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MICROSTRIP-MICROWAVE COUPLER

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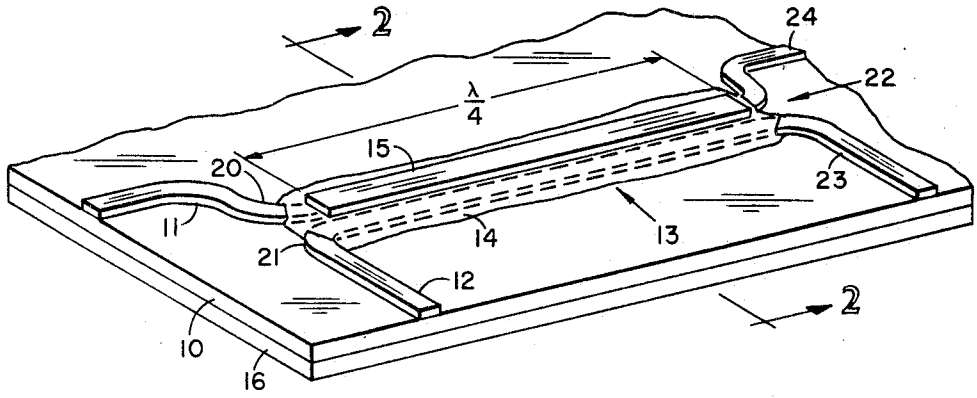

FIG. 1

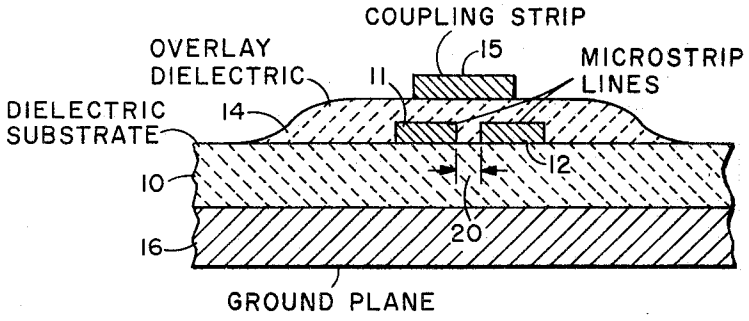

FIG. 2

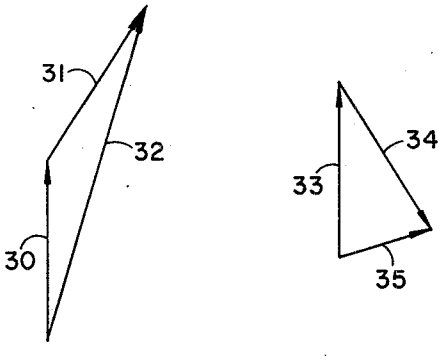

FIG. 3

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MICROSTRIP-MICROWAVE COUPLER

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ABSTRACT OF THE DISCLOSURE

A dielectric substrate has a pair of microstrip transmission lines extending along a straight line for one-quarter wavelength of a design operating frequency. The lines are covered by an overlay dielectric having a dielectric constant equal to the substrate dielectric constant. A coupling strip extends in spaced relation to the microstrip transmission lines over the dielectric and over both lines to confine the electromagnetic fields to within the overlay dielectric and provide improved directivity between the lines. The strip acts as a floating electrode. A ground plane is provided on the substrate.

Background of the invention

This invention relates to microwave circuits of the hybrid type and particularly to an electromagnetic coupler of the microstrip-line type.

It is known that in microwave transmission lines disposed on a dielectric substrate, part of the electromagnetic field associated with the transmission lines is contained in the dielectric substrate while another portion is in the air or other material over the transmission line, Because of the differing dielectric constants, the electromagnetic field for such transmission lines is nonuniform between the substrate and the air (or other material) over the microstrip transmission line. This nonuniformity has various electrical effects on the microstrip transmission lines, some of which are not easily predictable.

For example, it is known that the velocity of propagation in a microstrip transmission line varies with line width. This effect is caused by the electromagnetic field extending into the air above the transmission line which field becomes more significant for smaller line widths. The same variations in the electrical properties caused by the electromagnetic field in the air affects the attenuation and termination of microwave film devices such as attenuators, etc. The effect of such variations in parallel-coupled microstrip transmission lines is to disturb circuits which contain such coupled lines. Parallel-coupled microstrip transmission lines, as is well known, are directional couplers. These couplers are commonly analyzed by the superposition of odd and even mode operations of contributions to the voltages and currents in the two lines. In such couplers where there are inhomogeneous dielectric mediums, the velocity of propagation through the coupler is different in the odd and even modes. Additionally, there is a phase shift between the components of the odd and even modes which prevents cancellation of even and odd mode signals at the isolation port. The effect of this lack of cancellation between the modes causes a drastic reduction in the directivity.

For good coupling between the lines, very narrow gaps usually are required between parallel microstrip transmission lines. This requirement often makes such couplers impractical because of the tolerances required in obtaining good coupling.

Summary of the invention

It is an object of this invention to provide a microstrip-type microwave coupler having a uniform electromagnetic field, good directivity, and reasonable tolerances in manufacture.

A feature of the present invention includes the provision of an overlay dielectric material covering a pair of parallel microstrip transmission lines disposed on a dielectric substrate having a high dielectric constant. The overlay dielectric and the substrate have substantially identical dielectric constants.

Another feature is the provision of combined field restraining and floating coupling means disposed adjacent the microstrip transmission lines for limiting the electromagnetic field thereof to lie only within the dielectric material and improve the coupling between the two lines.

The combined means comprises a conductive strip disposed on the overlay dielectric and extending for the length of the coupler (one or more quarter wavelengths of desired midband frequency) to limit the electromagnetic fields between the lines to within the overlay dielectric material. The capacitive coupling between the lines is increased permitting the lines to be spaced further apart for the same degree of coupling, and coupling directivity is improved.

The drawing

FIG. 1 is a diagrammatic enlarged perspective view of a one-quarter wavelength microwave coupler utilizing the teachings of the invention and disposed on a dielectric substrate for connection to other microwave components (not shown).

FIG. 2 is an enlarged diagrammatic sectional view taken in the direction of the arrows along line 2—2 of FIG. 1 and shows the geometric relationships between the microstrip transmission lines forming the coupler and the combined means for restraining the electromagnetic fields and improving the coupling between the two lines.

FIG. 3 is a vector diagram illustrating phase relationship at coupling and isolation ports of the odd and even mode signal components.

Detailed description of the illustrative embodiment

Referring now to the drawing, like numbers indicate like parts and structural features in the two views. The two views in the drawing are based upon the figures in a publication made by the inventor and a co-worker at the International Conference on Microwave Theory and Techniques, IEEE, Boston, Mass., May 10, 1967, entitled "Microstrip Transmission Lines on High Dielectric Constant Substrates for Hybrid Microwave Integrated Circuits." An abstract of the paper was presented in the 1967 IEEE G-MTT (Professional Group on Microwave Theory and Techniques), Program and Digest, International Microwave Symposium, Boston, Mass., May 8–11, 1967, IEEE Catalog No. 17C66, beginning on page 129.

Referring more particularly to the drawing, a substrate **10** having a dielectric constant of 33, for example (which is considered a high dielectric constant) or of 9 supports a pair of microstrip transmission lines **11** and **12**. Material having high dielectric constant is titanium dioxide or magnesium oxide ceramics. The lines **11** and **12** have

straight parallel portions forming a coupler **13** which has a length of about one-quarter wavelength of a desired operating frequency. The spacing between lines **11** and **12** in the coupling portion **13** is small with respect to the width of the microstrip line, as best seen in FIG. 2. The illustrated coupler is referred to as a "tight" coupler, that is, a coupler having a high degree of coupling. For a "loose" coupler, one having a small amount of coupling, the spacing between lines **12** and **11** is increased.

After microstrip lines **11** and **12** are disposed on substrate **10**, a dielectric overlay **14** is formed over the two microstrip lines. The dielectric overlay **14** preferably has a dielectric constant equal to the dielectric constant of the substrate **10**, i.e., 33. Pastes providing the dielectric overlay **14** are well known and are made from the same ceramic base material.

A coupling strip **15** is disposed over the layer **14** symmetrically between the two microstrip transmission lines **11** and **12**. The conductive coupling strip **15** extends more than half way over the microstrip lines, as best seen in FIG. 2. The conductive coupling strip may extend beyond the longitudinal edges of microstrip lines **12** and **11** at least a distance equal to one-half the width of each microstrip line. The wider the conductive coupling strip **15**, the greater the added coupling. The limitation on width is that strip **15** begins to assume the characteristics of a ground plane, thereby defeating the purpose of this invention. The quantitative geometric relationships between the lines and strip **15**, including the width of the lines **11** and **12**, are calculated using known techniques involving microwave strip lines. The quantitative geometric relations should be expected to vary depending on the design objectives of bandwidth, coupling, and impedances.

The assembly is completed by the conductive ground plane or base plate **16** which extends contiguously with the substrate. Alternately, base plate **16** may be disposed just below the microstrip lines, but should be of sufficient extent to assume a ground potential. For ease of fabrication, it is usually best to make it contiguous with the substrate. Ground plane **16** may be sufficiently thick to serve as a support, may consist of a thin deposited metallic layer, or be formed in any manner to make a ground plane.

The coupling strip **15** is not connected to any other element but is a floating electrode. It must be of relatively small extent to prevent it from acting as a ground plane. Capacitive coupling between microstrip transmission lines **11** and **12** is increased by conductive strip **15**. Referring to FIG. 2, it is readily seen that the distributed capacitance between lines **11**, **12** and conductive strip **15** is quite large because of the large facing surfaces and small spacing therebetween. Between lines **11** and **12**, these distributed capacitances appear as two series-connected capacitors in parallel with the distributed capacitance between lines **11** and **12** in gap **20**. This increased capacitive coupling reduces the odd mode impedance. The increased capacitance also tends to equalize the phase-shift between odd and even modes to increase directivity with respect to a microstrip coupler not having conductive strip **15**. This floating electrode affects the odd mode propagation signals by assuming the zero potential since the floating electrode **15** is symmetrical to the two conductors having opposite polarity signals. This relationship increases the capacitance per unit length of line by a large amount and thereby reducing the electrical impedance of the odd mode. This action increases the effective coupling between the two lines.

The illustrated directional coupler operates as described below. An input signal is supplied over microstrip line **11** at **20** to couple energy to microstrip line **12** at **21**. This end of the coupler is then termed the "coupling port." Energy, of course, travels along the one-quarter wavelength coupler **13** toward the opposite end **22** and supplies no energy to line **12** at **23** termed the "isolation port." When input signals are supplied at **24**, the energy is coupled to line **12** at **23** and the arm **21** of line **12** receives no energy.

It is to be understood that this invention is utilizable with other than one-quarter wavelength microstrip couplers. For example, the coupler configuration, consisting of three one-quarter wavelength sections shown on page 776 of "Microwave Filters, Impedance Matching Networks and Coupling Structure" by Matthaei et al., McGraw-Hill, 1964, Library of Congress number 64–7937, may also use this invention to advantage. Other microstrip devices of varying microstrip line configurations may use this invention to advantage.

FIG. 3 is a vector diagram showing the relationships between the odd and even mode signals at the coupling and isolation ports of a coupler not having conductive coupling strip **15** and dielectric overlay **14**. At the coupling port **21** vector **30** represents the phase of the even-mode signal components, while vector **31** represents the odd-mode signal components, with vector **32** representing the vector sum or total net energy at coupling port **21**. Vector **32** is representative of the energy coupled from **20** to **21**. At the isolation port **23**, vector **33** represents the even-mode signal components, while vector **34** represents the odd-mode signal components. For perfect isolation of arm **23** from input signal arm **20**, vectors **33** and **34** should be 180° out of phase to cancel all signal components, thereby coupling no energy to arm **23**. However, due to the nonuniformity of the electromagnetic field, as above referred to, there is a phase shift between the even and odd mode signal components as illustrated by vectors **33** and **34**. The resultant vector **35** is representative of energy coupled to arm **23** from arm **20**. Such coupling destroys the directivity of coupler **13**. The addition of dielectric overlay **14** and coupling strip **15**, when properly designed as referred to above, restores the even and odd mode signal components to phase opposition at the isolation port **23** to thereby restore directivity to the coupler **13** while simultaneously improving fabrication tolerances for a given degree of coupling desired at the coupled port.

The effect of conductive coupling strip **15** and dielectric overlay **14** on the impedances of the odd and even mode is to diverge the impedance magnitude which improves coupling as set forth by Matthaei, supra, on page 779, Equation 13.02–3 when the velocities of propagation of the two modes are equal:

$$C=\frac{Z_{odd}/Z_{even}-1}{Z_{odd}/Z_{even}+1}$$

Where C is the coupling, Z_{odd} is the impedance of the odd mode and Z_{even} is the impedance of the even mode.

It is understood that the illustrated coupler is used with other components not illustrated and which may be closely associated therewith, such that the entire assembly, including the illustrated and claimed coupler, appears as one component, as does an integrated circuit containing many separate but integrated circuit elements.

What is claimed is:

1. A microstrip-microwave coupler which comprises:

(a) a ground plane;

(b) a dielectric layer formed on one surface of said plane;

(c) a pair of microstrip transmission lines disposed on the surface of said dielectric layer, said transmission lines extending in close spaced parallel relationship for a distance of about one-fourth wavelength at a given frequency;

(d) a dielectric overlay formed on the surface of said dielectric layer at least within the portion of said layer between the transmission lines, said overlay covering the transmission lines, said overlay having

a dielectric constant substantially equal to the dielectric constant of the dielectric layer; and

(e) a conductive strip formed on the dielectric overlay and spaced from the transmission lines by said overlay, said strip being located over at least a portion of each of the microstrip transmission lines and extending there along for a distance of about one-fourth wavelength at the given frequency, said coupling strip having a limited transverse dimension relative to the pair of microstrip transmission lines so that said strip is prevented from exhibiting the characteristics of a ground plane, said conductive strip essentially confining the electromagnetic fields between the pair of microstrip transmission lines to the combination of the dielectric layer and the dielectric overlay whereby the coupling between lines is increased.

2. The microstrip-microwave coupler of claim **1** where-

in said conductive strip is symmetrically disposed over said pair of microstrip transmission lines.

3. The microstrip-microwave coupler of claim **1** where said conductive strip extends over at least one-half of the width of each of said microstrip transmission lines.

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U.S. Cl. X.R.

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