

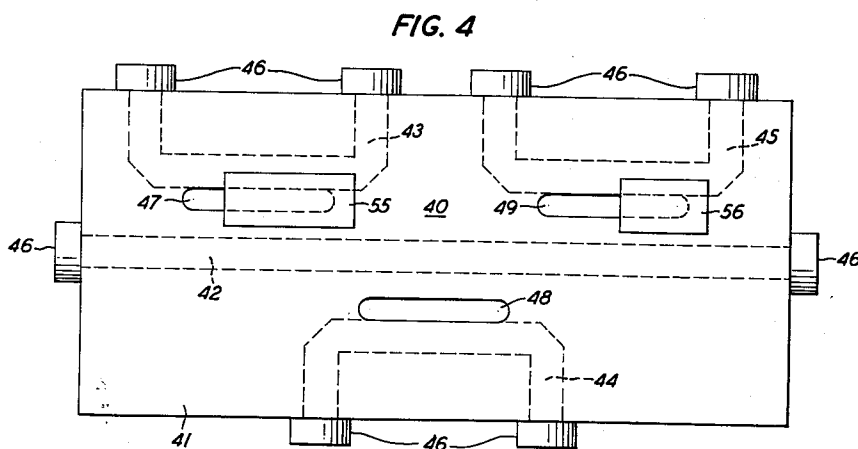
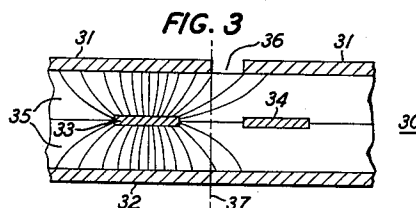
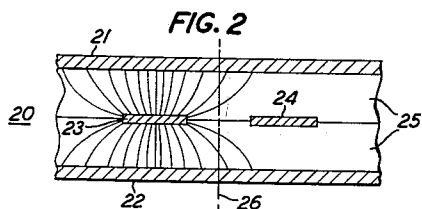
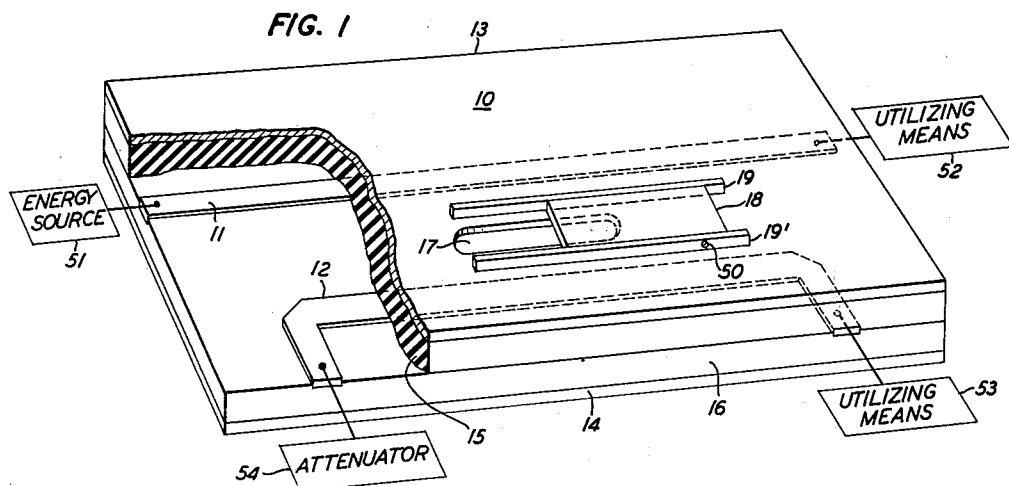
June 18, 1963

E. J. THERIOT

3,094,677

STRIP LINE WAVE GUIDE COUPLER

Filed Dec. 19, 1960



INVENTOR
E. J. THERIOT
BY
Ray M. Porter, Jr.
ATTORNEY

1

3,094,677

STRIP LINE WAVE GUIDE COUPLER

Eugene J. Theriot, Greensboro, N.C., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Filed Dec. 19, 1960, Ser. No. 76,643

5 Claims. (Cl. 333-10)

This invention relates to electromagnetic wave transmission and more particularly to directional couplers of the planar or strip line transmission line type.

There has developed in the art, as exemplified by printed circuit networks, a wide area in which thin flat conductive members separated by dielectric media have taken the place of the relatively bulky and cumbersome hollow pipe and circularly coaxial wave transmission lines. Broadly speaking, these planar transmission lines fall into two classes. The first class is one in which waves propagate along a narrow flat strip conductor dielectrically separated from a single wider conductive ground plane. These lines are commonly known as Microstrip, and are characterized by the transmission properties set out in an article by Maurice Arditi entitled "Characteristics and Applications of Microstrip for Microwave Wiring," beginning at page 31 of volume MTT-3 of "IRE Transactions on Microwave Theory and Techniques" (March 1955). Certain properties of Microstrip directional couplers are disclosed and claimed in United States Patent 2,951,218, issued August 30, 1960, to Mr. Arditi.

The second class of planar transmission lines comprises at least a triple conductor structure having one or more flat strip conductors centrally positioned between and dielectrically spaced away from a pair of outer conductive ground planes. These strip lines are electrically similar to the well-known coaxial lines. It is toward this second class of strip transmission lines that the present invention is directed, and to which the use hereinafter of the terms strip transmission line and strip line is intended to refer.

It is now well known that energy propagating along a first, or main, strip line may be directionally coupled onto a second, or auxiliary, strip line by bringing the center strip conductors of the auxiliary and the main lines into proximity. The amount of the coupling as well as its directivity will be determined by the physical parameters associated with the coupled lines.

It is oftentimes desirable that small adjustments in the amount of coupling between adjacent strip lines be made. The process for accomplishing this has been, however, crude and inexact. When, for example, the strip line comprised a pair of mirror image circuits printed on dielectric board the procedure involved assembling the unit, measuring the coupling, disassembling the unit, removing, or adding, a small segment from, or to, the center conductor, and reassembling and retesting the unit. Oftentimes a single unit required a plurality of adjusting operations since it was difficult to vary the width of the center strip the precise amount. Furthermore, the reassembled unit often had an alignment of parts slightly different from the original alignment, thus necessitating further adjustment.

It is, therefore, an object of the present invention to adjust the coupling of strip line directional couplers in a simple and precise manner.

It is a further object of the invention to adjust the coupling of strip line directional couplers by means externally accessible and readily available.

In accordance with the present invention it has been discovered that the amount of coupling between parallel path strip lines may be increased by removing a portion

2

of one or both ground planes in the vicinity of the adjacent strips. Reduced coupling may then be afforded by conductively covering an area of the removed ground plane. In this manner the amount of coupling in a strip line directional coupler may be easily controlled and trimmed to any desired value. The invention is particularly applicable in plural circuit couplers in which it is desired that a plurality of auxiliary coupling circuits couple identical amounts of energy from a main transmission circuit.

Thus, a further object of the invention is to adjust a plurality of strip line coupling circuits to couple equal amounts of wave energy from a main strip transmission line.

In accordance with a principal embodiment of the invention, first and second flat conductive strips are positioned in coupling proximity between a pair of conductive ground planes with a nonconductive aperture located in one of the ground planes in the area between the adjacent strips. A conductive member is mounted in superposed relationship to the aperture and is variably positionable over the aperture to afford control over the coupling strength between the lines.

The above and other objects of the invention, together with its various features, will be more readily understandable by reference to the accompanying drawing in which:

FIG. 1 is a partially beken away perspective view of a strip line directional coupler in accordance with the invention;

FIGS. 2 and 3 are transverse cross sectional views of strip line couplers given for purposes of explanation; and FIG. 4 is a top view of a multicircuit strip line coupler incorporating the principles of the present invention.

Referring more particularly to FIG. 1, there is shown a strip line directional coupler 10 in accordance with the present invention. The energy transmission paths comprise two parallel conductive strips 11, 12 spaced apart in the same plane and two conductive planes 13, 14 lying on opposite sides of said strips and in planes parallel to the common plane of said strips. The volume between strips 11, 12 and planes 13, 14 is occupied by slabs 15, 16 of low loss dielectric material such as Teflon-fiberglass, polystyrene or polyethylene, in accordance with well-known strip line techniques. The centrally positioned strip functions in a manner analogous to the center conductor of a circularly coaxial line. The two "ground planes" 13, 14 are analogous to the outer conductor of a coaxial line. In order that the coupler 10 be dominant mode and thus support only the lowest order strip line transmission mode (TEM), certain limitations must be met. First, the spacing between ground planes 13, 14 as well as the wider electrical dimension of strips 11, 12 must be less than one-half wavelength at the operating frequency and second, the central strips 11, 12 must be substantially centered between and substantially parallel to outer planes 13, 14. If either the ground plane spacing or the electrical width of the center strips exceeds one-half wavelength, conversion of power in the dominant strip line mode to higher order strip line modes may occur. A typical fabrication method for a strip transmission lines involves conductively printing center strips corresponding to strips 11, 12 on one side of a first dielectric board, fabricating a second dielectric board which is the mirror image of said first board, positioning these boards face to face and securing them in such position. The outer surfaces of the two boards are conductively coated and thus form ground planes corresponding to planes 13, 14.

Positioned within plane 13 in FIG. 1 is elongated aperture or slot 17, which extends completely through plane 13 and thus forms a nonconductive area in that ground plane.

Slot 17 is located in that portion of plane 13 which overlies the area between strips 11, 12. As illustrated in FIG. 1, the slot is positioned closer to strip 12 than to strip 11, and, with respect to an imaginary centerline between the strips, is completely on that side of the centerline toward strip 12. In general, the slot 17 should have a width equal to approximately one-half the spacing between the parallel strips to be coupled and should extend along these strips for a distance comparable to the coupling region. Such a slot has been found to increase the amount of energy coupled between adjacent strips by amounts of the order of one decibel. For a more complete understanding of this increase in coupling, reference may be had to FIGS. 2 and 3.

In FIG. 2 there is shown, in cross section, a strip type transmission line coupler 20 comprising outer parallel ground planes 21, 22 and center conductive strips 23, 24 separated by dielectric slabs 25. For purposes of discussion, it will be assumed that strip 23 is the main transmission path and is excited in the dominant TEM strip line wave mode. The electric field lines of such mode are illustrated in FIG. 2 as solid lines extending between strip 23 and planes 21, 22. As may readily be seen, the field lines in the vicinity of the edges of strip 23 fan outward in a fringing effect and thereby extend beyond the centerline 26 between the strips into the area which would be occupied by a dominant wave propagating on strip 24. By virtue of this extension of the field lines into the volume occupied by a wave on the adjacent strip, a wave of low intensity is coupled onto line 24. The amount of coupling is determined by the separation of the parallel strips, the length of the coupling section, and the width of the strips themselves.

FIG. 3 is a cross sectional view of a strip type transmission line 30 comprising outer parallel ground planes 31, 32 and parallel strips 33, 34 separated by dielectric slabs 35. Extending in ground plane 31 along and above the region of coupling between strips 33, 34 is slot 36. As in FIG. 2, it is assumed that strip 33 is the main transmission line and is excited in the dominant TEM wave mode. The approximate distribution of the electric field lines associated with this mode is designated by the solid lines extending between strip 33 and the outer conductive ground planes. Since the electric field lines terminate on conductive surfaces, slot 36 causes the normally symmetric wave pattern to be slightly distorted. In particular, it may be seen that several of the illustrated electric field lines extend well beyond centerline 37 into the volume occupied by a wave on strip 34. Since the electric field is thus constrained to extend further into the region of coupling with strip 34, the amount of coupling from strip 33 is increased.

Returning now to FIG. 1, it has been found that the increase in coupling between the lines occurs for various transverse positionings of slot 17 in the portion of ground plane 13 extending above the area between the strips 11, 12. However, the optimum positions are those in which the slot is disposed on the side of the centerline between the strips which is closer to strip 12, the "coupled-o" line. This optimum range obtains since the impedance discontinuity represented by slot 17 is minimized when the slot is positioned away from the main transmission strip, on which the higher power is propagating.

Mounted on plane 13 and positioned at least partially over slot 17 is conductive covering member 18. Member 18 may take the form of a rectangular plate, as illustrated in FIG. 1, or it may be of other conductive construction as will be described in connection with FIG. 4. In FIG. 1, plate 18 is slidably mounted between guiding lips 19, 19' and may be variably positioned to cover a selected amount of slot 17. When the desired position is attained, screw 50 in lip 19' may be tightened against plate 18 to hold it in place. Electrically, plate 18 serves to cancel the effect of slot 17 in the area of covering by presenting an unbroken conductive surface to propagating waves on strip

11. Thus, the propagating waves are not distorted to extend further into the region of strip 12. The amount of coupling between strips 11, 12 may, therefore, be easily controlled externally within a given range by variably positioning plate 18.

In the typical operation of the strip line coupler of FIG. 1, strip 11 is excited in the dominant TEM wave mode by energy source 51. This energy propagates along strip 11 and a substantial portion of this energy reaches utilizing means 52. When the vicinity of strip 12 is encountered, however, a portion of the energy on strip 11 is coupled onto strip 12 in the manner explained above in connection with FIGS. 2 and 3. The coupled energy proceeds primarily to utilizing means 53. However, since the directivity of the coupler is not perfect, a small amount of coupled energy may proceed in a direction opposite to the main propagation direction. Attenuator 54 is provided at the end of strip 12 opposite utilizing means 53 to dissipate this reverse-coupled energy. The amount of energy coupled from strip 11 to strip 12 may be controlled within a specified range by cover plate 18. As stated above, the presence of slot 17 increases the amount of energy coupled onto strip 12. Variations in the amount by which plate 18 covers, and therefore electrically neutralizes, slot 17 may be utilized to vary the amount of coupling provided.

FIG. 4 is a top view of a multiunit strip line directional coupler device 40 with respect to which the present invention has particularly utility. Illustrated is a sandwich type main strip line comprising a pair of outer ground planes 41 and a strip center conductor 42. Coupling circuits comprising strip center conductors 43, 44, and 45 are positioned in parallel path relationship with strip 42 over a portion of their lengths. The termini of each of strips 42-45 are fitted with circularly coaxial connectors 46 for interconnecting the coupler into an external circuit. Located in top ground plane 41 and positioned between each of strips 43-45 and strip 42 are slots or apertures 47, 48, and 49, respectively. If the dimensions of the various strips as well as their separation are properly selected, the power level on each of the coupled circuits may be in the range of one one-thousandth of the power in the main transmission circuit. That is, the couplers will be what is known in the art as 30 decibel couplers. Slots 47-49 may then increase the coupling of each coupler by 0.5 decibel. If a greater range of trimming is desired, a second slot may be positioned opposite each of the illustrated slots on the lower conductive ground plane. The ground plane slots may be utilized for the purpose of equalizing the coupling among the three couplers. One adjustment procedure involves measuring the coupling of each individual coupling circuit, thereby determining which circuit exhibits least coupling; and unrolling a strip of adhesive-backed metallic foil such as copper over the slots associated with the other coupling circuits until the coupling of the latter two circuits is decreased to equal the coupling of the first circuit. After the equalization procedure is completed, the foil is cut and permanently cemented in place. In FIG. 4 the circuit associated with strip 44 is shown to be that with least original coupling. Copper strips 55, 56 partially cover slots 47, 49, respectively, to attain an amount of coupling of wave energy from strip 42 to auxiliary strips 43 and 45 which is equal to that to strip 44.

In general, the above-described principles are applicable to any of the various symmetrical flat strip type transmission lines in which a central strip is sandwiched between and dielectrically spaced from a pair of external conductive ground planes. In all cases, it is to be understood that the above-described arrangements are simply illustrative of a small number of the many possible specific embodiments which can represent applications of the principles of the present 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. In combination, a first electromagnetic wave energy transmission path comprising a first flat conductive strip dielectrically spaced between a pair of parallel conductive ground planes,
 - a second electromagnetic wave energy transmission path comprising a second flat conductive strip dielectrically spaced between said pair of ground planes, said dielectric spacing between said pair of parallel planes and said first and said second strips being continuous,
 - said first and said second strips positioned in the same plane in transverse coupling proximity with a finite dielectric spacing between the adjacent edges of said strips,
 - and means for increasing the energy coupling between said first and said second strip,
 - said means comprising an elongated nonconductive aperture in one of said ground planes in the region overlaying said finite dielectric spacing between said strips.
2. The combination according to claim 1 in which said aperture is disposed to one side of the longitudinally extending centerline between said strips.
3. The combination according to claim 1 including means for adjusting the amount of coupling between said strips in the presence of said aperture,
 - said adjusting means comprising a conductive element positionable to cover variable areas of said nonconductive aperture.
4. An adjustable strip line directional coupler unit comprising a pair of dielectrically spaced conductive planes in overlaying parallel relationship,
 - a main electromagnetic wave energy transmission path comprising a first conductive member extending between and dielectrically spaced from said pair of conductive planes,
 - at least one auxiliary transmission path comprising a second conductive member extending between said pair of conductive planes and dielectrically spaced from said planes and from said first conductive member, the dielectric spacing between said con-

- ductive planes and said conductive members being continuous,
- said auxiliary path positioned in the field of waves supported by said main path,
- said conductive planes having at least one nonconductive aperture of variable area overlaying the dielectric region between said main and said auxiliary transmission paths, the amount of energy coupled from said main transmission path to said auxiliary transmission path being greatest when the variable area of said nonconductive aperture is maximized.
5. A strip line wave guide directional coupler for wave energy in a transverse magnetic mode comprising at least four conductive planar members extending coextensively parallel,
 - each of said members being dielectrically spaced from each other of said members along their coextensive portions by a continuous dielectric medium,
 - two of said members being wider in transverse dimension than the remainder of said members and positioned to extend on opposite sides of said remainder of members to sandwich said remainder of members therebetween,
 - each of said remainder of members being positioned in energy coupling relationship with at least one other of said remainder,
 - said two wider members having at least one nonconductive aperture therein superposed above the region of coupling between a pair of said remainder of members,
 - and means for decreasing the coupling between said pair of said remainder of members,
 - said means comprising a conductive member variably positionable over said aperture to render said aperture at least partially conductive.

References Cited in the file of this patent

UNITED STATES PATENTS

2,735,069	Riblet	Feb. 14, 1956
2,829,347	Tomiyasu	Apr. 1, 1958
2,901,709	Fitzmorris	Aug. 25, 1959
2,951,218	Arditi	Aug. 30, 1960