MICROWAVE STRIPLINE PHASE ADJUSTER

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ABSTRACT

This specification describes a microwave stripline phase adjuster wherein the phase of an applied signal is changed by continuous substitution of one dielectric material for another along a length of the stripline circuit path. A constant impedance is maintained by a simultaneous change in the width of the circuit path.

6 Claims, 4 Drawing Figures
1
MICROWAVE STRIPLINE PHASE ADJUSTER

GOVERNMENT CONTRACT

The invention herein claimed was made in the course of or under a contract with the Department of the Army.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to microwave stripline phase shifters and more particularly to a phase shifter wherein a phase shift is accomplished by a change of dielectric materials in the proximity of a length of a stripline circuit path while impedance is held constant by a concurrent change in the effective width of that path.

2. Description of the Prior Art

Several types of microwave phase shifters are known in the prior art. Some, like that disclosed in U.S. Pat. No. 3,405,375 issued to D. J. Kelley on Oct. 8, 1968, rely on a physical change in the length of the transmission path between two points in a circuit. Others, like that disclosed in U.S. Pat. No. 3,005,168 issued to D. L. Fye on Oct. 17, 1961, substitute one dielectric substance for another to produce a phase change while a constant impedance is maintained by a concurrent change in ground plane spacing. The size and complexity of these prior art phase shifters is a serious deterrent to their use in microwave circuits where space is at a premium. This is particularly the case in many microwave stripline applications.

It is therefore an object of this invention to provide an extremely simple microwave stripline phase adjuster.

It is another object of this invention to reduce the size of microwave stripline phase adjusters.

It is yet another object of this invention to provide a microwave phase adjuster ideally suited for use in microwave stripline circuits.

SUMMARY OF THE INVENTION

These and other objects of this invention are accomplished, in accordance with the principles of this invention, by disposing a slideable member, comprising segments of high and low dielectric materials, in slideable cooperation with an exposed length of stripline conductor path, having a relatively wide portion in the vicinity of the low dielectric slide segment and a relatively narrow portion in the vicinity of the high dielectric slide segment. Motion of the slideable member changes the relative proportions of high and low dielectric materials along the length of the relatively narrow portion of exposed stripline conductor, thereby changing the phase of the applied signal.

In addition, a conductor path segment, which is approximately the same width as the relatively wide stripline conductor path portion and which is in slideable electrical contact with the exposed stripline conductor path, is bonded to the slide segment of low dielectric constant. Accordingly, both dielectric constant and conductor path width are changed as the slideable member is moved, thereby maintaining the impedance of the phase adjuster at a constant value.

Further features and objects of this invention, its nature, and various advantages, will be more apparent upon consideration of the attached drawing and the following detailed description of the drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an exploded perspective view of the microwave stripline phase adjuster of this invention;
FIG. 2 is a sectional view of the phase adjuster of this invention taken along the centerline shown in FIG. 1;
FIG. 3 is a perspective view of the phase adjuster slide showing the underside thereof; and
FIG. 4 is a top view of another possible configuration of the exposed conductor path segment of FIG. 1.

2
DETAILED DESCRIPTION OF THE INVENTION

Microwave stripline circuit elements generally comprise a lower conducting sheet or plate 22, a lower dielectric sheet 24, an upper dielectric sheet 34, and an upper conducting sheet 32 arranged as shown in FIG. 1. The required materials are bonded or otherwise held together in any well-known manner, for example, with mechanical fasteners. Current is conducted through the circuit by wire of a suitable flexible circuit (e.g., strips 26 and 28) known as active conductors or circuit paths, enclosed between the dielectric sheets in the above assembly. Most of the energy transmitted is, however, propagated in electrical fields set up in the dielectric material between the circuit paths and the exterior conducting surfaces 22 and 32, called ground planes.

Since the velocity of microwave energy propagation in a stripline circuit is a function of the dielectric constant of the material used for dielectric sheets 24 and 34, the phase of a signal at one point along a circuit path relative to that at another point along the path may be changed by changing the dielectric material along a portion of the circuit path between those points. The impedance of a stripline circuit, on the other hand, is a function of the dielectric constant of the material used, the ground plane spacing, and the circuit path width. Accordingly, if the dielectric material is changed to obtain a phase shift, one or both of these other parameters must also be changed if impedance is to remain constant.

FIG. 1 illustrates apparatus constructed according to the principles of this invention whereby the dielectric material in the proximity of a length of a stripline conductor path may be gradually changed to obtain a variable phase shift without changing the impedance of the stripline circuit. The phase shifter of FIG. 1 comprises a portion of a microwave stripline circuit constructed in the manner described above but with upper ground plane 32 and upper dielectric sheet 34 (i.e., upper shield member 30) cut away to expose a portion of circuit path having segments 26, 27, and 28. Path segments 26 and 28 are of what might be termed normal width. Given the ground plane spacing and dielectric material to be used, path segments 26 and 28 are assigned dimensions, determined by the application of well-known formulas, such that the desired impedance per unit path length for the circuit is realized. Connecting path segment 27, however, in made considerably narrower for reasons discussed below and may in addition be arranged in a zig-zag pattern as shown in FIG. 4, to increase its electrical length without taking up more circuit area.

Inserted into the slot or groove in the upper member 30 of the stripline circuit element of FIG. 1 is a longitudinal, slideable member 10. As shown in FIGS. 1, 2, and 3, slideable member 10 is divided transversely into two dielectric segments 14 and 16 having markedly different dielectric constants. The material of slide segment 14 is preferably the same as the material of dielectric sheets 24 and 34. This usually will be a material (e.g., polyethylene) having a relatively low dielectric constant. Slide segment 16, on the other hand, is a dielectric material having a relatively high dielectric constant (e.g., a ceramic material). Both segments of slide 10 are backed by a continuous metal ground plane 12 similar to ground planes 22 and 32. The final component of slide 10 is a conducting strip 18 bonded to the underside of slide segment 14 and having one end at the interface between segments 14 and 16. Conducting strip 18 is as wide as or slightly wider than paths 26 and 28.

Both conducting strip 18 and dielectric segment 16 are at least as long, measured along centerline 15, as path segment 27 is, measured along that center-line. Moreover, the cut away portion, slot, or groove in upper dielectric sheet 34 and in upper ground plane 32 is long enough to permit location of the interface between slice segments 14 and 16 anywhere along the length of path segment 27. Accordingly, when in position as shown in FIGS. 1 and 2, slide 10 may be moved from one extreme position where the entire length of exposed conductor path 27 is under the slide segment 16 to a second extreme position where all of exposed conductor path 27 is under the
slide segment 14. The positioning of slide 10 also places conducting strip 18 in physical and electrical contact with portions of paths 26 and 27. The portion of path 27 not in contact with strip 18 is exposed to the segment (i.e., segment 22) of slide 10 of high dielectric constant. Apparatus (not shown) may be attached to slide 10 to facilitate the movement of the slide. This apparatus may be a simple knob or handle, set screw, etc. for fixing the location of slide 10. In addition, indicating means (not shown) such as a pointer may be affixed to slide 10 to cooperate with a suitable dial or scale (also not shown) affixed to upper ground plane 12.

Depending on the position of the interface between segments 14 and 16 of slide 10 along the length of path segment 27, more or less of the length of that path segment will interact with slide segment 16, the slide segment having the high dielectric constant. Since the microwave energy travels at a slower speed in the region of the material of higher dielectric constant, the greater the proportion of the length of path segment 27 interacting with slide segment 16, the greater the relative phase difference between signals on path 26 and those on path 28.

It is noted that if the dielectric constant of the material of slide segment 16 is very much higher than that of dielectric sheets 24 and 34, most of the energy propagating along that portion of circuit path segment 27 which is sandwiched between dielectric sheet 24 and slide segment 16 will be propagated in an electrical field set up in slide segment 16 between path segment 27 and ground plane 12. Thus this portion of the microwave circuit must be analyzed substantially as a microstrip rather than as a stripline. It is highly desirable that any phase adjustment not change the impedance of the circuit in which the adjustment is made. In order to accomplish this the circuit path segment (i.e., segment 27) which interacts with high dielectric slide segment 16 must have the same impedance per unit length as the remainder of the circuit. Since the other parameters affecting impedance (i.e., dielectric thickness, dielectric constant, and conductor thickness) are relatively fixed, it is the width of segment 27 which must be altered to achieve the desired impedance per unit path length. As is well known, the impedance per unit length of a microstrip is given by

\[
Z = \frac{-377 h}{2\pi k + 1} \left( \ln \frac{1.452 + 2.43 h}{1.452 + 2.43 h} \right) (1)
\]

where

- \( h \) = dielectric thickness
- \( k \) = dielectric constant
- \( W_c \) = effective width of the conductor
- \( t \) = conductor thickness

The width of the effective conductor, the effective width in relation (1) is given by

\[
W_c = W_n + \Delta W (2)
\]

where

\[
\Delta W = \frac{f}{\pi} \left( \ln \frac{2h}{t} \right) (3)
\]

\( W_n \) = width of conductor before consideration of presence of dielectric sheet 24 and ground plane 22.

Finally, \( W_n \), as determined from the foregoing relationships, must be reduced to account for the presence of dielectric sheet 24 and ground plane 22 below segment 27. As is shown in FIGS. 1 and 3, the actual required width of path segment 27 is considerably less than the width of path segment 26.

Not all of the length of path segment 27 will necessarily be required to interact with slide segment 16 to establish the desired phase relationship between signals on leads 26 and 28. Therefore where narrower path segment 27 is not adjacent to high dielectric slide segment 16, it is overdriven by conducting strip 18 which, as has been stated above, is affixed to the under side of low dielectric slide segment 14 and which is as wide as circuit path 26. Conducting strip 18 may be slightly wider than path 26 to ease fabrication tolerances on the alignment of strip 18 and path 28. In the event that strip 18 is made wider than path 26 and to compensate for the slightly altered effective line location between ground planes, ground plane 12 should be slightly raised, as shown in any of the figures, in the region opposite strip 18.

As an example of a specific phase shifter of the type described herein, a phase shift of approximately 180° can be achieved using components with the following characteristics:

- Relative dielectric constant of dielectric sheets 24 and 34 and slide segment 14: 2.32 (polyethylene).
- Relative dielectric constant of slide segment 16: 30.0 (ceramic).
- Thickness of sheets 24 and 34: one-eighth inch.
- Thickness of ceramic slide segment 16: 167 mils.
- Width of input and output paths 26 and 28: 182 mils.
- Width of narrow path segments 27: 26.5 mils.
- Projected length of zig zag narrow path segment 27: 1.5 inch.

It is to be understood that the embodiments shown and described herein are illustrative of the principles of this invention only, and that modifications may be implemented by those skilled in the art without departing from the spirit and scope of the invention. For example, a zig-zag pattern may be used for narrow path segment 27, as discussed above, to increase the effective length of that path segment without taking up additional circuit area. As another example, circuit paths leading to and from the portions of paths 26 and 27 which interact with slide 10 need not join those portions at right angles. Any convenient angle may be used so long as the angle chosen does not result in exposure of any of the circuit path as the slide 10 is moved. Another possible modification of the geometry employed is the use of a circular or arcuate slideable member in a similarly shaped slot or groove.

What is claimed is:

1. Constant impedance microwave stripline phase adjusting apparatus comprising:
   - a microwave stripline circuit element having a conducting circuit path enclosed between upper and lower planar members, each of said members including a conducting sheet adjoining a dielectric sheet, said upper member having an interior section cut away to expose a segment of said circuit path, said exposed circuit path segment having a relatively wide portion and a relatively narrow portion;
   - a dielectric slide inserted in said cut away section, said slide having a first segment having a relatively low dielectric constant and a second segment having a relatively high dielectric constant;
   - a relatively wide conducting strip affixed to said slide segment of low dielectric constant, said strip being aligned in said slideable electrical contact with said exposed circuit path segment so that the dielectric constant of said slide adjacent to said relatively narrow circuit path portion and the effective width of said relatively narrow circuit path portion are simultaneously changed as said slide is moved; and
   - a conducting sheet affixed to the surface of said slide opposite said strip.

2. A constant impedance microwave stripline phase adjuster comprising:
   - a microwave stripline circuit element including upper and lower dielectric sheets physically attached together and enclosed between upper and lower conducting ground planes, said upper dielectric sheet and said upper ground planes being grooved to expose a length of microwave circuit path, said exposed circuit path having a relatively narrow first segment and a relatively wide second segment;
   - a dielectric member in slideable cooperation with said exposed circuit path, said dielectric member having a first segment of dielectric material of relatively high dielectric constant positioned to interact with a portion of said first
a conductive strip attached to said second segment of said dielectric member parallel to and in slideable electrical contact with said exposed circuit path, said conductive strip having substantially the same width as said second segment of said exposed circuit path so that the width of said remainder of said first segment of said exposed circuit path is effectively the width of said second segment; and

a metal ground plane attached to the exterior surface of said dielectric member.

3. A constant impedance microwave stripline phase adjuster comprising:
a microwave stripline circuit element including upper and lower dielectric sheets physically attached together and enclosed between upper and lower conducting ground planes, said upper dielectric sheet and said upper ground planes being grooved to expose a segment of microwave circuit path, said exposed circuit path having a relatively narrow first segment and a relatively wide second segment;
a dielectric member in slideable cooperation with said exposed segment of circuit path, said dielectric member having a first dielectric segment of relatively high dielectric constant at the end of said dielectric member adjacent to said first segment of said exposed circuit path and having a second dielectric segment of relatively low dielectric constant at the end of said dielectric member adjacent to said second segment of said exposed circuit path;
a conductive strip attached to said second segment of said dielectric member parallel to and in slideable electrical contact with said exposed segment of circuit path, said conductive strip having the same width as said second segment of said exposed circuit path; and

a metal ground plane attached to the exterior surface of said dielectric member;
said dielectric member being slideable from one extreme position where said first segment of said dielectric member is substantially the only portion of said member interacting with said first segment of said exposed circuit path to a second extreme position where said first segment of said exposed circuit path is in electrical contact with said conductive strip over virtually all of the length of said first segment of said exposed circuit path so that both the dielectric constant of said dielectric member adjacent to said first segment of said exposed circuit path and the effective width of said first segment of said exposed circuit path are simultaneously changed as said dielectric member is moved.

4. A constant impedance microwave stripline signal phase adjuster comprising:
a stripline circuit element including a sheet of dielectric material having a relatively low dielectric constant, affixed on one side to a first metal ground plane and affixed on the other side with a first, relatively narrow, signal conductor path;
a longitudinal slide having first and second faces, said slide being divided transversely into a first segment of relatively high dielectric material and a second segment of dielectric material having the same dielectric characteristic as said sheet of dielectric material;
a second relatively wide signal conductor path affixed on said first face of said low dielectric material slide segment; and

a second metal ground plane affixed to said second face of said slide;
said slide disposed in said stripline circuit element, the first face of said longitudinal slide in slideable electrical contact with said first signal conductor path so that the dielectric constant of the material adjacent to said signal conductor path and the effective width of said signal conductor path are simultaneously changed as said slide is moved in relation to said stripline circuit element.

5. A constant impedance microwave stripline phase adjusting circuit element comprising:
a stripline circuit element the upper dielectric sheet and upper ground plane of which are cut away to expose a segment of circuit path, said exposed segment of circuit path having a relatively narrow first segment and a relatively wide second segment;
a slideable dielectric member having a first segment with a relatively high dielectric constant and a second segment with a relatively low dielectric constant backed by a metal ground plane, said slide being aligned in said cut away portion of said upper dielectric sheet and said upper ground plane so that the interface between said first and second segments of said slideable member is positioned over said first segment of said circuit path, so that said first segment of said slideable member is over a portion of said first circuit path segment, and so that said second segment of said slideable member is over the remainder of said first circuit path segment and said second circuit path segment; and

a conductive strip having width approximately the same as said second circuit path segment, affixed to said second slide segment adjacent to said exposed circuit path segment, parallel to and in electrical contact with said second circuit path segment so that the width of said remainder of said first circuit path segment is effectively the same as the width of said second circuit path segment.

6. A constant impedance microwave stripline phase adjusting apparatus comprising:
a first conducting member having upper and lower surfaces;
a first dielectric member having upper and lower surfaces, said lower surface adjoining said first conducting member upper surface;
a conducting circuit path segment affixed to the upper surface of said first dielectric member, a section of said segment being narrower than the remainder of said segment;
a second dielectric member having upper and lower surfaces, said lower surface adjoining the upper surface of said first dielectric member, said second dielectric member having an interior section removed to expose said conducting circuit path segment;
a second conducting member having upper and lower surfaces, said lower surface adjoining said second dielectric member upper surface and having an interior section removed coterminally with said removed section of said second dielectric member;
a dielectric slide member having upper and lower surfaces and positioned within said removed interior section of said second members, said slide member comprising adjoining segments of high and low dielectric constant, said segment of high dielectric constant positioned adjacent to said narrower section of said circuit path segment and said segment of low dielectric constant positioned adjacent to the remainder of said circuit path segment;
a conductive material of width substantially the same as the remainder section of said circuit path segment having upper and lower surfaces, said upper surface affixed to said lower surface of said slide member segment of low dielectric constant and in slideable contact with said circuit path segment so that both the dielectric constant of said slide member adjacent to said narrower section of said circuit path segment and the effective width of said narrower section of said circuit path segment are simultaneously changed as said slide member is moved; and

a third conducting member affixed to the upper surface of said dielectric slide member.

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