of the two fin elements being no more than several percent of a wavelength at the cut-off frequency of the wave guide, the spacing being dimensioned to form a physically smooth and continuous wave path having first and second tapered sections of wave path and a uniformly narrow section of wave path intermediate said tapered sections, the first tapered section of wave path extending in an axial plane within the hollow wave guide and tapered gradually from the transverse dimension of said hollow wave guide to the transverse dimension of the narrow section of wave path, and the second tapered section of wave path extending into the coaxial transmission line and being tapered gradually from the separation between the inner and outer conductors of the coaxial line to the transverse dimension of the narrow section of wave path.

3. In combination, a hollow conductive wave guide, a coaxial transmission line, and means forming a physically smooth and continuous wave path for coupling wave energy between said hollow wave guide and said coaxial transmission line comprising two thin coplanar fin elements spaced apart along their entire length, the thickness of the two fin elements being no more than several percent of a wavelength at the cut-off frequency of the wave guide, the spacing being dimensioned to form a physically smooth and continuous wave path having first and second tapered sections of wave path and a narrow section of wave path intermediate said tapered sections, the first tapered section wave path extending in an axial plane within the conductive wave guide for matching the characteristic impedance of the hollow wave guide to the characteristic impedance of the narrow section of wave path, and the second tapered section of wave path extending in an axial plane of the coaxial transmission line for matching the characteristic impedance of the

coaxial transmission line to the characteristic impedance of the narrow section of wave path.

4. In combination, a hollow conductive wave guide having a predetermined transverse dimension forming a main waveguiding path, two coaxial transmission lines to be coupled with said hollow wave guide, and means for coupling wave energy between said hollow wave guide and said coaxial lines comprising two finlines positioned in parallel longitudinal planes along a portion of the length of the hollow wave guide, the two finlines being spaced apart approximately one-third the guide transverse dimension, each of the finlines comprising two thin coplanar conductive elements spaced apart along their entire length and having their opposing surfaces form a physically smooth and continuous wave path of the interspace therebetween, the thickness of the two fin elements being no more than several percent of a wavelength at the cut-off frequency of the wave guide, said opposing surfaces spaced to form first and second tapered sections of wave path and a narrow section of wave path intermediate said tapered sections, the first tapered section being positioned along the hollow wave guide for matching the characteristic impedance of the hollow wave guide to the characteristic impedance of the narrow section of wave path, and the second tapered section extending to form a continuation of one of said coaxial transmission lines for matching the characteristic impedance of the coaxial transmission line to the characteristic impedance of the narrow section of wave path.

5. In combination, a hollow conductive wave guide having a predetermined transverse dimension, means forming a plurality of auxiliary waveguiding paths, each of said auxiliary wave guiding paths having a transverse dimension across which an electric field of electromagnetic wave energy can be supported, and means for coupling wave energy between said hollow conductive wave guide and said plurality of auxiliary paths comprising a like plurality of finlines positioned coextensively along parallel longitudinal planes of the hollow wave guide, each of the finlines extending to form a continuation of a separate one of the auxiliary waveguiding paths and comprising two thin coplanar conductive elements spaced apart along their entire length and having their opposing surfaces form a physically smooth and continuous wave path of the interspace therebetween, the thickness of the two fin elements being no more than several percent of a wavelength at the cut-off frequency of the waveguide, said continuous wave path having first and second tapered end sections and a narrow section intermediate said tapered sections, the first tapered section being positioned along the hollow wave guide and tapered gradually from the transverse dimension of the hollow wave guide to the transverse dimension of the narrow section, and the second tapered section being positioned along an auxiliary waveguiding path and tapered gradually from said transverse dimension of said auxiliary waveguiding path to the transverse dimension of the narrow section of wave path.

6. In combination, a hollow conductive wave guide having a predetermined transverse dimension, a plurality of coaxial transmission lines to be coupled with said hollow wave guide, and means for coupling wave energy between said hollow wave guide and said plurality of coaxial transmission lines comprising a like plurality of finlines extending coextensively in parallel planes along a portion of the length of said hollow wave guide, each of the finlines comprising two thin coplanar conductive elements spaced apart along their entire length for forming a physically smooth and continuous waveguiding path of the interspace between said elements, the thickness of the two fin elements being no more than several percent of a wavelength at the cut-off frequency of the wave guide, said continuous waveguiding path having first and second tapered sections and a narrow section intermediate said tapered section, the first tapered section is positioned along

the hollow wave guide and the second tapered section extends to form a continuation of one of the coaxial transmission lines.

7. Apparatus forming a hybrid coupler comprising a main hollow wave guide, first and second coaxial transmission lines to be coupled with said main hollow wave guide, and first and second finlines for coupling energy between said main wave guide and said first and second coaxial lines respectively, the two planar finlines being spaced apart along the wave guide axis and the plane of the first finline being rotated an angle of 45 degrees about the wave guide axis with respect to the plane of the second finline, each of the finlines comprising two thin coplanar conductive elements spaced apart along their entire length for forming a physically smooth and continuous wave path along the interspace between their opposing surfaces, the thickness of the two fin elements being no more than several percent of a wave length at the cut-off frequency of the wave guide and the opposing surfaces of the conductive elements being spaced apart to form first and second tapered sections of wave path and a narrow section of wave path intermediate said tapered sections along said physically smooth and continuous wave path, the first tapered section being positioned axially along a portion of the hollow wave guide and tapered gradually from the transverse dimension of the hollow wave guide to the transverse dimension of the narrow section, and the second tapered section extending to form a continuation of one of said coaxial lines and tapered gradually to the transverse dimension of the narrow section along the finline, the corresponding tapered sections of the two finlines located along the main wave guide being oriented in opposite senses.

8. In a combination for forming a hybrid coupler, a main hollow wave guide, means defining first and second auxiliary waveguiding paths in energy coupling relation with said main hollow wave guide, said auxiliary wave guiding paths each having a transverse dimension across which an electric field of electromagnetic wave energy can be supported, and first and second finlines for coupling energy between said main wave guide and said first and second waveguiding paths respectively, the two planar finlines being spaced apart along the wave guide axis and the plane of the first finline being rotated an angle of 45 degrees about the wave guide axis with respect to the plane of the second finline, each of said finline structures comprising two thin coplanar conductive elements spaced apart along their entire length, the thickness of the two fin elements being no more than several percent of a wavelength at the cut-off frequency of the wave guide, the spacing between the two thin conductive elements dimensioned to form a physically smooth and continuous wave path having first and second tapered end sections and a narrow section intermediate said tapered sections, the first tapered section being positioned axially along a

portion of the main hollow wave guide and tapered gradually from the transverse dimension of said main hollow wave guide to the transverse dimension of the narrow section of wave path, and the second tapered section extending to form a continuation of one of said auxiliary wave guiding paths and tapered gradually from said transverse dimension of said auxiliary path to the transverse dimension of the narrow section of wave path.

9. Apparatus forming a power dividing junction comprising a main hollow wave guide, means defining first and second auxiliary waveguiding paths in energy coupling relation with said main hollow wave guide, said auxiliary wave guiding paths each having a transverse dimension across which an electric field of electromagnetic wave energy can be supported, and first and second finlines for coupling wave energy between said main wave guide and said first and second waveguiding paths, respectively, each of said finline structures comprising two thin coplanar conductive elements spaced apart along their entire length, the thickness of the two fin elements being no more than several percent of a wavelength at the cut-off frequency of the wave guide, the two finlines extending within the main wave guide and being spaced apart along the wave guide axis and the plane of the first finline being rotated a predetermined angle about the wave guide axis with respect to the plane of the second finline, each of the finlines being characterized in that the opposing surfaces of its two conductive elements bound a physically smooth and continuous wave path having first and second tapered end sections and a narrow section intermediate said tapered sections, the first tapered section of wave path extending axially along a portion of the hollow wave guide and having its width tapered gradually from the transverse dimension of the hollow wave guide to the transverse dimension of the narrow section of wave path, and the second tapered section of wave path extending along a different one of said two auxiliary waveguiding paths and having its width taper gradually from said transverse dimension of said auxiliary path to the transverse dimension of the narrow section of wave path.

References Cited in the file of this patent

UNITED STATES PATENTS

2,546,840	Tyrrell	Mar. 27, 1951
2,633,493	Cohn	Mar. 31, 1953
2,660,667	Bowen	Nov. 24, 1953
2,691,731	Miller	Oct. 12, 1954
2,702,366	Ginzton	Feb. 15, 1955
2,724,090	Moore	Nov. 15, 1955

OTHER REFERENCES

Ragan: Microwave Transmission Circuits, vol. 9, M.I.T. Rad. Lab. Series, May 1948, pp. 358-361.