United States Patent [19]

West

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[45] **Oct. 30, 1973**

[54] **TRANSMISSION LINE USING A PAIR OF STAGGERED BROAD METAL STRIPS**

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[21] Appl. No.: **206,420**

[52] **U.S. Cl.** ..... **333/84 R,** 333/6, 333/84 M

[51] **Int. Cl.** **H01p 3/02,** H01p 3/08

[58] **Field of Search** ..... 333/84 R, 84 M, 10

[56] **References Cited**

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Attorney—Edward J. Norton

[57] **ABSTRACT**

A transmission line is formed by a pair of parallel, staggered, broad metal strips. In one embodiment, the broad metal strips are on opposite surfaces of a dielectric substrate with at most a relatively small overlap of the broad metal strips.

8 Claims, 8 Drawing Figures

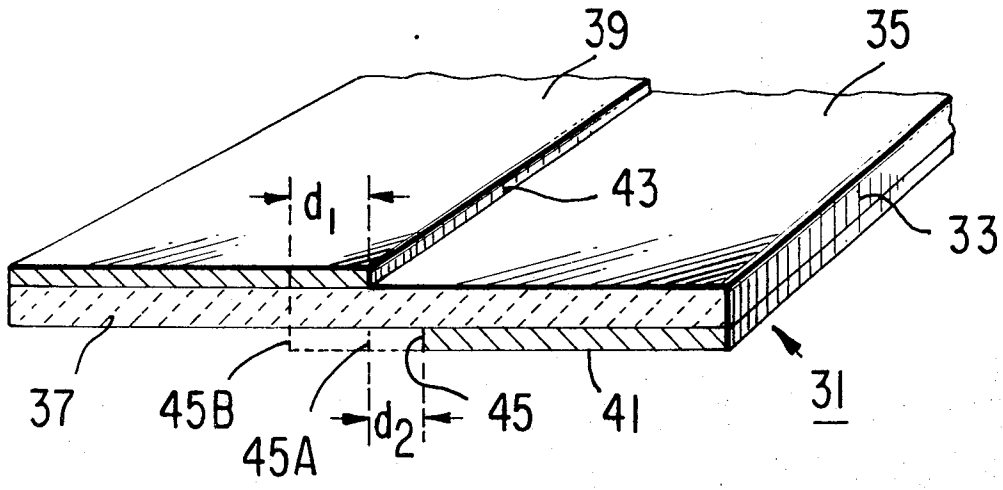


Fig. 1.

PRIOR ART

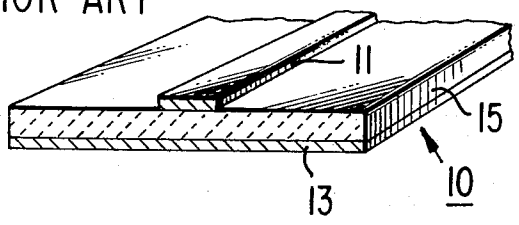


Fig. 2.

PRIOR ART

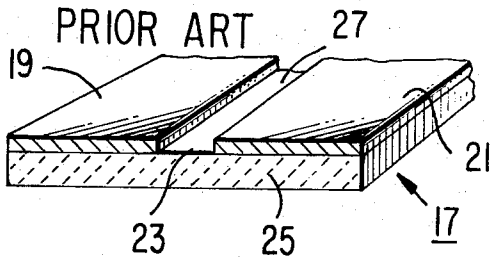
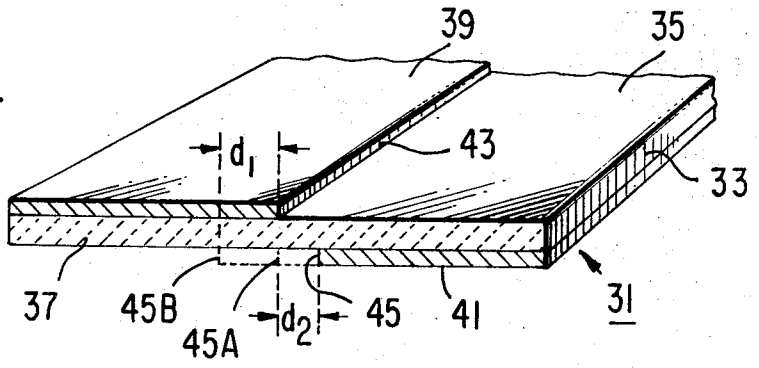


Fig. 3.



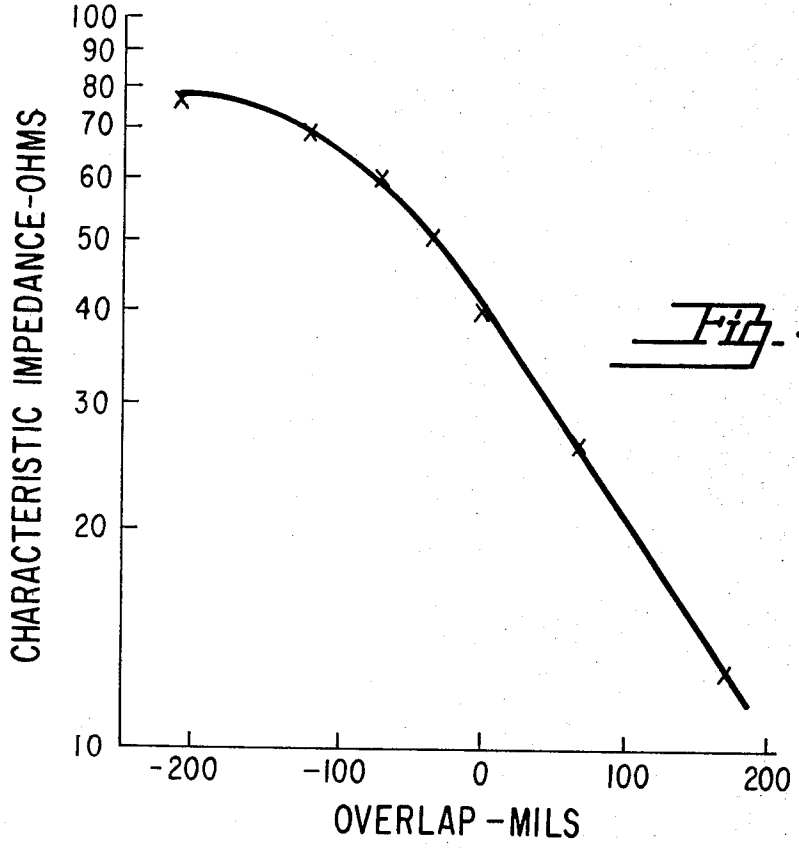


Fig. 4.

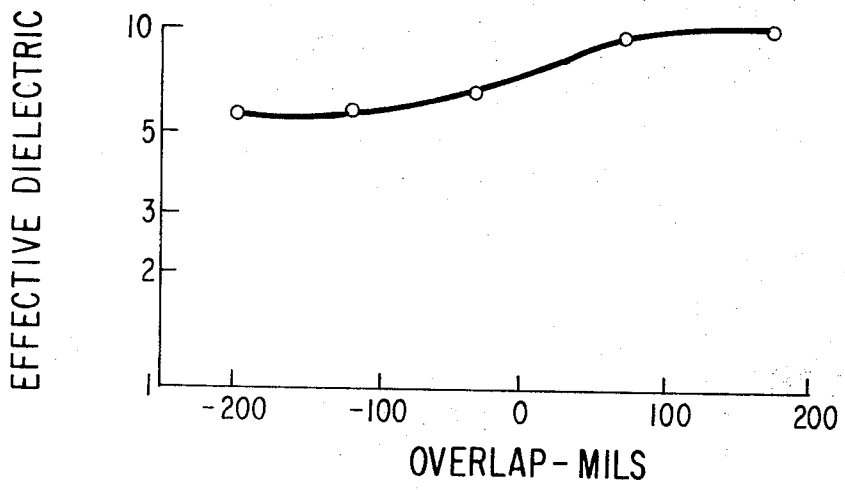

EFFECTIVE DIELECTRIC
10
5
3
2
1
-200
-100
0
100
200
OVERLAP - MILS

Fig. 5.

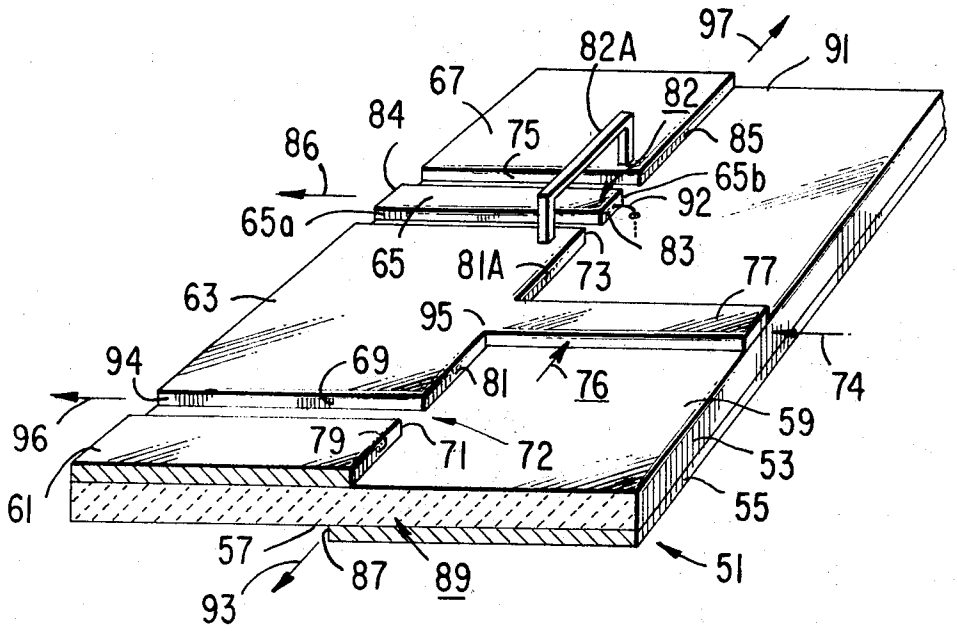

97
91
82A
67
82
84
75
85
86
65b
92
65a
83
65
81A
73
77
63
95
94
69
81
76
74
59
96
79
71
72
53
61
55
57
87
89
51
93

Fig. 6.

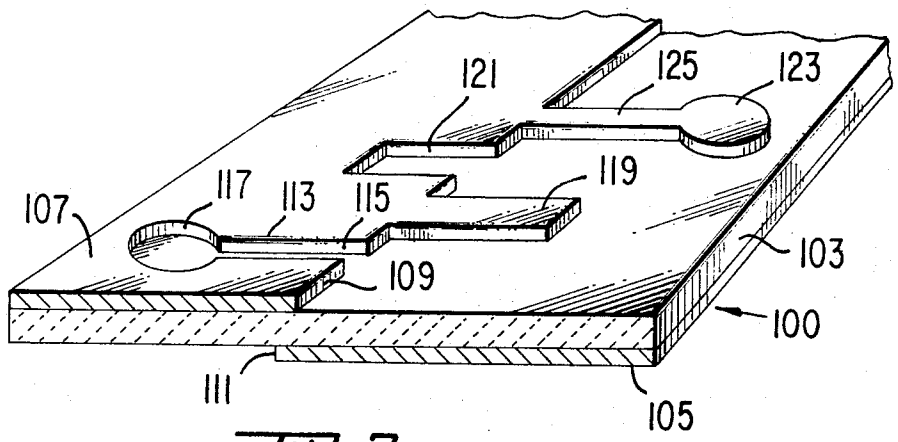

121
125
123
119
117
113
115
107
103
109
100
111
105

Fig. 7.

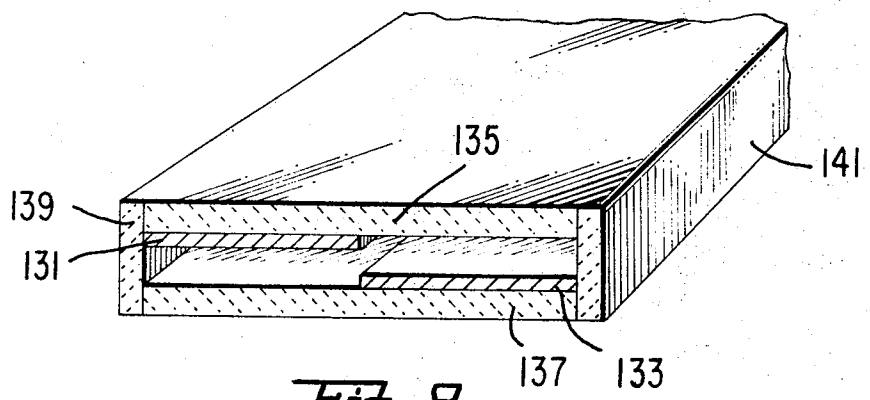

135
141
139
131
137
133

Fig. 8.

TRANSMISSION LINE USING A PAIR OF STAGGERED BROAD METAL STRIPS

BACKGROUND OF THE INVENTION

This invention relates to transmission lines and more particularly to a transmission line formed by a pair of off-centered or staggered broad metal strips spaced parallel to each other by a relatively broader dielectric medium.

The advent of miniaturization to microwave circuitry has brought about the development of many forms of new nonconventional open transmission lines. Some of the most common forms are the microstrip transmission line, the symmetrical strip transmission line, the slot transmission line, the coplanar strip transmission line and the dielectrically loaded parallel plane transmission line. The microstrip transmission line includes a narrow conductive strip spaced by a single dielectric substrate from a single relatively wider ground planar conductor. The symmetrical strip transmission line includes a narrow conductive strip sandwiched between a pair of dielectric substrates and a pair of wider ground planar conductors. The slot transmission line includes a pair of coplanar relatively broad conductive strips spaced from each other so as to form a narrow open slot therebetween. The pair of broad conductive strips in the slot transmission line are fixed to the same surface of a dielectric substrate. The coplanar strip transmission line includes a narrow strip-like conductor and a relatively broader ground conductor spaced from each other on the same surface of a dielectric substrate. The dielectrically loaded parallel plane transmission line includes a pair of parallel plane conductors overlapping each other and spaced by a dual dielectric medium. In the case where one dielectric is air, a second higher dielectric material is centered between two wider parallel plane conductors.

Since each of the above types of transmission lines has advantages and disadvantages, a single structure realizing the features of two or more types of transmission lines is desirable. Such a transmission line structure should facilitate the provision of distributed series and shunt inductive and capacitive reactances therealong.

SUMMARY OF THE INVENTION

Briefly, a transmission line is provided which includes only a pair of broad metal strips spaced by a dielectric medium therebetween. The broad metal strips are staggered or off-centered with an edge of one advanced relative to the corresponding edge of the other with a maximum overlap substantially less than one-half the width of either broad metal strip. The orientation of the metal strips, the spacing between the metal strips and the dielectric constant of the medium therebetween are determined so that the electromagnetic field associated with an electromagnetic wave coupled to the transmission line is essentially confined in the region between the metal strips.

DETAILED DESCRIPTION

A more detailed description follows in conjunction with the drawings wherein:

FIG. 1 is a perspective view of a prior art microstrip transmission line.

FIG. 2 is a perspective view of a prior art slot transmission line.

FIG. 3 is a perspective view of a transmission line according to the present invention.

FIG. 4 is a plot of characteristic impedance vs. overlap for the transmission line of FIG. 3.

FIG. 5 is a plot of effective dielectric constant vs. overlap for the transmission line of FIG. 3.

FIG. 6 is a perspective view of a branched line network using slot transmission line, microstrip transmission line, coplanar transmission line and the transmission line according to FIG. 3.

FIG. 7 is a perspective view of a transmission line as shown in FIG. 3 with distributed inductive and capacitive reactances.

FIG. 8 is a perspective view of a further embodiment of the invention.

Referring to FIG. 1, there is illustrated a microstrip transmission line 10. In this arrangement a narrow strip-like conductor 11 is spaced above a relatively broader (more than twice as wide) ground planar conductor or plate 13 by a slab of dielectric 15. The electromagnetic field of electromagnetic waves propagating along the microstrip transmission line 10 extend primarily in the region between the narrow strip-like conductor 11 and the ground conductor or plate 13.

Referring to FIG. 2, there is illustrated a slot transmission line 17. In this arrangement two relatively broad conductive plates 19 and 21 (broad compared to narrow conductor 11 in FIG. 1) are spaced from each other on the same surface 23 of a dielectric substrate slab 25. The broad conductive plates 19 and 21 run generally parallel and are equally spaced from each other to form an open slot 27 therebetween. The width of slot 27 is approximately equal to the width of conductor 11 in FIG. 1. The electromagnetic field of an applied electromagnetic wave is primarily in the dielectric substrate 25 in the region between the two broad conductive plates 19 and 21.

Referring to FIG. 3, there is shown a transmission line configuration 31 according to the present invention. The line includes a substantially flat slab or substrate 33 of dielectric material having opposed parallel surfaces 35 and 37. On a portion of one surface 35 of slab 33 is a first, relatively broad, conductive plate 39. On a portion of the opposite surface 37 of the slab 33 is a second, relatively broad, conductive plate 41. The conductive plate 39 is in a staggered position relative to plate 41, i.e. the left hand edge of plate 39 as viewed in FIG. 3 is advanced relative to the left hand edge of plate 41 as viewed in FIG. 3. The major portion (more than ½) of the conductive plate 39 extends along the surface 35 in a nonoverlapping relationship relative to the plate 41. The edge 43 of the plate 39 is closely spaced from the edge 45 of plate 41. The spacing between the plates 39 and 41 and the dielectric constant and thickness of the substrate 33 are determined to primarily confine the electric field of electromagnetic waves coupled to the transmission line in the substrate 33 between the conductive plates 39 and 41. With the edge 43 of conductive plate 39 aligned with the near edge of plate 41 as shown by dashed line 45A, the characteristic impedance is substantially independent of the thickness of the slab 33. By way of example, it has been found that for an alumina substrate (dielectric constant of 9.6) with the edges of plates 39 and 41 aligned, the natural impedance was 40 ohms for substrates both 10 mils and 25 mils thick.

The two conductive plates **39** and **41** may be staggered so that they overlap slightly (distance d_1) with the edge of plate **41** at position **45B** in FIG. **3**. In this overlapped configuration, the impedance is lower and the fields are essentially contained within the area of the overlap. The amount of overlap is substantially less than half the width of either of the plates **39** or **41** and is on the order of the width of the narrow strip-like conductors in microstrip transmission lines.

The two conductive plates **39** and **41** may be staggered with underlap as when the nearest edge of plate **41** is at position **45**, a distance d_2 from the aligned position **45A**. In this underlapped position, a higher impedance is associated with this line and a larger percentage of the energy propagates outside the dielectric substrate.

Referring to FIG. **4**, there is illustrated a plot of the characteristic impedance vs. overlap for the transmission line shown in FIG. **3**, when the substrate **33** is alumina (dielectric constant of 9.6) and the thickness is 25 mils. Consideration of FIG. **4** shows that as the plates **39** and **41** are arranged from an underlapped position of 200 mils (indicated by −200 mil overlaps) to the overlapped position of about 175 mils, the characteristic impedance of such a line changes from about 78 ohms to about 12 ohms. At the zero lapped position, the characteristic impedance was 40 ohms.

Referring to FIG. **5**, there is illustrated a plot of effective dielectric constant vs. overlap for the line shown in FIG. **3** having the dielectric constant of 9.6 and a thickness of 25 mils. An increase in effective dielectric constant from the −200 mils underlap position to the 200 mils overlap position is shown. The low effective dielectric constant for the underlapped case is due to the larger percentage of the energy propagating outside the dielectric material and consequently the effective dielectric constant approaches that of air.

Referring to FIG. **6**, there is illustrated a branched line network **51**. In this network **51**, there is provided a flat dielectric slab **53** having a first plate **55** on one broad surface **57** of substrate **53**. On the opposite broad surface **59** of substrate **53** is a plurality of aligned plates **61, 63, 65** and **67**.

The first plate **61** slightly overlaps the plate **55** to form with plate **55** a staggered, parallel plate transmission line as described in connection with FIG. **3**. The second plate **63** has its edge **69** closely spaced from edge **71** of plate **61** to form with that plate a slot transmission line **72**.

The edge **73** of plate **63**, opposite edge **69**, is closely spaced from the edge **65***a* of a narrow strip-like conductor plate **65**. Edge **75** of broad plate **67** is closely spaced to the edge **65***b* of narrow strip-like conductor plate **65** so that the combination of plates **63, 65** and **67** form a coplanar transmission line **82**. A conductive member **82A** extends above the substrate **53** and conductive strip **65** to provide a connection between plates **63** and **67** to maintain equal potential at these plates. For a further description of coplanar transmission line see an article by C. P. Wen entitled "Coplanar Waveguide: A Surface Strip Transmission Line Suitable for Nonreciprocal Device Applications." This article is found in IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-17, No. 12, Dec. 1969, on pages 1,087 to 1,090.

The plate **63** has a finger-like, narrow strip-like conductive extension **77** spaced from and extending over broad conductive plate **55**. The finger-like extension **77** forms with the broad conductive plate **55** and the substrate **53** a microstrip transmission line **76**.

The conductive plates **61, 63, 65** and **67** are aligned so that the edge **79** of plate **61**, the edges **81** and **81A** of plate **63**, edge **83** of plate **65** and edge **85** of plate **67** slightly overlap the near edge **87** of the conductive plate **55**. The plates **61, 63, 65** and **67** are so arranged relative to plate **55**, and the dielectric constant and the thickness of substrate **53** is determined, so that a staggered transmission line as described in connection with FIG. **3** is provided by the combined plates **61, 63, 65** and **67** and the plate **55**.

In the operation of the network **51**, electromagnetic signal energy in the direction of arrow **74** can be coupled to microstrip transmission line **76** formed by narrow conductive strip **77** and plate **55**. The electromagnetic signal waves may be coupled by means of a coaxial cable and connector with the center conductor coupled to narrow conductive strip **77** and the grounded outer conductor connected to plate **55**. The electromagnetic signal waves propagate in the direction of arrow **74** to point **95**, whereupon the wave energy divides. Electromagnetic signal waves propagate along the staggered parallel plate transmission line in the direction of arrow **93** to end **89** and in the direction of arrow **97** to end **91**. Coupling out of the network at end **89** may be accomplished by connecting one lead of a balanced line to plate **55** and the other lead to plate **61**. Likewise coupling out of the network at end **91** may be accomplished by connecting one lead of a balanced line to plate **55** and the other to plate **67**.

Electromagnetic signal waves propagating in the direction of arrow **93** also excite waves across the slot between plates **61** and **63** in the slot line mode. The electromagnetic signal waves that are coupled across the slot travel along the slot transmission line **72** in the direction of arrow **96** to end **94**. Coupling out of the network **51** at end **94** may be provided by coupling one end of a balanced line to plate **61** and the other lead to plate **63**.

Electromagnetic signal waves propagating toward end **91** in the direction of arrow **97** also excite waves in the coplanar transmission line mode. This excitation may be enhanced by a wire **92** connecting end **83** of plate **65** to plate **55** through the substrate **53**. The electromagnetic signal waves that are excited in the coplanar line **82** travel in the direction of arrow **86** toward terminal end **84** of the network **51**. Coupling out of network **51** may be provided by a coaxial connector and cable where the inner or center conductor is coupled to plate **65** and the outer or ground conductor is connected to plates **63** and **67**.

Referring to FIG. **7**, there is illustrated how both distributed series and shunt reactances of either sign may be formed on the staggered transmission line **100**. The transmission line **100** includes a flat slab **103** of dielectric material having on its opposite parallel surfaces broad conductive plates **105** and **107**. The plates **105** and **107** are staggered with respect to each other and are slightly overlapped near the ends **109** and **111**, respectively, to form the transmission line **100**. A distributed series capacitor in slot line is provided by the slotted structure **113** having the narrow slot transmission line section **115** terminated in the circular aperture section **117**. A shunt capacitor in microstrip is achieved by the bar **119** extending over plate **105**. A slot line series

inductor is achieved by the slot **121** in plate **107**. A distributed microstrip shunt inductance is provided by the combination of the circular conductive pad **123** and narrow conductor **125** extending over plate **105** and coupled from plate **107**.

An alternative transmission line construction is illustrated in FIG. **8**. In this arrangement the conductive plates **131** and **133** are on different substrates **135** and **137**, respectively, The substrates **135** and **137** are parallel to each other and hence the plates are parallel to each other. The plates **131** and **133** are spaced by being fixed to dielectric spacers **139** and **141**. Again, as shown in FIG. **3**, the plates **131** and **133** can be configured in a parallel staggered relationship with the plates either slightly overlapped or slightly underlapped.

What is claimed is:

1. A transmission line capable of propagating electromagnetic waves over a range of frequencies comprising:

only two substantially flat metal strips,

said metal strips being arranged parallel to each other with a dielectric medium therebetween and with each of said metal strips having a leading and a trailing edge relative to a given direction, said metal strips being staggered relative to each other with the leading edge of a first of said metal strips being closely spaced with the non-corresponding trailing edge of the second of said metal strips and with said leading edge of said first metal strip being spaced a distance from said non-corresponding trailing edge of said second metal strip no more than half the width of either metal strip, the spacing between the metal strips and the dielectric constant of the medium therebetween being determined so that the electromagnetic fields associated with electromagnetic waves coupled to the transmission line are essentially confined to the region between the metal strips, said metal strips being the only conductors of said transmission line with said electromagnetic waves being coupled to said transmission line only at said metal strips.

2. A transmission line capable of propagation of electromagnetic waves over a range of frequencies comprising:

a dielectric substrate and only two relatively flat broad metal strips,

the first of said relatively broad metal strips being attached to one surface of said substrate and having a leading edge relative to a given direction,

the second of said relatively broad metal strips being attached to the opposite surface of said dielectric substrate and having a trailing edge relative to said given direction, said second metal strip being oriented in staggered, parallel relationship to the first metal strip with said leading edge of said first metal strip being closely spaced with said non-corresponding trailing edge of said second metal strip, and with said leading edge of said first metal strip being spaced a distance from said non-corresponding trailing edge of said second metal strip no more than half the width of either metal strip, the spacing between the metal strips and the dielectric constant of the medium therebetween being determined so that the electromagnetic fields associated with electromagnetic waves coupled to the transmission line are essentially confined to the region between the metal strips, said metal strips being the only conductors of said transmission line with said waves being coupled to said transmission line only at said metal strips.

3. The combination as claimed in claim **2** wherein said substrate is substantially broader than either of said metal strips.

4. The combination as claimed in claim **2** wherein said metal strips overlap each other with said leading edge of said first metal strip overlapping said trailing edge of said second metal strip.

5. The combination as claimed in claim **4** wherein the maximum overlap is less than half the width of either metal strip.

6. The combination as claimed in claim **2** including a narrow strip-like conductor extending along said one surface of said substrate from said first metal strip above said second metal strip to form a microstrip transmission line.

7. The combination as claimed in claim **2** wherein said first metal strip has a narrow slot therein for separating said first metal strip over a substantial portion thereof into two broad metal sheets for forming a slot transmission line.

8. The combination as claimed in claim **2** wherein said first metal strip has a pair of parallel slots closely spaced to each other to form a narrow conductor spaced between two broad conductors to form a coplanar transmission line.

* * * * *